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UTILITY POLES, PRESERVATIVES and SOIL CONTAMINATION

by

PAUL C. GARGIULO

A dissertation submitted to the Graduate Faculty
in Earth and Environmental Sciences in partial fulfillment
of the requirements for the degree of
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Abstract

Utility Poles, Preservatives, and Soil Contamination

by Paul C. Gargiulo

Advisor: Dr. Victor Goldsmith, Professor, Geography Department, Hunter College

Utility poles have historically been treated with a variety of chemical preservatives, using a number of methods, in an attempt to control and minimize wood decay as well as to maintain the pole's integrity and lengthen its in-service life. The use of preservatives has raised a number of environmental, health and economic concerns related to the leaching of preservative from the pole into the environment. Creosote and pentachlorophenol are the two most predominant wood preservatives in today's market. These pesticides, to varying degrees, are found in the soil surrounding the pole, thereby, creating concerns of potential soil and ground water contamination.

Today, there are material alternatives to wood that could reduce the introduction of toxic chemicals into the environment. Concurrently, the associated costs for utility companies using wood poles has drastically increased over the past few years, creating the need to find less expensive methods to connect the customer to the utility network.

To determine the extent of preservative leaching from utility poles, soil was collected from within six feet of treated utility poles at depths ranging from the surface to three feet. The soil was collected from the southwestern portion of Long Island, New York. The soil samples were analyzed for pentachlorophenol (PCP), creosote, dioxins and furans. Soil samples were collected from roadside locations composed of silty-loam, and from beach locations composed of sand, to determine the capability of these soils to retain preservative. All soil samples were collected within the glacial outwash plains of the southeastern portion of New York State. Soil conditions were favorable at this location to analyze for differences between a well compacted silty loam with smaller pore spacing and sandy (beach) soil which was poorly consolidated and had larger pore spacing.

Analyses conducted as part of this study revealed that PCP contamination was found in the soil within the first three inches of the pole, and diminished to background levels at two feet, for all depths sampled. Samples were collected at distances from the poles at: three-inches, two-feet, four-feet, six-feet and 12-feet. The PCP soil sample collected from the surface within three-inches of the pole was above the US Environmental Protection Agency (EPA) soil cleanup standard indicating the need for the soil to be handled and disposed as a hazardous waste. Total dioxins and furans were detected within the first six feet of the pole, but without any correlation with distance from the pole or with depth. All measured dioxin and furan concentrations were below the US EPA recommended soil remediation goal. Creosote was detected within the first three inches of the pole, diminishing to background levels at two feet from the pole, for all depths sampled. All creosote concentrations were below the US EPA soil cleanup standard. More porous sandy soils did not retain the preservatives as well as soils composed of silty loam. The latter displayed significantly better retention properties for PCP, creosote, dioxins and furans, possibly indicating the inability of sandy soils to retain preservative.

To review the efficacy of alternate pole materials, a comparison between wood and fiberglass reinforced composite (FRC) poles was performed using environmental and economic considerations. Fiberglass poles were chosen from the non-wood category for their strength and handling properties as well as the absence of leaching preservative. Costs over the life of the pole, and environmental waste minimization were the deciding factors. The initial installation cost of a fiberglass pole is approximately three times the price of wood, when calculating the lifecycle cost of PCP preserved poles as well as the potential for costly soil cleanup costs, fiberglass is approximately one half the price. These analyses indicate that the benefits of using FRC utility poles outweigh the current rationale for using preservative-treated wood poles.

A life cycle analysis was also conducted taking into consideration the US EPA's current focus on specific wood preservatives, and reviewing their cumulative effect on health and the environment. This preservative focus by the EPA is an indication that the potential for more restrictive regulations regarding use, maintenance and disposition of preservative-treated utility poles, as well as preservative contaminated soil, is looming on the horizon.

This study shows that: a) dioxins leach from PCP treated poles and can be detected in soil within the first three inches of the pole; b) PCP contaminated soil was slightly above the EPA soil clean-up standard of 100 ppm at the surface located three inches from the pole; c) silty soils retain preservative better than sandy soil; and, d) fiberglass is a highly desirable alternative to wood poles for protection of the environment, and reduction of the total (lifecycle) cost of utility poles.

The results of this research are consistent with the study by the Electric Power Research Institute (EPRI, 1995), as PCP preservative was found in silty soil surrounding utility poles, and that there is a decrease in the concentration of preservative with distance from the pole. The soil sample collection sites for the EPRI study were various physiographic regions throughout New York State. This dissertation focused its sample collection in southeastern New York State, specifically, the southwestern portion of Long Island. However, this research differed from the EPRI study by analyzing for the presence of dioxins in soil surrounding preservative treated poles. Also the EPRI study did not sample creosote treated poles.

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TABLE of CONTENTS

PAGE

Chapter 1

Chapter 2

PAGE

Chapter 3

Chapter 4

PAGE

Chapter 5

Chapter 6

PAGE

APPENDIX 1

APPENDIX 2

LIST of TABLES

PAGE

LIST of ILLUSTRATIONS

CHAPTER 1

INTRODUCTION

Soil contamination resulting from preservative treated utility poles varies among published field data. This dissertation attempts to quantify the extent of contamination to determine if it exceeds the United States Environmental Protection Agency's (EPA) soil cleanup standards for the geographic area and soil type studied. If soil contamination does exceed the EPA standards, the overall impact to the wood preserving industry as well as corporations using these utility poles would be significant.

This study focuses on utility poles with an average age of 22 years located within a specific geographic area. The reason for focusing on an older age group was to determine if, over time, natural soil attenuation reduced excess preservative concentrations to a level below the EPA remediation guideline, in those cases where there was significant leaching from in-service utility poles. The geographic area is important because climate plays a large role in pole weathering as well as soil attenuation, which is the lessening of preservative in soil. The following is a brief background on preservatives, utility poles and the process for application of preservative to a utility pole.

WOOD PRESERVATIVE HISTORY

For over 4,000 years, preserving chemicals have been used to minimize the effects of moisture and insects on wood products. Wood preservation began in the Eastern

Mediterranean where the Egyptians (c.2000 B.C.) applied "natural oils to wooden plows in order to retard the effects of moisture on wood. The Greeks (c.1,000 B.C.) used naturally durable timbers in conjunction with a variety of construction techniques in order to keep the wood dry, resulting in an increase in the in-service life of the wood. During the Roman Empire, the Romans also made use of various oils, which protected the wood from boring organisms.

During the 15th and 16th centuries, Europe experienced a major wood shortage. This came at a time when the need for preserving wood was critical. Europe's major powers were totally dependent on sailing ships which were constructed of wood and vulnerable to decay and wood boring organisms. In an attempt to overcome this problem the British Navy used copper sheathing over the wood in an attempt to retard the degradation of the wood on their ships.

During the 19th century, the United States experienced an increase in the development and use of wood preservatives as a result of intense railroad construction programs (Webb & Gjovik, 1988). These construction programs were designed to link the major industrial cities within the United States. As a result, there was a significant increase in the shortage of naturally durable timbers such as black locust, cedar, chestnut and white oak.

Utility Poles

The use of wooden utility poles began in 1889. The primary function of the poles was to suspend cable in an attempt to bring electrical and telephone service from the central utility facility to the customer. Video companies are now using existing utility poles to provide their customers with additional viewing channels for television, in an attempt to avoid the cost of burying video cable. This recent trend clearly illustrates that the utility pole has not yet outlived its usefulness in today's high technology world.

Utility poles, also known as joint use poles termed because they are used by a variety of telephone, electric power and cable TV utilities, are replaced periodically due to physical damage, service needs or biodegradation. The current average life of a wood utility pole is approximately 30 to 45 years depending on weather phenomena, preservative treatment methods, periodic maintenance (i.e., ground line soil treatment), soil conditions, and geographic area. Utilities experience minimal problems with the pole as long as it remains in service. Concerns increase when the pole is taken out of service and the surrounding soil may need to be remediated (i.e., cleaned up) due to preservative contamination. The extent of soil disposition depends entirely on the type of preservative and groundline treatment utilized during the pole's time in service. These environmental concerns will be discussed further in Chapter 4.

PRESERVATIVES

There are two general classifications of wood preservative treatments in commercial use today, oil-based and water-based treatments. These classifications are based on the chemical composition of the preservative and/or the carrier vehicle used to deposit the preservative into the wood. The most common preservatives used (over time) to inhibit pole degradation by fungi and insects are discussed in the next section by type and use.

Preservative research over the past three decades (1970s, 1980s and 1990s) focused on the development of new waterborne preservatives. This research was partially driven by fluctuations in oil supplies, cost, and the potential (regulatory enforced) discontinuation of oil-borne treatments. However, the cost of oil and oil-borne products have not increased as quickly as expected, resulting in a decrease in research for waterborne alternatives, and an increase in research for enhancements to oil-borne preservatives.

Oil-borne/Oil-Based Preservatives

Creosote, one of the oldest of preservatives, began its use as a wood preservative in the United States in 1865 (Webb & Gjovik, 1988). It is the only preservative used as a 100% active ingredient, thus making it the only oil-based preservative that is not oil-borne. There are three varieties of creosote used in today's market place: coal-tar creosote, beechwood creosote, and creosote bush.

Coal-tar creosote does not occur naturally in the environment and is a product of high temperature treatment of coal. It is the most widely used wood preservative in the United States. Approximately 300 chemicals have been identified in coal-tar creosote including over 240 polycyclic aromatic hydrocarbons (PAHs) and semi-volatile organic compounds (SVOCs). However, the predominant chemicals found in coal-tar creosote that potentially cause harmful health effects are PAHs, phenols, and cresols. This study's focus is the use of preservatives in utility poles and their effect on the environment; therefore, emphasis will be placed on coal-tar creosote since it is a wood preservative.

Coal-tar creosote is usually a heavy, oily, liquid that is amber to brown in color. Mixtures of creosote and other coal-tar products are black. The ground residual creosote found at hazardous waste sites is most often a black, heavy liquid. It has a sharp smoky odor and a burning taste. It burns easily, but does not dissolve readily in water.

Some components of the creosote mixture can enter groundwater or change (biodegrade) into other substances while other parts persist in treated wood products for decades. Although creosote usage has declined in recent years, in 1995 it was still the second largest volume of wood preserving solution used (AWPI, 1996). Approximately 18% of today's utility pole market consists of creosote treated wood.

Pentachlorophenol (penta or PCP) has been in use since the late 1940's. PCP is an oil-borne preservative that is dissolved in a blend of petroleum co-solvents and carrier oils. The amount of PCP used in the wood treating solution is approximately 5% to 9% by weight. Its current use in today's utility pole market is approximately 40% to 45% of wood utility poles in service (Bailey, 1996). However, the use of penta is beginning to decline partly due to the presence of chlorinated compounds in the mixture. These chlorinated compounds are associated with the production of dioxins during the penta formulation process. Additional information about dioxins will be discussed in Chapter 4.

Copper naphthenate (CN) is an oil-borne preservative that is blended as a solution with a petroleum oil carrier to a concentration of 1.0% to 2.0 % copper as metal. Both the copper and naphthenic acid are toxic to fungi, but the effects of naphthenic acid on decay fungi have not been studied as extensively as the effects of the copper. Copper naphthenate was first used as a wood preservative in 1889 and was commercially available in Denmark in 1911 (Hartford, 1973). During World War II, when there was a shortage of creosote, copper naphthenate was widely used in its place. At the end of the war, creosote once again became the treatment of choice. During the past few years, Copper naphthenate has been re-introduced into the market and has just been approved by the American Wood Preservers Association (AWPA) as a treatment for wood utility poles. It accounts for approximately 2% of today's market. The AWPA standards have made important contributions in specifying the quality and quantity of primary wood treatments (AWPA 1995).

Water-borne Preservatives

The last twenty years has seen growth in water-borne systems for utility pole treatment. Water-borne pole treatments capture approximately 35% to 40% of today's market. These chemicals are dissolved in water and can be used at a variety of concentrations dependent on the final preservative retention desired.

Inorganic Arsenicals

Chromated copper arsenate (CCA), and ammoniacal copper zinc arsenate (ACZA) are the two main water-based preservatives. During the 1970's and 1980's, there was significant growth in the use of waterborne preservatives. However, the market share of waterborne preservatives has remained in the 40% range for use in wood poles. CCA is the dominant preservative of choice in this category followed by ACZA. Almost all CCA pole treatments are used with southern yellow and other pine species, where as ACZA treatments are used primarily with Douglas fir. ACZA treatments are often specified in locations where there are known woodpecker hazards. This is due to its property to protect against woodpecker borings.

CCA is a broad-spectrum wood preservative that was first patented in 1933. The effectiveness of CCA in protecting softwoods, both in laboratory tests and in field exposures, is well documented. However, the performance of hardwoods treated with CCA tends to vary from excellent to very poor. In most cases, the failure of CCA-treated hardwood is attributed to attack by soft-rot fungi. Another concern of CCA is it effect on climability due to the resulting surface hardness from CCA treatment. Climability is the ease in which the utility lineman can climb a pole using gaffs(climbers). A hard pole creates some difficulty in securing the gaff resulting in a safety climbing hazard. Additional research has tested water-repellent emulsions mixed with CCA to reduce hardness. The results indicated no effect on the preservative's ability to protect wood from bio-deterioration and also addressed concerns on the climability and weathering qualities of the poles. The emulsions had no adverse affect on climbability and weathering of southern pine poles. However, this has had little effect on the usage rate of waterborne preservatives.

In summary, creosote, PCP, and CCA are the three predominant wood preservatives in today's market. These pesticides are found to varying degrees in the soil surrounding the pole, thereby, creating concerns of potential soil and ground water contamination.

Preservative selection for use with wood poles is strictly a matter of utility preference based on their requirements. As indicated, some major considerations that must be addressed when choosing a preservative for a specific use are climate, bio-degradation rate, and the physical characteristics of pole species. Also, cost and availability are considerations. Considerations must also be given to species and preservatives since they are not always compatible. All of the previously discussed preservatives are effective in protecting against biological degradation and insect attack providing the preservative penetrates the pole to the proper depth. At the proper penetration depth as well as proper periodic maintenance, the pole will have a reasonably long in-service life.

WOOD POLE PREPARATION and TREATMENTS

Treated wood utility poles are the product of a manufacturing process using several wood treatment processes. The preservative process depends on the wood species used and climate, soil type, and pH of soil. The following explains the processes that are used in the preparation of utility poles for preservative treatment.

A. Wood Utility Pole Preparation

The objective of the utility pole pre-treatment and preservative treatment process is to prevent (minimize) fungi and insects from gaining access to the inner unprotected core or heartwood by entering through the thin shell (sapwood) and/or checks (openings) in the pole. The depth of penetration by a wood preservative is dependent on the method of pre-treatment, preservative treatment process, wood species, and the proportion of sapwood to heartwood. This preparation is crucial to the over-all in-service life of the pole. The

Western Wood Preservers Institute (WWPI), after the evaluation of in-service pole inventories and inspection records, has recently reported longer projected in-service life (Morrell. J.J., 1996). The usual 35 to 45 years expected in-service life has been changed to reflect the high probability of an in-service life of 50 to 75 years. These claims may also be stimulated by the increase in marketing of non-wood utility poles.

Utility pole preparation is comprised of numerous steps, peeling, drying, conditioning, incising, cutting and framing prior to the application of the wood preservative (Morrell. J.J., 1996).

Peeling

The peeling process removes the bark and inner cambium layer allowing the preservative to penetrate deeply into the wood with a minimum amount of difficulty.

Pole Conditioning and Seasoning (Drying)

Conditioning and seasoning refers to the drying techniques utilized to prepare pole material for preservative treatment. Once the bark and cambium layers have been removed, the pole is then dried in order to enhance penetration and reduce shrinkage and checking which has a tendency to occur after preservative treatment. It is important to first remove water from the wood cells prior to treatment due to the difficulty for the preservative to penetrate wet wood. The only type of preservative treatment that can penetrate wet wood is the diffusion method, which uses water to move the preservative into the wood.

Steam Conditioning

Steam Conditioning is one of the most common forms of conditioning used prior to the application of an oil preservative treatment. This process involves steam heating wet wood poles while in a pressurized cylinder, resulting in an increase of the internal temperature of the wood. After a prescribed period of time, the poles are then subjected to a vacuum. The purpose of introducing the vacuum is to lower the boiling point of water and allow it to be extracted from the wood. This process continues until the cylinder temperature drops to 160°F. When the cylinder reaches this temperature, the process is stopped and the wood is then ready for preservative application.

Air Drying

The air drying seasoning method is not often used, since it requires long seasoning periods and usually results in uneven drying. Also, there is a certain amount of pole degradation associated with this uncontrolled method of seasoning. Air drying is the most common treatment for reducing the moisture content in western red cedar and lodgepole pine poles.

Kiln drying

Kiln drying accelerates drying under controlled conditions and is usually the pre-treatment of choice for waterborne preservatives. This process results in more consistent penetration and retention of the applied preservative. However, if this process is not closely monitored, there is the potential for overdrying of the outer portion of the pole resulting in an improper moisture gradient.

Pole Framing

Pole framing is defined as the cutting, drilling and gaining of wood poles either in the field or prior to placing the poles into service. Field framing is the second largest cause of reduction in longevity of utility poles (especially Douglas-fir). Ideally framing should be performed prior to preservative application or at the very least prior to placing the pole into service. Field framing without the application of a preservative usually results in decay at the top portion of the pole. Boring through the treated wood into untreated heartwood provides for an excellent route for fungal infection. The fungi will travel through the bolt holes and spread throughout the interior of the pole causing decay damage that can range up to 8 feet above and below the bored hole. This process usually occurs over a period of 8 to 10 years. If poles cannot be framed prior to treatment and installation, then framing in the field should be treated with liberal amounts of copper - naphthenate. However, field application is by no means an adequate substitute for pressure treating.

Incising and Radial Drilling

The incising process requires uniformly spaced incisions cut into the surface of the pole at a depths of 5/8 to 3/4 of an inch in a longitudinal pattern (see Figure 1.1). The purpose of the incising process is to insure preservative penetration throughout the treated zone. Radial drilling is basically similar to incising except that the holes are deeper and somewhat larger. This is performed prior to seasoning in order to allow for the pole's internal incised/drilled spaces to dry uniformly. Since the poles dry uniformly, the drying stresses that occur when wood dries are also uniform. This process is designed to enhance the effect of the preservative application to the pole.

Through Boring

Through boring is another pre-treatment process that is primarily used on the Douglas-fir species (see Figure 1.1). Seven holes approximately 1/16 of an inch in diameter are bored approximately four feet above and four feet below the groundline area of the pole. The hole is then penetrated with preservative.

Kerfing

Kerfing is a procedure designed to relieve subsequent drying stresses. This relief results in the prevention of the development of checks that can penetrate beyond the treated shell. This results in the reduction of the incidence of internal decay especially in thin sapwood species, around the ground line. During the kerfing procedure, cuts are made four feet above and four feet below the groundline penetrating the wood between 2 1/2 to 4 inches. These uniform patterns insure penetration and retention of preservative throughout the treated zone. An example of a specific species' need for pre-treatment is the Douglas-fir. This species is intolerant to poor treatment application. Therefore, anything that assists in gaining a uniform and deeper penetration treatment is an advantage for a long service life. Western red cedar poles, on the other hand, are not full length incised and usually require only incising in the groundline areas. The standard incising for this species is one foot above and two feet below the groundline. When adequately seasoned, the cedar sapwood is easily penetrated with preservative.

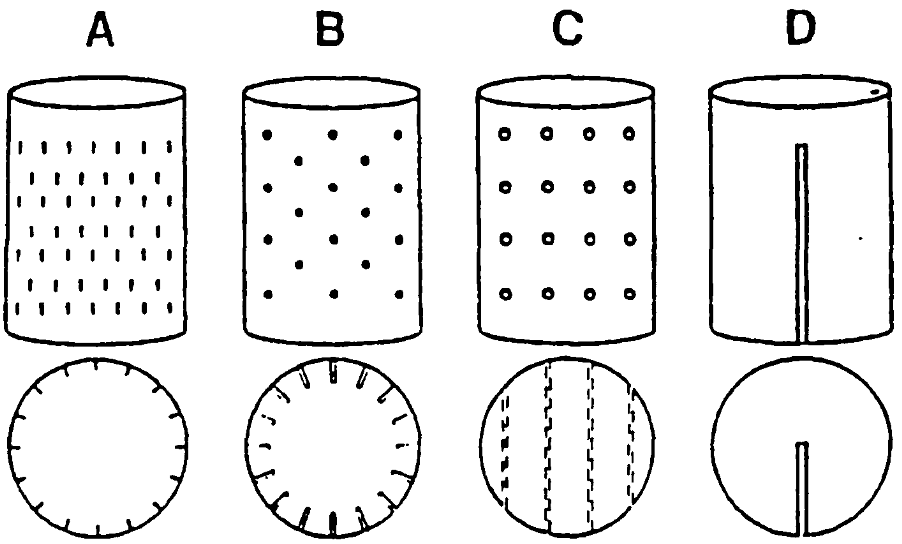


FIGURE 1.1. Illustrates: A) Deep Incising; B) Radial Drilling; C) Through-Boring; and D) Kerfing (Morrell, JS, 1996).

Sterilization

Sterilization is a process that attempts to kill or minimize by delaying the effects of fungi, which are present in wood at the time of treatment. Fungi, if not destroyed, can result in internal decay that significantly reduces the in-service life span of the pole. This detrimental effect usually occurs when the preservative is not heated to a temperature high enough to destroy fungi existing in the interior portion of the pole. In an attempt to eliminate the fungi, wood pole is heated long enough in either the preservative or the drying kiln, immediately preceding the preservative treatment, to ensure a core temperature in excess of 150°F (65°C).

B. Preservative Treatment Methods

Preservative treatment is the next step once the initial preparation is completed. The following are preservative treatment methods used in utility pole preservation (Morrell, J.J., 1996; Bailey, R.T., 1996). There are two types of treatment processes: the pressure process and the non-pressure process. Within these processes there is the application of oil-borne, as well as water-borne, preservatives.

The Pressure Process

The primary objective of pressure treatment in the wood preservation process is to impregnate the cells in a wood pole with preservative deep enough so there will be adequate protection from wood destroying fungi and insects. This process begins by placing the pole in an airtight steel cylinder or autoclave where it is subjected to pressure. This process which forces the preservative into the wood is the most common method used in the commercial treatment of wood. This process allows for pre-conditioning, greater penetration, and better preservative retention control all performed within the same chamber.

Two of the most common variations of the pressure process are the full-cell process and the empty-cell process. The full cell process is designed to give the most penetration of preservative into the wood by filling the wood cells. The empty-cell process is designed to reach the same depth of penetration using less preservative (than the full-cell process) with a lower amount of excess retention. This is accomplished by coating just the walls of the wood cells.

The Full Cell Process or Bethel Process

The full cell treatment process is also known as the Bethel process. It subjects seasoned wood to an initial vacuum prior to inserting the preservative solution in the vacuum cylinder. This process is used predominantly with waterborne preservatives, although oil-borne preservatives can be used with this process. However, there is a greater chance that "kickback" will occur afterward. Kickback is the release of unabsorbed preservative. During this process the preservative completely fills the wood cells of the pole and results in the highest possible preservative retention. The vacuum draws most of the air out of the wood cells and in turn, draws the preservative solution into the cells. This process continues until the preservative reaches its required depth. This procedure results in a reduced level of kickback although some level occurs during the final vacuum stage after the pressure in the chamber is released.

Empty Cell or Reuping Process

Developed by Max Rueping in 1902, this method is used mainly to control the amount of oil-based chemical or preservative retained by the wood pole. It subjects the wood pole to increasing pressure inside the chamber. This initial exposure to pressure compresses the air within the wood cells. Once the air is compressed, the chamber is flooded with the preservative solution under pressure $\approx$150 psig and the temperature is increased to a maximum of 200^0 F (ex, Southern pine). After a specified period of time, the chamber is drained and subjected to a final vacuum (22 in of Hg). The purpose of the final vacuum is to remove excess preservative solution from the outer few inches of the pole. The result is an effective penetration and coating of preservative within the cell walls with no residual liquid left behind that may result in kickback.

Lowery Process

The Lowery Process is a modification of the "empty cell process". This modification utilizes the air that is naturally trapped in the wood cells at atmospheric pressure during the drying process. This modification removes the (empty cell process) step exposing the pole to the initial pressure phase. This modification results in a reduction of additional air injected into the cells, prior to the pressure treatment of the pole. The end result is similar to the empty cell process using the compressed air in the cells force out the excess preservative. However, this process is infrequently used since the final retention of preservative is higher than required for most oil-based applications.

The Boulton Treatment Process

This process is usually used with creosote or a creosote solution. Green wood is placed in a treating cylinder and submerged in hot creosote oil which is itself the heat transfer medium. The cylinder is heated to at least 200^0F and subjected to a vacuum. This lowers the boiling point, allowing the conditioning of the wood to occur at a much lower temperature, as well as the extraction of water. Water vapors are then condensed, collected and measured to calculate the desired moisture level of the wood. The Boulton Process also sterilizes the wood, eliminating pre-existing fungus or decay. This is an important step, especially if the pole is used in a climate prone to fungus or decay (See Figure 1.2). This process also gives the additional benefit of allowing the wood to check in the cylinder, allowing for the treatment of naturally occurring season checks. The Boulton process is the most common method for reducing the moisture content in Douglas fir poles.

Non-Pressure Processes

Thermal Process

The thermal process, also known as the "hot and cold process," is the most effective non-pressure process for treating wood. This process places air seasoned or kiln dried wood in baths of hot and cold liquid preservative, usually creosote or pentachlolophenol. The concentration of preservative forced into the wood during this process is usually more than is necessary for protection. Therefore, it is necessary for periodic adjustments to control the volume of the preservative retained by the wood. This process is most effective on western red cedar and pine, since their sapwood is easily treated. It is not recommended for use with yellow pine or any other difficult-to-treat species.

Preservative Retention/Penetration

As indicated earlier the amount of preservative forced into the wood is usually more than is necessary for protection. The adjustments made to control the amount of preservative retained in the wood not only results in cost saving by reducing excess preservative, it also minimizes kickback and the preservative's impact on the environment.

In order to effect this fine balance preservative treatment volumes are increased during the initial process allowing for recouping of a higher volume of excess treatment during the final phases. This scenario tends to increase the preservative retention during the final phase. It must be noted that retention tends to vary from pole to pole as well as specie to specie.

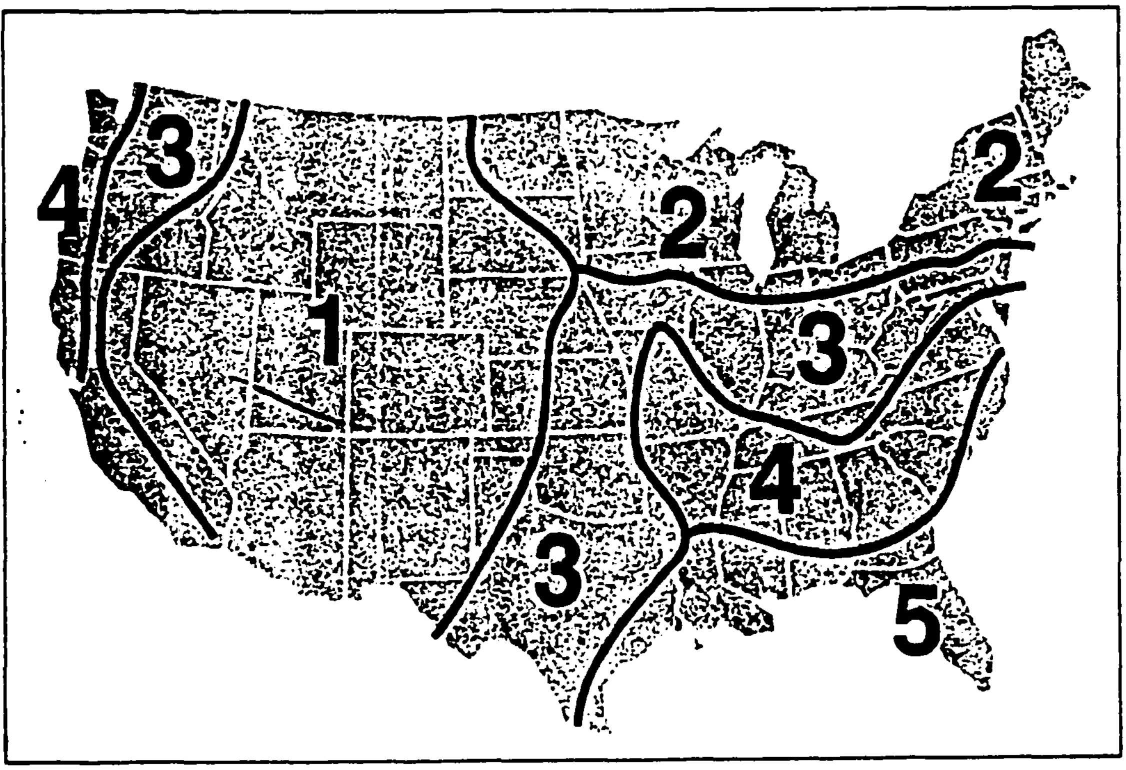


FIGURE 1.2. Map of United States Illustrating Areas of Decay Risk for Poles in various locations (Morrell, JS, 1996). This relative decay risk gradient progresses from a 1 indicating low risk, to a 5 indicating a high decay risk. Less humid areas (1) have a lower probability for decay hazard; whereas, areas of high humidity (5) have a greater potential for decay. The southeastern portion of the country where there is higher humidity and decay is most severe is rated as a (5).

Non-Pressure water-borne preservative application differs by allowing the water, the preservative carrier, to evaporate in the cells. As the wood dries, the preservative treatment is left behind in the cell voids. This process controls preservative retention by adjusting the volume of preservative introduced during the treatment phase, thereby lessening the amount of kickback during drying.

Post Treatment Fixation

This final treatment attempts to fix the preservative in the wood cells, thus minimizing kickback while in service. This fixation process is basically a function of time, temperature, humidity and material type.

C. Remedial Treatment for In-Service Utility Poles

Situations occur that require occasional or periodic utility pole maintenance in order to optimize their in-service life and to combat wood decay caused by fungi and insects. This maintenance requires treatment to be applied in the field and are classified as either internal or external remedial treatments.

Internal Remedial Treatments

Internal treatments are divided into three categories: void treatments, fumigants, and water diffusable systems. Each treatment depends on the organism to be protected against and the relative safety of its use during application.

Void treatment, as the name suggests, is the application of preservative to large cavities inside the utility pole. The intent is to coat the inside of the void with preservative to prevent further enlargement (decay) of the void. Void applications include the use of sodium fluoride and copper naphthenate, which may be amended with insecticides.

Fumigants are solids or liquids that have high vapor pressures. These fumigants volatilize in the wood and travel (longitudinally) from the point if infusion through the wood material for distances up to ten feet and completely through the cross section. Assays of poles before and after application indicate that most decay fungi are eliminated within one year of application using metham sodium (32.7% sodium n-methyldithiocarbamate), chloropicrin (96% trichloronitromethane) or methylisothiocyanate (MITC) (Morrel & Corden, 1986; Morrel, 1989). All are liquids and must be handled with extreme care.

Metham sodium, chloropicrin and MITC

Metham sodium, the most widely used wood fumigant, is a caustic liquid. It causes skin burns and is toxic to aquatic life. Chloropicrin is highly volatile and difficult to handle. It is extremely irritating to nasal membranes, necessitating the use of a respirator during application. It is desirable because of its exceptionally long period of protection of 15 to 20 years. At the present time, a formulation of encapsulated chloropicrin is undergoing a review by the EPA. This formulation is safer to handle during application and has a slower release time, resulting in an extension of maintenance cycles (Love et. al., 1996). MITC, a potent fungicide, is used where risk of human contact is minimal. MITC is a by-product of Basamid. Basamid is a crystalline flowable powder that decomposes to MITC, carbon disulfide, hydrogen sulfide, and formaldehyde (Ruch, and Johnson. 1957). It is stable at normal temperatures, as long as moisture is not present. This makes it an excellent candidate for use as a more stable and easier to handle fumigant.

Tests indicate that simultaneous application of Basamid and additives can increase MITC production. Therefore, Basamid has the potential to be used in utility poles to preventing internal decay. If further test results substantiate these findings, Basamid with these additives will substantially increase in-service pole life, applicator safety and protection of the environment (Forsyth & Morrell, 1993).

Water Diffusable Treatments

Boron and fluoride are water diffusable and can be substituted for the above pole treatments. These alternatives are utilized to reduce the human toxicity of fumigants. Both move through wood when free water is present, i.e., when wood moisture content is >30%. However, their pattern of movement and retention time in diverse wood types may differ (Becker, 1976; Morrell et. al., 1990). The water solubility of boron and fluoride make them vulnerable to eventual loss from wood poles as a result of leaching. The loss rate is dependent on the volume of rainfall, wood species, and the type of original preservative treatment.

External Remedial Treatment

External decay controls are usually applied to control pole decay at the groundline or applied directly portions of the pole that may have been damaged by cutting, drilling, or natural occurrences that may minimize the pole's ability to ward off decay. Failure to protect the pole after field fabrication will result in above ground internal decay development and render the pole susceptible to failure during high winds or ice. Copper naphthenate (2% as copper) is usually the preservative of choice. It is applied topically to the pole at the time the damage/work occurs (Graham & Helsing, 1979).

One potential option for long term fixation is the use of borates. Borates are active against a wide range of wood decay fungi and insects, while being relatively innocuous from a health and environmental viewpoint. The only drawback from the use of borates is that they are quickly leachable, resulting in a short period of protection. The application of boron in the form of a paste, immediately after exposure, provides excellent protection against fungal attack.

Studies on the use of alkylammonium compounds, a non-heavy metal wood preservative, have led to AWPA approval of didecyldimethyl ammonium chloride (DDAC) as a wood pole treatment. This approval is limited to above ground application.

Groundline Treatment

Groundline bandages have had a long history of success among North American utilities. Groundline bandages presently in use include copper naphthenate, boron, fluoride, and to a lesser degree pentachlorophenol. Groundline bandages generally stop decay within 0.5 inch to 1 inch of the pole's surface. Most applications occur between the groundline and 18 inches below the surface. The application depth may vary with rainfall (since sites with greater than 20 inches of rain annually usually have deeper decay below the groundline). The protective period provided by groundline bandages varies with wood species, degree of damage, the type of chemical system, and climate. The treatment cycle for this application is usually 10 years depending on local moisture levels. Shorter cycles are recommended for more tropical regimes, while longer periods of up to 15 to 20 years are recommended for dryer environments.

SUMMARY

Creosote, pentachlorophenol (PCP), and chromium copper arsenate (CCA) are the primary preservatives applied to minimize the vulnerability of wood poles to biological degradation and insect attack. These pesticides to a varying degree are found in soil surrounding the pole, creating concerns of potential soil and ground water contamination. Studies must be performed to identify the extent of soil contamination and clean-up cost resulting from in-service utility poles and groundline treatment. Technological advances in wood preservative application have proven to be effective in minimizing contamination. However, the toxicity of these preservatives continues to be a hazard to the environment, as well as to those who live nearby.

There is a significant amount of research currently being performed on both oil-borne and water-based wood preservatives. Copper-based preservatives, especially ammoniacal copper quat (ACQ) solutions and dimethyl dithio carbamate is presently being studied. The intent of this research is to discover compatible fixation agents, and additives to inorganic arsenical preservatives. This research ranges from water repellents and dye to the addition of oil, to make the wood product easier for utility workers to climb (climability). Ethylene glycol is currently under study for use with CCA as a means to enhance climbability. Preservative manufacturers indicate that utility poles properly treated and maintained can be expected to have an in-service life expectancy well beyond 50 years. This 50-year time frame has not been proven scientifically and may be in response to the non-wood utility pole industry's claim of an 80-year in-service life span.

Corporate user concerns regarding in-service wood utility poles are based on the cost of extending in-service pole life, pole disposition and remediation of the soil surrounding the pole. Cost of replacing the pole has also drastically increased, encouraging more research to find economical methods for pole preparation, preservative treatment, periodic in-service treatment, and disposition. Disposition of used utility poles and surrounding soil may possibly become a future issue. It is reported that current federal regulatory actions could eventually lead to the exclusion of all metal containing preservatives (Preston, 1996). Additionally, environmental regulations may become more stringent causing a significant increase for disposition of wood preservative containing wastes. These issues must be addressed today before they become a regulatory reality. Once regulations are promulgated, it may be very expensive to meet the new environmental standards. It should be more cost effective to be proactive and modify current corporate procurement practices to anticipate these changes regarding utility pole disposal. This is especially relevant with today's business needs of corporate cost cutting and downsizing; the need to implement less costly methods using complete life cycle analysis, as a means of competition and survival.

CHAPTER 2

LITERATURE REVIEW

The preservative treated wood pole is a product of a combination of variables, which include preservatives used, preservative treatments and tree species. Equally important is the geographic area, which includes climate, soil type, and soil pH. These are the major factors that affect the in-service longevity of the wood pole. These factors also play a role in determining the potential for environmental contamination. The development of the wood preservative industry worldwide is historically based on the need to protect nondurable woods from wood-destroying organisms. As the demand for naturally durable timbers increased and their cost rose, the use of more readily available nondurable wood species, in conjunction with wood preservatives, became an economical solution to the utility's construction problems.

The following studies provide background information to provide a better understanding of the interaction between wood preservatives, in-service treated wood products, and their surrounding environment. Studies performed on pentachlorophenol (PCP) and creosote have helped us gain insight to their potential hazards as well as their benefits as wood preservatives.

PENTACHLOROPHENOL

Toxicity

Pentachlorophenol (PCP) is toxic to many forms of life (US EPA - IRIS). The EPA has placed all products containing PCP in the "restricted use" category under the Federal Insecticide, Rodenticide and Fungicide Act (FIFRA). In addition, the EPA has also labeled PCP as a registered algaecide, bactericide, disinfectant, fungicide and an insecticide. As part of this registration, labels are required for all PCP products as well as their related components, warning of potential fetotoxicity.

The effects of chlorophenols on plant mitochondria have shown that PCP is a powerful uncoupler of oxidative phosphorylation, the process that stores chemical energy in ATP within cells. Observations of PCP toxicity in experimental outdoor ponds indicated that PCP concentrations of 50 to 100μg/L in water with a pH of 7.3 to 10.3, had no direct effect on zooplankton or fish growth and survival (Crossland & Wolff, 1985).

The potential for animal (and human) fatalities related to PCP is detailed in a report issued by the National Research Council (1981). This report concluded that for a spectrum of mammalian species, the LD50 is constant at 150 mg/kg of body weight. The USDA (1992), in corroboration with a National Research Council's study, reported that pigs and poultry have died from exposure to PCP that was absorbed from wood shavings used as bedding materials. Additional studies, exposing young cattle to technical grade and pure grade PCP to determine the chronic toxicity of the two types of PCP, indicated that exposure to the impure technical grade PCP was more toxic to young cattle than exposure to pure PCP. An explanation for this result was that the toxicity of PCP was possibly related to its impurities; which included lower chlorinated phenols, polychlorinated dioxins and furans and chlorobenzenes (Jones, 1984).

Examples of Toxicity to the Human Population

An incident occurred in a St. Louis hospital nursery where children were inadvertently poisoned when PCP contaminated detergent was used to wash their diapers and bedding. However this was an isolated incident, most PCP poisonings have occurred in occupational settings (Robson et. al., 1969). A study of occupational hazards related to PCP concluded that: a) toxicity of PCP was a greater concern than that of its contaminants; b) the hexachlorodibenzeno-p-dioxin (HCDD) contaminant causes chloracne in concentrations present in technical PCP; c) PCP is embryotoxic and teratogenic; and d) technical PCP may cause long term liver damage. It was also noted that there was no safe exposure level of PCP for pregnant woman (Williams, 1982).

Environmental Characteristics of PCP

In Soils

PCP in acidic soils was found to be less mobile and more persistent than in pH neutral soils (Choi & Aomine, 1972). Soil adsorption was found to occur at a greater extent in strongly acidic soils than in soils of moderate acidity. Adsorption experiments have shown that PCP was released at a greater rate from the soil as pH increased. The concentration decreased as clay was added to the solution, indicating adsorption to clay particles. In desorption experiments the precipitated PCP dissolved readily when saturated soil was washed with deionized water. The PCP adsorbed in clay was also released, however at a much slower rate. These findings show the potential for PCP to migrate through soil into local aquifers as well as nearby rivers and streams.

Groundwater Migration

The effect of PCP on groundwater migration (Banerji et al., 1986) indicated that the organic content of the soil and pH were equally important properties with respect to adsorption of PCP. It was found that soil adsorption significantly increases with decreasing pH, and that adsorption on soils is reversible. Although PCP initially remains in soil, it is slowly with a potential for entering into groundwater. This release occurs when water with a higher pH concentration passes through the zone of contamination.

In Water

The toxicity of PCP is increased by the lowering of pH in the aquatic environment (Arsenault, 1976). Its solubility in an aqueous environment was found to increase exponentially with pH (Choi & Aomine, 1974). Additional research indicated that increased acidity (lower pH) tends to prolong the persistence of PCP in an aqueous environment. A high soil pH will release more PCP to the aqueous phase than a more acidic soil, increasing the probability of release into the groundwater and underground streams. Studies performed by Stuart and Robertson (1985) also indicate that the toxicity of PCP is much greater for aquatic biota than for terrestrial biota. This release from soil can have very deleterious effects. One example of PCP's effect on wildlife in the aquatic environment is indicated by its direct effect on zooplankton and fish growth and survival. The PCP contaminant had a toxic effect on filamentous algae, which resulted in decreased levels of dissolved oxygen (DO) as the algae decayed. Dissolved oxygen is necessary to sustain life in the aqueous environment. The decreased levels of DO in turn resulted in a reduction of the Rainbow Trout population of a specific area.

Photodegradation

PCP degrades readily in the presence of light. In nature, the amount of available light is dependent on latitude, time of day, time of year, source intensity, cloud cover and water turbidity (NRC, 1982). In the aquatic environment photolysis proceeds very slowly at depths greater than 20 cm. because of the reduction of available light by dissolved and particulate substances (Hwang et. al., 1986). PCP degradation due to the presence of light results in by-products less toxic than PCP. It was also found that photosynthetic rates were found to be dependent on pH levels (Wong & Crosby, 1978).

Biodegradation

A strong correlation was identified between the rate of PCP degradation and the organic content of the soil. Soils with a high organic content were found to biodegrade PCP faster than soils with lower organic content. Soils containing higher concentrations of clay minerals resulted in a lower rate of biodegradation (Kuwatsuka & Igaradhi, 1975). Additional studies were carried out studying the effects of soil moisture content and the rate of PCP removal. The greatest PCP removal rates were detected at 15% and 20% (wt/wt) water soil content. At 50% water content, no PCP mineralization was detected over a 10-day period. However, the biodegradation rate began to proceed at a very rapid rate over an extended time period, indicating that the same amount of PCP as found in the drier soils was degraded. Sandy soils had the slowest mineralization rates and loam the fastest (Martinson et. al., 1986). This was clearly related to the total organic content (TOC) of the soil. To summarize, biodegradation will increase with TOC, pH, temperature, and will be faster under aerobic conditions in the presence of locally adapted microbes. Based on this information this dissertation compared the difference in preservative concentration in both sandy soils and soils composed of silty loam.

A study performed by the Ontario Hydro Research Division (1991) focused on PCP found in soils within the Canadian environment. They found that PCP was a contributor to ambient concentrations of PCP in environmental compartments, such as wildlife and humans. The most predominant source of environmental PCP contamination appeared to be from the wood preservative treatment facility used in the study. This facility, as a result of poor environmental practices, contaminated nearby streams and soil surfaces.

The study also measured soil concentrations of PCP in the vicinity of treated utility poles. The results indicated that PCP was not detectable at distances greater than 0.25 meters from the treated pole, with a detection limit of 0.05 ppm. PCP concentrations dropped significantly within this distance from 500 ppm to a few ppm. Some possible explanations for this may be: a) very little PCP leaches from the pole, b) there is an initial leaching during the first couple of years after installation, limiting detection of PCP to that period, and c) PCP concentrations in soil, biodegrade rapidly after the initial leaching period.

A study performed by the Electric Power Research Institute (EPRI, 1995) focused on PCP in soils adjacent to in-service utility poles in New York State. This study attempted to identify the extent of the release, migration, attenuation and biodegradation of PCP of in-service utility poles through the State. Their results indicated general trends in attenuation and migration potential. Sample data revealed a rapid decline of PCP concentrations with increasing depth and distance from the pole. PCP decreased by approximately three orders of magnitude between three inches and eight inches from the pole, with an overall average decrease of slightly over one order of magnitude. Their results also indicated that there was no clear pattern of contamination with respect to sample depth; no correlation between any physical parameters and chemical results (chlorophenol and Total Petroleum Hydrocarbons); no linear correlation between any physical or site specific characteristic and the results of the PCP (concentration) analysis; and Total Petroleum Hydrocarbons (TPH) and PCP concentrations appeared to be independent of one another. Also found was a rapid decrease in concentration of both PCP and TPH concentrations with increasing distance from the pole. No similar phenomena were observed with respect to sample depth.

My interview in 1996 with members of Bell Canada's environmental department reviewed their study of PCP distribution in soil surrounding treated utility poles in wilderness areas of the Canadian southeast. This study corroborated the results of the Electric Power Research Institute study on soils (1995). The Canadian study analyzed utility poles with an average age of approximately 15 years.

The overall result of these studies indicated that PCP contamination is contained close to the utility pole. Its migration from the pole is dependent on soil type, soil chemistry, local weather and topography, initial level of pole treatment, age of pole, pH and geographic location. There was a variation of two orders of magnitude in soil-water distribution coefficients. PCP values indicated a high correlation to the total organic carbons (TOC) content of the soil for two regimes of pH. Biodegradation rates also varied by almost three orders of magnitude. No correlation with other parameters was found by these studies.

PCP Treated Wood Disposition (Disposal)

Another concern by users of treated wood is its disposition. Treated wood has the potential for incurring exorbitant disposition fees, if the federal government reclassifies this used material as a hazardous waste by lowering the toxicity characteristic leaching procedure (TCLP) level for PCP and creosote. If this happens, cleanup costs will drastically increase. In, 1992, Bellcore estimated a disposal cost of $2000 per penta pole if classified as an EPA hazardous waste (Bellcore Letter, 1992).

A study performed by EPRI focused on extract levels of PCP (EPRI, Jan 1992) and creosote (EPRI, Mar 1992) from treated utility poles and crossarms. The result of the PCP study indicated that extract levels for PCP-treated poles and crossarms were well below the TCLP limit. The mean PCP concentration was 1.92 mg/l which was well below the PCP TCLP regulatory level of 100 mg/l. These concentrations are well below levels that would cause the tested materials to be classified as hazardous waste under the present Resource Conservation and Recovery Act (RCRA).

The result of the creosote study also indicated that treated wood poles and crossarms extract levels were found to be well below the TCLP limits for cresols. The mean creosote concentration was 1.61 mg/l well below the creosote regulatory level of 200 mg/l.

Landau Associates, Inc. (1992), on behalf of the Washington Public Ports Association (WPPA) conducted a similar study. TCLP analysis was conducted on creosote treated wood products used in the waters of Puget Sound. Thirty-six samples were analyzed from wood produced and placed in service between the mid-1920s and the 1980s. The TCLP results for cresol concentrations ranged from 0.02 to 39 mg/l, below the regulatory level of 200 mg/l. Their research also examined 36 samples for PCP and found 35 samples at non-detectable levels and one sample at 0.017 mg/l, well below the TCLP criteria of 100 mg/l.

CREOSOTE

The Association of American Railroads (1994) performed a TCLP review of railroad crossties. The study examined TCLP characteristics of 28 individual samples, representing at least two dozen crossties from all over the U.S. The samples were taken from crossties ranging from 50 years of age to new ties, from various hardwoods. Virtually all crossties are treated with creosote; thus, the only extractable organics present to any extent were the o-, m-, and p- isomers of cresol, along with pentachlorophenol and phenol. The highest level of any cresol isomer detected in the leachate was 7.5 mg/l which is far below the regulatory level of 200 mg/l. This report concluded that creosote treated crossties should not be classified as hazardous waste.

All of the above studies indicate that creosote-treated poles and crossarms are a non-hazardous solid waste and support the generator knowledge that PCP and creosote-treated wood is not currently a hazardous waste. However, the US EPA is currently studying PCP and its effects on the environment; and, is beginning to focus on the environmental and health implications of the use of creosote. This indicates that there is a potential, based on the results of their findings, for the current regulatory standards for PCP or creosote containing wastes to become more stringent.

Copper-based preservatives especially ammoniacal copper quat (ACQ) solutions and dimethyl dithio carbamate are currently being studied. Boron is also being studied and has shown to be a good preventicide. However, boron has a tendency to leach into its surroundings when exposed to moisture. Studies are being performed to discover compatible fixation agents, and additives to inorganic arsenical preservatives. This research includes the study of water repellents and dye as well as the addition of oil to make the wood pole easier to climb. Ethylene glycol is currently under study for use with CCA as a means to enhance climbability.

FUMIGANTS

Fumigants are routinely used by utility companies in the United States as part of remedial treatment programs for wood poles. These chemicals effectively eliminate actively growing decay fungi and provide many added years of protection. However, each of the registered formulations has inherent disadvantages in either physical properties or application methods. The following list some advantages and disadvantages of fumigants.

Metham sodium (32.7% sodium N-methyldithiocarbamate), vorlex(R) (20% MITC, 80% chlorinated C-3 hydrocarbons), and chloroplcrin (trichloronitromethane) are applied as liquids. They can easily be spilled and are difficult to recover. Chloropicrin is extremely irritating to nasal membranes, making the use of a respirator necessary during application. A fourth formulation, MITC-Fume (methylisothiocyanate), is solid at room temperature and sublimes readily to a gas, but is very caustic, necessitating glass encapsulation that is more expensive than any of the liquid formulations. While all of these chemicals are highly effective, there is a need for safer, less volatile fumigants for remedial treatment of decaying wood.

BASIMID

A potential new form of wood fumigant, basamid (3,5-dimethyltetrahydro-1,3,5,2 Dazomet and Mylone) is a crystalline flowable powder and has been used extensively as a soil sterilant. A study by Forsyth and Morrell (1993) reviewed the effect of selected additives on the decomposition of basamid (3,5-dimethyltetrahydro-1,3,5,2-thiadiazine-2-thione) to MITC, a potent fungicide for remedial treatment to control wood decay. The objective was to identify a compound that could be added to Basimid that would allow it to be applied safely, as well as pose a minimal hazard to the environment.

Basamid decomposes to form MITC, carbon disulfide, hydrogen sulfide, and formaldehyde (Ashley & Leigh. 1963). The problem with this decomposition is that it is too slow to be effective (Forsyth & Morrell, 1992). Laboratory tests indicated that basamid decomposition was enhanced when it was amended with copper sulfate and a powdered (p 12) buffer (Sexton & Lebow. 1988).

The overall result of these tests indicate that copper sulfate plus a (pH 12) buffer added to basamid significantly enhanced its decomposition to MITC resulting in MITC levels that exceeded those from metham sodium, a standard commercial treatment. Further testing indicated MITC levels with this treatment declined much less rapidly and was more evenly distributed throughout pole stubs than in treatments with metham sodium indicating longer and better protection from internal decay. Also since the basamid compound is a solid and less volatile, it will substantially increase applicator and environmental safety. Other trials adding glucose, lignin, boron, ethanol, methanol, acetone, or water to basamid had little to no effect on MTIC production. These results suggest that basamid may be used for preventing internal decay in utility poles.

SUMMARY

The preceding literature review indicated there are preservative leaching and soil contamination issues associated with treated in-service utility poles. The extent of this leaching and contamination is dependent on many factors. Research suggests that soil type, pH, temperature, organic and moisture content of the soil, local weather and topography, initial level of pole treatment, age of pole, and sunlight all play a significant role to varying degrees in the soil retention of PCP and creosote. The majority of these variables affecting soil retention are geologic and geographic in nature, with the soil composition being composed of parent rock, and the topography and moisture content a result of its location. The soil texture of samples collected during this study was silty loam at the roadside locations and sandy at beach locations.

It was found that as long as PCP remains fixed in the treated wood or in the adjacent soils, concerns for environmental contamination is minimal. Environmental and health concerns arise if PCP migrates from the application site towards ground or surface water. As previously indicated, the migration of PCP through soils are dependent on pH, which varies according to soil type, vegetation type, precipitation acidity and volume, and local industry discharges.

The observed trend is that wood preservative contamination is limited to areas close to the pole, declining in concentration with increasing depth and distance from the pole. It has been suggested (EPRI, 1995) that PCP was not detectable in soils at distances greater than 0.25 meters from the treated pole, with the detection limit of 0.05 ppm. PCP concentrations dropped significantly within this distance from 500 ppm to a few ppm. Creosote and PCP wood pole samples indicated a significantly lower TCLP concentration in relationship to the regulatory standard. This is a strong indication that under the standards used today treated wood poles can be treated as non-hazardous waste for disposition.

Additional research is still necessary to determine the total effect environmental contamination by PCP/creosote has on health and the environment. It is well established that PCP contains dioxins (2, 3, 7, 8-tetrachlorodibenzo-*p*-dioxin) and furans (2, 3, 7, 8-tetrachlorodibenzo-*p*-dioxin). As noted, the two compounds 2, 3, 7, 8-tetrachlorodibenzo-*p*-dioxin (TCDD) and 2, 3, 7, 8-tetrachlorodibenzo-*p*-dioxin (TCDF) are classified as probable human carcinogens and pose a serious health hazard. Creosote contains PAHs, which are also classified as probable human carcinogens posing serious health and environmental concerns. Inorganic arsenic and certain arsenic compounds (CCA) have been determined to be known human carcinogens.

To date, there are still some unanswered questions regarding wood preservatives and soil contamination. As indicated by the research, there is no definite timeline model for soil attenuation. This information is important in the sense that soil remediation is a costly undertaking. If indicators can be developed for determining the level of preservative contamination in soil, then, much of today's soil sampling costs can be avoided. Along the same line of reasoning, if it can be shown that soil contamination from in-service utility poles does not present itself as an environmental or safety hazard, then much of today's soil remediation costs can be avoided.

Additional attempts should be made to determine significant correlations between the preservative and soil distance, depth, pH, type, organic content, residency time of contaminant, physical parameters, as well as groundwater contamination. This information could prevent many conditions that are hazardous to the environment as well as to peoples' health. It has already been established that a high soil pH will release more PCP in the aqueous phase than a more acidic soil, thereby increasing the probability of release into groundwater and underground streams were the toxicity is much greater for aquatic biota.

If this toxic effect was generalized over a wide variety of estuarine or coastal environments, the results could very well effect spawning grounds as well as the size of local fish populations. Thus, impacting the fishing industry as well as the trickle down effect to the rest of the economy.

EPA STUDIES

At the time of this writing, the US EPA was reviewing the result of this study as well as a number of other studies in order to consider possible reclassification of PCP and its uses.

The concentration of PCP or creosote in soil needs to be quantified by testing soil under a variety of geographic conditions. Other considerations should be given to pole age and soil type in order to develop a baseline to determine the average concentration of preservative under these varying conditions. This will enable utilities to predict the amount of soil contamination prior to pole removal. As a result, they will properly dispose of the soil either as a hazardous or industrial waste without the need for soil sampling.

The following chapter will detail preservative sampling results from soil collected, as part of this study, within three-inches to six-feet from in-service utility poles. The age of these utility poles treated with either PCP or creosote ranged from 15 to 45 years. The geographic area chosen for this study has a temperate coastal climate and is located in the glacial outwash plain of southwestern Long Island. Soil conditions were favorable to analyze for differences between a well compacted silty loam with smaller pore spacing and sandy (beach) soil which was poorly consolidated and had larger pore spacing.

These results obtained from this study can be used as a guideline to determine the preservative concentration of soil adjacent to utility poles, providing the criteria based on the parameters of this dissertation (eg., soil type and geographic location) is the same as used in this study. Additional studies will need to be performed before these results can be extrapolated to other parts of the country.

CHAPTER 3

ANALYSIS of SOIL SURROUNDING PRESERVATIVE TREATED UTILITY POLES

OBJECTIVE

This section will discuss and quantify the extent of soil contamination measured from in-service utility poles treated with creosote and pentachlorophenol (PCP). These data will be presented as a function of depth and distance from the pole in relation to the background level taken from the surface at a distance of 12 feet. The in-service age of the poles sites sampled ranged from six to 41 years.

There are four objectives that are to be achieved from analyzing these data. One is the quantification of soil contamination from creosote and PCP associated with treated utility poles; second, determination of trace amounts of dioxins and furans in the pesticide; third, evaluation of cost effective alternatives to wood poles (Chapter 6); and fourth, recommendation regarding a long term process for minimizing preservative releases to the environment (Chapter 7).

Sampling Location

The geographic area chosen for this field study was the southeastern portion of New York State, specifically the coastal areas of Staten Island, Queens and southwestern Nassau County. The soils in this region are composed of glacial outwash, allowing for observations of preservative leachate concentration effect on soils in this region. The soils sampled during this study were composed of silty loam collected along the roadside and sandy soil collected along the beaches of Long Island's south shore. These soils were chosen for comparison of preservative impact on soil type. Specific areas within this region were selected for soil type and their accessibility and proximity to populated areas. See area maps in Appendix 2.

The sample collection areas were divided into two types of locations: a) roadside composed of silty loam (a soil high in organic content) and, b) sandy beach areas. Newer poles were purposely avoided to focus on soil retention issues resulting from older poles. All poles selected were treated with either the wood preservative creosote or PCP. Utility poles visibly leaching preservative/oil into the surrounding soil were not included in the sampling strategy. This was done to avoid biasing the sampling results.

Methods and Procedures

The soil sampling strategy was to collect soil from the surface and proceeded down at one-foot increments through the original entry hole to a three-foot depth. This process was repeated for distances of three inches, two feet, four feet, and six feet from the pole. The only exception was at 12 feet, where only a surface background sample was collected. This 12-foot sample represented soil not compromised with preservative leachate from the pole. Each sample was comprised of a three-inch composite sample from the depth at which it was collected. Care was taken not to disturb the soil from previous sampling levels while boring to the next sampling point. This sampling strategy attempted to ascertain where soil concentrations of preservative reached background levels as defined by the 12-foot surface sample.

Materials

The materials used for the collection of soil were a Johnson Hand Auger with a two-inch diameter coring bit, a small hand garden shovel, distilled water, and clean glass sampling jars (supplied by Philip Analytical). All sampling jars were immediately sealed and labeled with a predetermined code to designate date and soil sample location. This procedure eliminated errors in sample identification. The soil samples were shipped by air to Philip Analytical Laboratories in Reading PA for chemical analysis. After each sample was collected, the auger and shovel were systematically washed with distilled water and hand dried.

Sample Collection Method

Samples were collected along a straight line from the south side of the pole (whenever possible) for consistency. Each sample was collected from four predetermined distances from the pole, three inches, two-feet, four-feet and six-feet. At each distance, four samples were collected from the surface, one-foot, two-foot and three-foot depths. At the 12-foot distance, only a surface sample was collected for background purposes. (See Figure 3.1). A total of 17 samples were collected per utility pole.

A total of 15 utility pole locations were selected for the soil sampling. Of the 15 utility poles, eight were located along the roadside and the soil composed of silty/loam and seven were located in sandy beach soil. The roadside sample locations consisted of six PCP and two creosote treated poles. The sandy beach sample locations consisted of four PCP and three creosotes treated poles.

Analysis

Philip Analytical Laboratories used the following US EPA recommended analytical protocols to analyze the soil core samples. It must be noted that the laboratory strictly followed the Quality Control standards as required by the US EPA for each analytical method.

- US EPA Method 8270 was used to analyze for PCP; analysis was performed using gas chromatography/mass spectrometry (GC/MS)
- US EPA Method 8270C was used to analyze for creosote (semi-volatile organic compounds SVOCs); analysis was performed using GC/MS
- US EPA Method 8290 was used to analyze for dioxins/furans (PCDDs and PCDFs); analysis was performed using high resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS)
- US EPA Method 9045 was used to analyze for soil pH. Test methods for evaluating solid waste, physical/chemical methods, SW846, third edition, US EPA, 1986 with all promulgated revisions.

All sample results were calculated on a dry weight basis. The US EPA, as well as most state environmental agencies, require this procedure. Using a dry weight basis eliminated the diluting effect of water or other liquids on the concentration of other analytes in the soil sample, and assists in comparing solid samples collected from different areas.

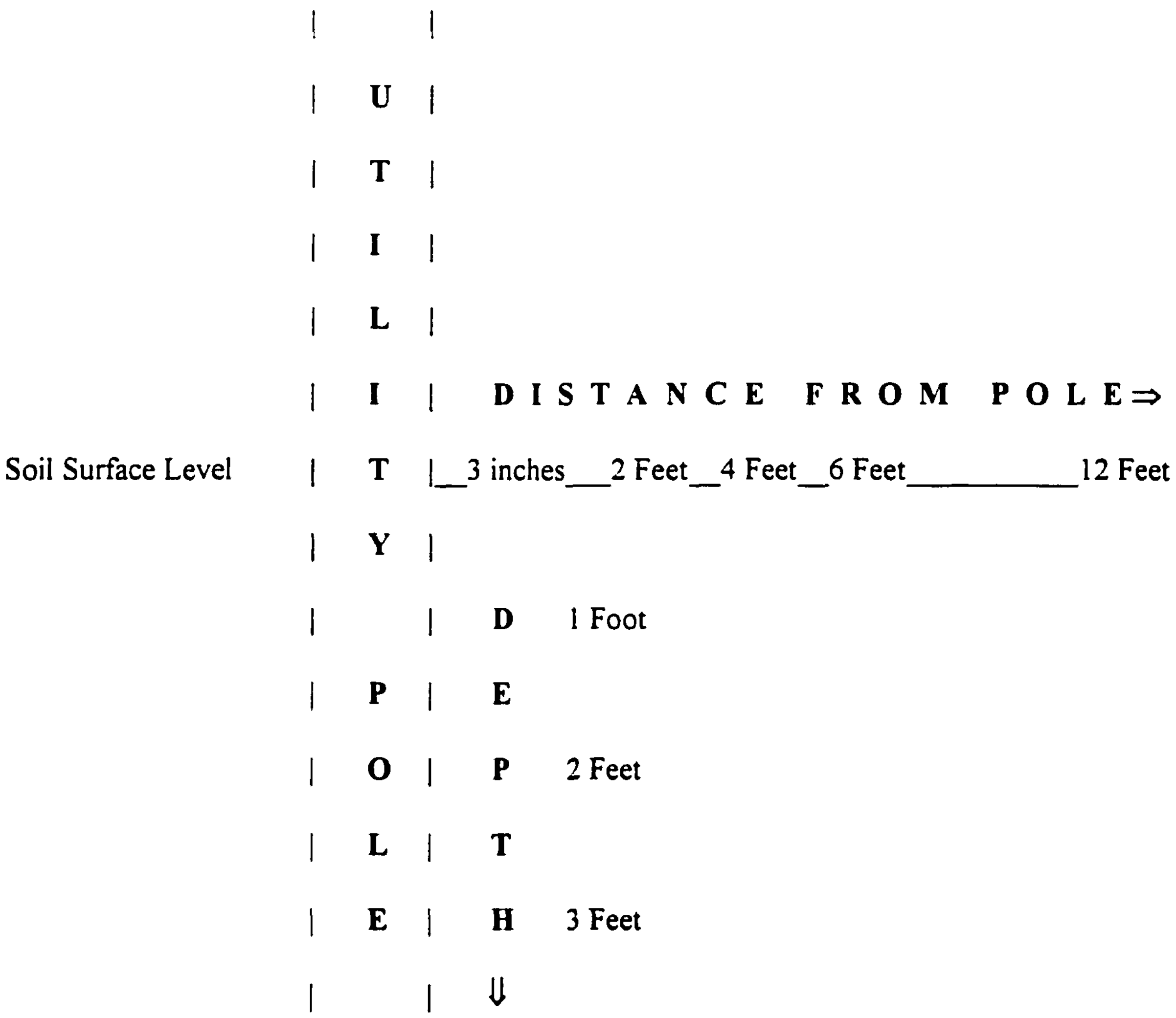


FIGURE 3.1. Diagram of sampling strategy used for collection of soil samples from adjacent utility poles.

Statistical Testing

Statistical analysis tested the null hypothesis, indicating no significant difference between the soil sampling points.

A two-way analysis of variance (ANOVA) with replication was used to determine if the average concentration of contaminants differed among sampling point locations at different depths and distances. This analysis was done for both beach and roadside locations. The result of the ANOVA of PCP, creosote, TCDD, 2,3,7,8-TCDD, TCDF and 2,3,7,8-TCDF indicated no significance ($p<0.05$) within or between sampling points for either beach or roadside locations. Samples points collected from beach locations were statistically analyzed separately from samples collected from roadside locations.

Non-Parametric Statistical Testing

Non-Parametric statistical testing was used because of the small sample sizes. The Mann-Whitney U test, Kolmogorov-Smirnov Z test, and Wilcoxon test were used to test obvious differences for PCP and creosote between background levels and levels based on observations from graphed sampling results from each pole location (beach and roadside). Statistical testing involved comparing selected average high to low sampling point concentrations from within the same location. The same statistical methods were used to compare sample point locations with high average concentrations to the background sample. Additional non-parametric statistical testing was conducted to determine if there was any significance between beach concentrations and roadside concentrations as a function of depth. This was used to determine if there was any difference in preservative retention between sandy soil and silty loam.

Results

Soil concentrations diminished as a function of distance from the pole. As shown in Figures 3.1 through 3.4 and A-1 through A-32, the concentrations of creosote, PCP, TCDDs, TCDFs and their congeners were lower with increasing distance from the utility pole.

All sample results referenced in this text are average concentrations of sampling points at depth and distance unless otherwise noted.

Pentachlorophenol (PCP)

It should be noted that the PCP roadside sampling included one site which had readings slightly higher than the norm. Statistical analyses were conducted both with the sample and without the sample. As a result, the sample was left in the database and had no substantial effect on the significance of the statistical analysis. As expected, soil concentrations diminished as a function of distance from the pole. The results between the beach and roadside locations varied slightly, but the trend remained similar.

PCP Results Summary

PCP Roadside

PCP roadside analysis indicated only one sampling point above background levels. The only elevated concentration found above the US EPA action level was the surface sample collected from the three-inch distance from the pole (see Table 3.1). This data point concentration dropped off to the background level at a distance of two feet from the pole (see Figure 3.2). The remaining samples starting from the three-inch distance were at background through all distances. All individual distance samples from three inches to six-feet, ranged from 6.26E+02 mg/kg to 1.10E-01 mg/kg with an average sample concentration of 1.45 E+01 mg/kg (ppm).

Roadside statistical analysis indicated no significant difference ($p<0.05$) when comparing sampling points from within the same location, indicating that all sample points were within background levels for that location. Additional analyses were conducted comparing the elevated roadside surface sample from the three-inch distance to the 12-foot background sample location. No significant difference ($p<0.05$) was found between the two sample distances, thus verifying that all remaining sample points were within background levels. The surface sample (1.08E+02 mg/kg) collected at three-inch distance from the pole did exceed the US EPA action level for PCP of 100ppm for clean up of contaminated soil.

AVERAGE PCP ROADSIDE DISTANCE (ft.)	DEPTH SURFACE Concentration mg/kg*	DEPTH 1 FOOT Concentration mg/kg	DEPTH 2 FEET Concentration mg/kg	DEPTH 3 FEET Concentration mg/kg
0.25	1.08E+02**	2.10E+01	2.70E+01	5.64E+00
2	7.63E+00	7.12E+00	6.85E+00	5.68E+00
4	8.11E+00	7.02E+00	6.58E+00	6.85E+00
6	8.18E+00	7.93E+00	6.80E+00	1.73E-01
12	5.69E+00			

TABLE 3.1. Average PCP soil concentrations collected from roadside utility pole locations. Distance from pole is measured in feet at sample depths ranging from the surface to three feet.

*mg/kg = Milligrams per kilogram or parts per million (ppm).

**US EPA Soil Remediation Action Level for PCP = 1.0E+02 mg/kg or 100ppm. Average PCP laboratory limit of detection = 1.9E-01 mg/kg or 0.19ppm.

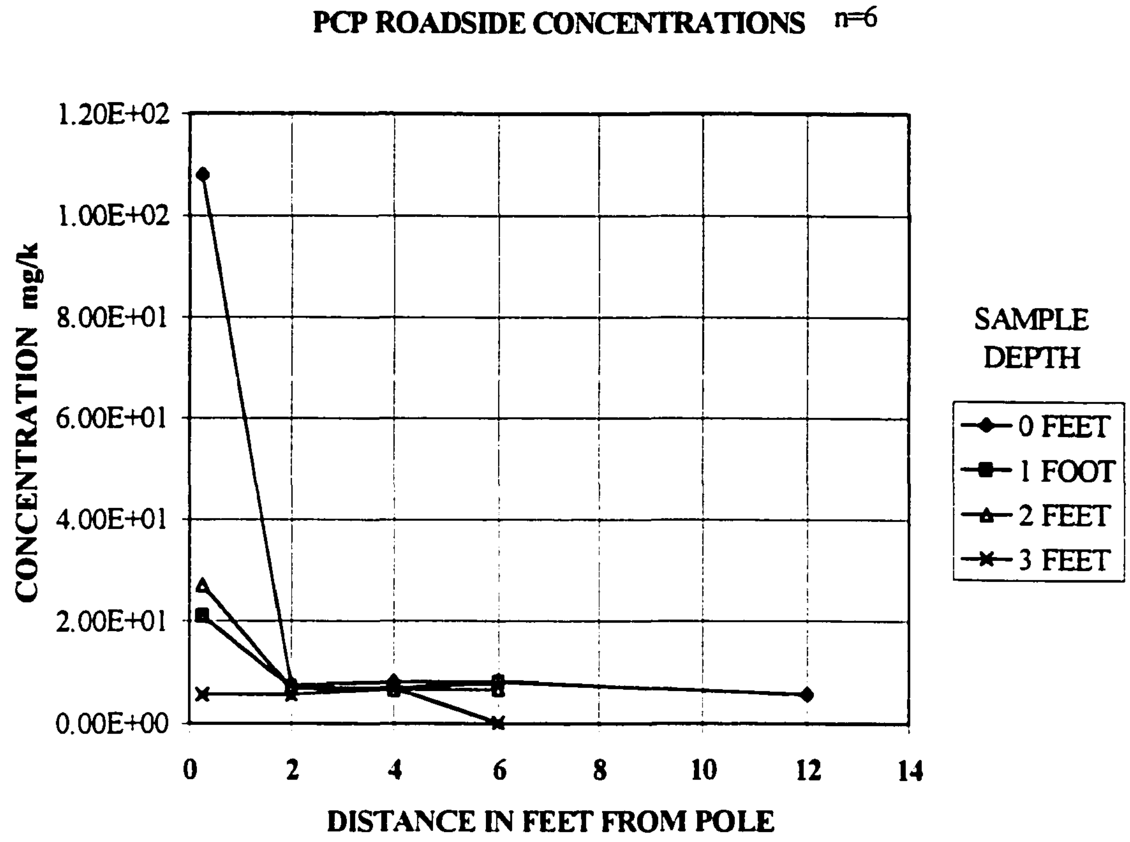


FIGURE 3.2 PCP concentrations in silty/loam soil (roadside area) at depth varying by distance from the utility pole.

US EPA Soil Remediation Action Level for PCP = 1.00E+02 mg/kg or 100ppm.

Average laboratory PCP limit of detection = 1.9E-01 mg/kg or 0.19 parts per million (ppm). All graphed values are either at or above this limit.

PCP Beach

PCP beach concentrations followed the same pattern as the PCP roadside samples. The only elevated beach PCP concentration in this sampling sequence was the average surface sample collected at the three inch distance from the pole (see Table 3.2). This data point concentration dropped off to the background level at a distance of two feet from the pole.

The remaining samples starting from the three-inch distance was at background through all distances (see Figure 3.3). All individual distance samples from three-inches to six-feet, ranged from 1.3E+01 mg/kg to 1.10 E-01 mg/kg with an average sample concentration of 3.83E-01 mg/kg.

Similarly, PCP beach statistical analysis indicated no significant difference ($p<0.05$) found when comparing sampling points from within the beach location. Additional analyses were conducted comparing the elevated surface sample from the three-inch distance to the 12-foot background sample point. No significant difference ($p<0.05$) was found between the two sample distances. Thus, verifying that all remaining sample points were within background levels for that location.

Elevated PCP concentrations were observed at the three-inch distance from the pole. Sample concentrations dropped off to their respective background levels at a distance of two feet from the pole.

Statistical testing was conducted to determine if there was any significant difference between roadside concentrations and beach concentrations. Sampling points from various depths were compared with their counterparts from each location. Similar testing was conducted comparing distance from each location. These analyses showed that roadside samples collected at the surface and two-foot depth were significantly higher ($p<0.1$) than corresponding sample concentrations taken from the same depths at the beach location.

The one-foot and three-foot depth comparison of roadside to beach locations, resulted in non-significant ($p<0.05$) findings. See Figures A-1 to A-4.

AVERAGE PCP BEACH DISTANCE (ft.)	DEPTH SURFACE Concentration mg/kg*	DEPTH 1 FOOT Concentration mg/kg	DEPTH 2 FEET Concentration mg/kg	DEPTH 3 FEET Concentration mg/kg
0.25	3.46E+00	3.93E-01	1.73E-01	2.48E-01
2	2.73E-01	1.70E-01	1.70E-01	1.73E-01
4	1.65E-01	1.65E-01	1.65E-01	1.68E-01
6	1.65E-01	1.68E-01	1.68E-01	1.65E-01
12	1.60E-01			

TABLE 3.2. Average PCP soil concentrations collected from beach utility pole locations. Distance from pole is measured in feet at sample depths ranging from the surface to three feet.

Average PCP laboratory limit of detection = 1.9E-01 mg/kg or 0.19 parts per million (ppm).

*mg/kg = Milligrams per kilogram or ppm.

US EPA Soil Remediation Action Level for PCP = 1.00E+02 mg/kg or 100ppm.

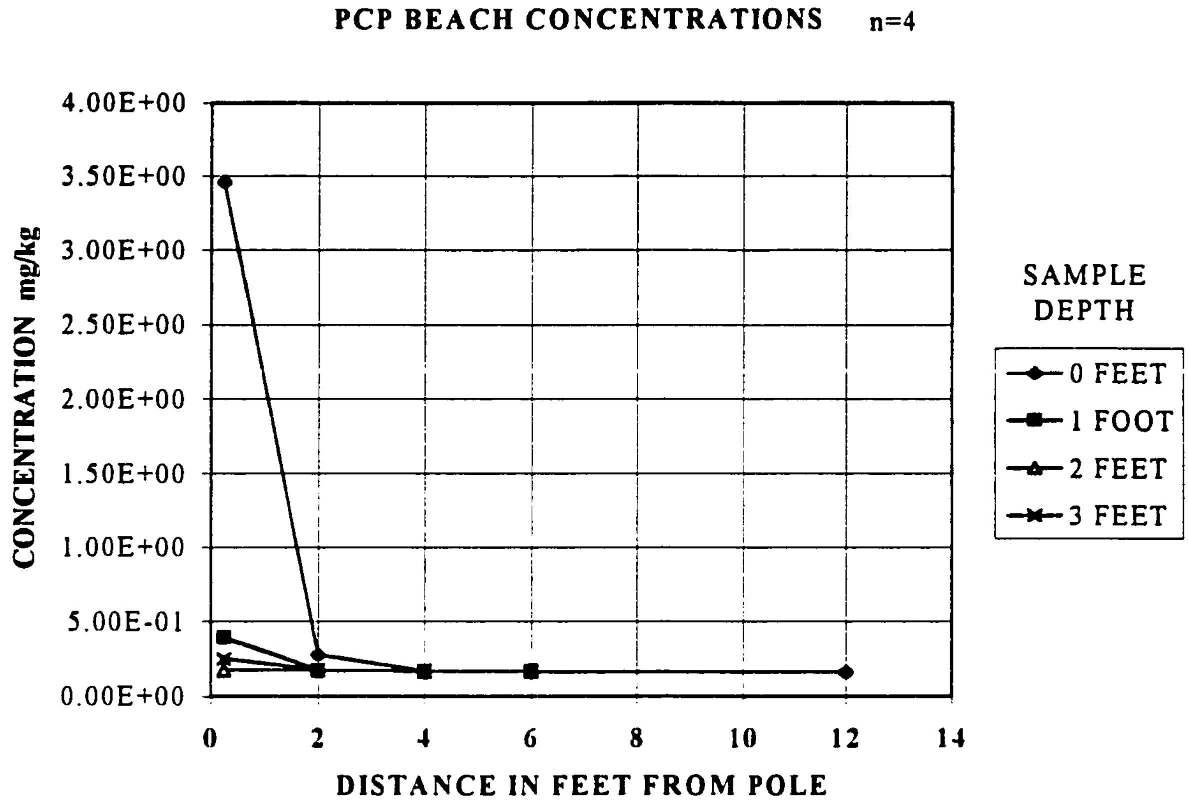


FIGURE 3.3. PCP concentrations in sandy soil (beach area) at depth varying by distance from the utility pole.

US EPA Soil Remediation Action Level for PCP = 1.00E+02 mg/kg or 100ppm. If the action level were plotted on this scale, the graph would be approximately six feet high. Average PCP laboratory limit of detection = 1.9E-01 mg/kg or 0.19 parts per million (ppm). All graphed values are either at or above this limit.

Dioxins and Furans

It was suspected that soil containing PCP preservative contained trace amounts of dioxins and/or furans. Sampling was conducted to determine the presence of TCDD and TCDF concentrations particularly congeners 2,3,7,8-TCDD and 2,3,7,8-TCDF. These congeners are believed to be the most toxic of this group and therefore were specifically isolated.

TCDD Results Summary

TCDD Roadside

The average surface concentration at three inches from the pole was higher by a factor of 2.8 when compared to concentrations at the one, two, and three-foot depths from the same distance (see Table 3.3). TCDD roadside samples reached background level at approximately two-feet from the pole (see Figure A-5). All individual distance samples from three-inches to six-feet ranged from 6.30E-02 ng/g to 5.00E-04 ng/g with the average sample concentration of 3.86E-03 ng/g (ppb).

AVERAGE TCDD ROADSIDE DISTANCE(ft.)	DEPTH SURFACE Concentration ng/g*	DEPTH 1 FOOT Concentration ng/g	DEPTH 2 FEET Concentration ng/g	DEPTH 3 FEET Concentration ng/g
0.25	1.56E-02	2.38E-03	9.50E-03	7.13E-03
2	6.83E-03	4.49E-03	3.35E-03	2.63E-03
4	7.25E-03	3.70E-03	5.43E-03	4.13E-03
6	4.20E-03	2.81E-03	2.13E-03	1.94E-03
12	2.43E-03			

TABLE 3.3. Average TCDD soil concentrations collected from roadside utility pole locations. Distance from pole is measured in feet at depths ranging from the surface to three feet.

*ng/g = Nanograms per gram or parts per billion (ppb).

Average TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt).

US EPA dioxin recommended preliminary residential soil remediation goal = 1.0 E+00 ng/g or 1ppb per Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

Statistical tests were conducted to compare obvious differences based on observations from graphed sample results of beach and roadside locations. TCDD roadside analyses indicated a significant ($p<0.1$) difference when comparing the average surface sample at the three-inch distance with the 12-foot (surface) background sample. No significance ($p<0.05$) was found when comparing the remaining sampling points from the two-foot distance to the 12-foot background sample. Thus, indicating that the roadside samples from the two-foot distance were all within background levels (2.43 E-03 ng/g).

TCDD Beach

Samples collected from beach locations were all close to the background level (1.97E-03 ng/g) (see Table 3.4). The only exception was the surface sample located two feet from the pole. This sample was found to be much higher than the other sampling points at this location. There was no obvious explanation for this anomaly in this sampling sequence. TCDD beach samples (see Figure A-6). All individual distance samples from three-inches to six-feet ranged from 4.70E-02 ng/g to 7.00E-04 ng/g with an average sample concentration of 2.27E-03 ng/g.

As with the TCDD roadside analysis, TCDD beach analysis indicated a significant ($p<0.1$) difference when comparing the average surface sample at the three-inch distance with the 12-foot average surface background sample. No significance ($p<0.05$) was found when comparing the remaining sampling points from the two-foot distance to the 12 foot background sample, indicating that the beach samples from the two-foot distance were all within background levels.

AVERAGE TCDD BEACH DISTANCE(ft.)	DEPTH SURFACE Concentration ng/g*	DEPTH 1 FOOT Concentration ng/g	DEPTH 2 FEET Concentration ng/g	DEPTH 3 FEET Concentration ng/g
0.25	1.96E-03	1.28E-03	1.48E-03	3.32E-03
2	9.07E-03	1.58E-03	1.55E-03	2.50E-03
4	1.62E-03	1.74E-03	1.98E-03	1.72E-03
6	1.55E-03	1.55E-03	3.42E-03	2.32E-03
12	1.97E-03			

TABLE 3.4. Average TCDD soil concentrations collected from beach utility pole locations. Distance from pole is measured in feet at sample depths ranging from the surface to three feet.

*ng/g = Nanograms per gram or parts per billion (ppb).

Average TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt).

US EPA dioxin recommended preliminary residential soil remediation goal = 1.0 E+00 ng/g or 1ppb per Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

TCDD roadside concentrations collected from the one and three-foot sampling depths were found to be significantly ($p<0.05$) higher in concentration than respective samples collected from the same depths in sandy beach areas. There is no known reason for this variation in the results. The surface and two foot depth comparison of roadside to beach locations, resulted in non-significant ($p<0.05$) findings. The remaining statistical tests indicated no significant differences between roadside and beach concentrations. All samples from both beach and roadside locations dropped off to background levels on or about two feet from the pole. See Figures A-5 to A-10.

2,3,7,8 TCDD Results Summary

2,3,7,8 TCDD Roadside

2,3,7,8 TCDD sampling points from the three-inch distance to the four-foot distance varied without any pattern as a function of depth or distance. See Table 3.5. All individual distance samples from three-inches to six-feet ranged from 2.80E-02 ng/g to 5.00E-04 ng/g with an average sample concentration of 3.05E-03 ng/g. Sample concentrations reached background levels at a distance of six feet from the pole. See Figure A-11.

Statistical tests were conducted to compare obvious differences based on observations from graphed sample results of beach and roadside locations. No statistically significant difference ($p< 0.05$) for 2,3,7,8 TCDD roadside levels was found when comparing average sampling points from each distance and depth. Results indicated all that roadside samples were within the 12-foot background levels (2.47 E-03 ng/g). Additional testing indicated no significant difference ($p<0.05$) found when comparing roadside sampling points from the three-foot depth at .25 inches from the pole to the 12-foot background sample. This is a strong indication that all sample points were within the background level for that location. Roadside concentrations dropped off to the background level at a distance of six feet from the pole.

2,3,7,8 TCDD Beach

Samples collected in sandy soil (beach) were all close to the 12-foot surface background level (1.88E-03 ng/g) with only two sampling points being somewhat, but not significantly, higher. The three-foot sample depth at three-inches from the pole and the two-foot sample depth at six-feet from the pole, were found to be higher than the other sampling points at this location (see Table 3.6). The average sample concentration collected at the three-foot sample depth did not drop down to background levels until four feet from the pole (see Figure A-12). All individual distance samples from three-inches to six-feet ranged from 1.40E-02 ng/g to 8.00E-04 ng/g with an average sample concentration of 1.71E-03 ng/g.

AVERAGE 2,3,7,8-TCDD ROADSIDE DISTANCE(ft.)	DEPTH SURFACE Concentration ng/g*	DEPTH 1 FOOT Concentration ng/g	DEPTH 2 FEET Concentration ng/g	DEPTH 3 FEET Concentration ng/g
0.25	3.20E-03	2.17E-03	4.71E-03	7.07E-03
2	6.15E-03	4.46E-03	3.91E-03	2.60E-03
4	6.63E-03	3.85E-03	4.85E-03	4.07E-03
6	1.80E-03	2.81E-03	2.09E-03	1.86E-03
12	2.47E-03			

TABLE 3.5. Average 2,3,7,8 TCDD soil concentrations collected from roadside utility pole locations. Distance from pole is measured in feet at depths ranging from the surface to three feet.

*ng/g = Nanograms per gram or parts per billion (ppb).

Average 2,3,7,8-TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt).

US EPA dioxin recommended preliminary residential soil remediation goal = 1.0 E+00 ng/g or 1ppb per Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

No significant difference ($p< 0.05$) for 2,3,7,8 TCDD beach sample levels was found when comparing sampling points from each distance and depth. Beach samples, with only two exceptions, stayed at background levels from the three-inch distance from the pole to the background sample. Additional testing indicated no significant difference found when comparing sampling points from each of the two exceptions (three-inch/three foot-depth and the six-foot surface samples) to the 12-foot surface samples. Thus, verifying that all sample points were within background levels for that location.

BEACH 2,3,7,8-TCDD DISTANCE(ft.)	**DEPTH SURFACE Concentration ng/g***	**DEPTH 1 FOOT Concentration ng/g**	**DEPTH 2 FEET Concentration ng/g**	**DEPTH 3 FEET Concentration ng/g**
0.25	**1.64E-03**	**1.17E-03**	**1.37E-03**	**3.32E-03**
2	**1.40E-03**	**1.55E-03**	**1.45E-03**	**2.47E-03**
4	**1.62E-03**	**1.70E-03**	**1.50E-03**	**1.68E-03**
6	**1.52E-03**	**1.48E-03**	**3.33E-03**	**1.43E-03**
12	**1.88E-03**			

TABLE 3.6. Average 2,3,7,8 TCDD soil concentrations collected from beach utility pole locations. Distance from pole is measured in feet at depths ranging from the surface to three feet.

*ng/g = Nanograms per gram or parts per billion (ppb).

Average 2,3,7,8-TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt).

US EPA dioxin recommended preliminary residential soil remediation goal = 1.0 E+00 ng/g or 1ppb per Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

Statistical testing was also conducted to determine if there was any significant difference between roadside concentrations and beach concentrations. Sampling points from various depths were analyzed. Roadside sample concentrations in soil collected from the surface was significantly higher ($p<0.1$) than the corresponding sample collected from the beach location. Additional analyses of the one-foot and two-foot sampling depths were also found to be significantly ($p<0.05$) higher than the corresponding samples collected from sandy beach areas. The three foot depth comparison of roadside to beach locations, resulted in a non-significant finding. See Figures A-13 to A-16.

TCDF Results Summary

TCDF Roadside

TCDF roadside sample results indicated that the majority of sampling points (with the exception of the surface sample at the two-foot distance) reached background level at two feet from the pole (see Table 3.7). The surface sample concentration at the two-foot distance spiked and then dropped to background level at four feet from the pole. From this point, it rose slightly to the 12-foot level (see Figure A-17). All individual distance samples from three inches to six-feet ranged from 8.10E-01 ng/g to 5.00E-04 ng/g, with an average sample concentration of 4.63E-02 ng/g.

TCDF roadside surface concentration at three inches from the pole was slightly higher, but not significantly ($p<0.05$) higher, than the one to three-foot sample depths from the same distance. The surface sampling point at the two-foot distance from the pole was significantly higher ($p<0.05$) than the 12-foot background level. Analyses also indicated that the surface sampling point at the two-foot distance was significantly higher ($p<0.05$) than the one, two and three-foot sample depths from that same distance.

AVERAGE TCDF ROAD SIDE DISTANCE(ft.)	DEPTH SURFACE Concentration ng/g*	DEPTH 1 FOOT Concentration ng/g	DEPTH 2 FEET Concentration ng/g	DEPTH 3 FEET Concentration ng/g
0.25	1.86E-01	5.80E-02	1.15E-01	1.18E-01
2	3.23E-01	1.31E-02	1.57E-02	1.70E-02
4	2.98E-02	7.50E-03	1.13E-02	9.73E-03
6	5.35E-02	2.42E-02	1.08-E02	5.46E-03
12	1.26E-01			

TABLE 3.7. Average TCDF soil concentrations collected from Roadside Pole locations. Distance from pole is measured in feet at depths ranging from the surface to three feet.
*ng/g = Nanograms per gram of parts per billion (ppb).
Average TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt).
US EPA furan recommended preliminary residential soil remediation goal = 1.0 E+00 ng/g or 1ppb per Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

Additional statistical comparisons of average roadside depth samples, from the three-inch distance to the corresponding samples at the four and six-foot distances, resulted in a number of significant findings. The three-inch distance was significantly higher ($p<0.05$) than the four-foot distance at the two and three-foot depths. The same result occurred when comparing the three-inch and six-foot distances.

Additional testing indicated no significant difference when comparing the remaining sampling points from each to the 12-foot surface samples, thus verifying that all remaining sample points were within background levels for that location.

TCDF Beach

TCDF beach surface samples at the three inch and two foot distances, as well as the three-foot depth sample at three inches from the pole, were somewhat higher than the background level for this location (see Figure A-18). The remaining samples collected at this location were all close to the 12-foot surface background level (see Table 3.8). The average surface sample concentration did not drop down to background level until four feet from the pole.

TCDF beach statistical analysis indicated no significant difference ($p<0.05$) when comparing sampling points from within the same location, indicating that all sample points were within background levels for that location. An additional analysis was conducted comparing the elevated three-foot depth sampling point at the three-inch distance to the 12-foot background sample point. No significant difference ($p<0.05$) was found between the two sample distances, thus verifying that all sample points were within background levels. Possibly, this is the result of recent climatic conditions causing a release of leachate containing TCDF from the pole. All remaining sample points dropped to background level at two feet from the pole. All individual distance samples from three inches to six-feet ranged from 7.80E-01 ng/g to 8.00E-04 ng/g with an average sample concentration of 1.80E-02 ng/g.

AVERAGE TCDF BEACH DISTANCE(ft.)	DEPTH SURFACE Concentration ng/g*	DEPTH 1 FOOT Concentration ng/g	DEPTH 2 FEET Concentration ng/g	DEPTH 3 FEET Concentration ng/g
0.25	1.05E-01	1.53E-02	1.57E-02	1.50E-01
2	8.39E-02	7.33E-03	1.41E-02	9.67E-03
4	3.60E-02	1.78E-03	8.06E-03	1.71E-02
6	1.12E-02	1.67E-03	5.00E-03	2.81E-02
12	2.52E-03			

TABLE 3.8. Average TCDF soil concentrations collected from beach utility pole locations.

*ng/g = Nanograms per gram of parts per billion (ppb).

Average TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt).

US EPA furan recommended preliminary residential soil remediation goal = 1.0 E+00 ng/g or 1ppb per Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

Statistical testing was also conducted to determine if there was any significance between roadside concentrations and beach concentrations. Sampling points from various depths were compared with their counterparts from each location. TCDF roadside sample concentrations collected from the surface, one-foot, and two-foot sampling depths were found to be significantly ($p<0.05$) higher than respective samples collected from the same depths in sandy beach areas. The three-foot depth comparison of roadside to beach locations resulted in a non-significant difference. See Figures A-19 to A-22.

2,3,7,8 TCDF Results Summary

2,3,7,8 TCDF Roadside

2,3,7,8 TCDF roadside sample results for the most part started at background levels with only one exception, the two-foot depth sample at three inches from the pole (see Figure A-23). This concentration was slightly higher, but not significantly higher than the surface, one and three-foot depth samples at that same distance. An additional elevated concentration (3.9E-02 ng/g) was observed at the 12-foot background sampling location. The 12-foot background sample spiked for no apparent reason. All individual distance samples from three inches to six-feet ranged from 2.10E-01 ng/g to 5.00E-04 ng/g with an average sample concentration of 5.75E-03 ng/g. See Table 3.9.

The 2,3,7,8 TCDF the surface sample located three inches from the pole was significantly ($p<0.1$) higher when compared to the roadside background surface sample located at 12 feet from the pole. However, no significance ($p<0.1$) was found when comparing the two-foot depth sample at three-inches from the pole to the 12-foot background sample. Additional analyses indicated no significance ($p<0.05$) found when comparing the average three-inch sampling distance to the two-foot sampling distance. No significant difference ($p<0.05$) was found for the remaining 2,3,7,8 TCDF roadside sampling depths when compared to the two, four and six-foot distances. These results indicate that all but the two elevated samples were at the background level for this location.

2,3,7,8–TCDF ROADSIDE DISTANCE(ft.)	DEPTH SURFACE Concentration ng/g*	DEPTH 1 FOOT Concentration ng/g	DEPTH 2 FEET Concentration ng/g	DEPTH 3 FEET Concentration ng/g
0.25	2.56E-03	1.92E-03	2.24E-02	5.76E-03
2	7.88E-03	3.44E-03	3.30E-03	2.01E-03
4	8.02E-03	4.72E-03	4.72E-03	4.03E-03
6	8.15E-03	6.94E-03	1.71E-03	1.43E-03
12	3.90E-02			

TABLE 3.9. Average 2,3,7,8-TCDF soil concentrations collected from roadside utility pole locations. Distance from pole is measured in feet at depths ranging from the surface to three feet.

*ng/g = Nanograms per gram of parts per billion (ppb).

Average 2,3,7,8-TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt).

US EPA furan recommended preliminary residential soil remediation goal = 1.0 E+00 ng/g or 1ppb per Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

2,3,7,8 TCDF Beach

Samples collected in sandy soil at the beach location were all close to the 12-foot surface background level (see Table 3.10), with only two samples being somewhat, but not significantly higher. The three-foot depth concentration at three inches from the pole was slightly elevated and the two-foot depth sample at six-feet from the pole sample spiked for no apparent reason. All individual distance samples from three inches to six-feet ranged from 6.00E-04 ng/g to 5.00E-02 ng/g with an average sample concentration of 1.93E-03 ng/g. All remaining sampling points dropped off to background levels at a distance of two-feet from the pole. The three-foot sample depth concentration reached background at four-feet from the pole (see Figure A-24).

2,3,7,8-TCDF BEACH DISTANCE(ft.)	DEPTH SURFACE Concentration ng/g*	DEPTH 1 FOOT Concentration ng/g	DEPTH 2 FEET Concentration ng/g	DEPTH 3 FEET Concentration ng/g
0.25	1.30E-03	2.12E-03	1.07E-03	2.58E-03
2	1.03E-03	1.23E-03	1.13E-03	2.00E-03
4	1.25E-03	1.42E-03	1.30E-03	1.34E-03
6	1.20E-03	1.22E-03	2.90E-03	1.27E-03
12	1.48E-03			

TABLE 3.10. Average 2,3,7,8, TCDF soil concentrations collected from beach utility pole locations. Distance from pole is measured in feet at depths ranging from the surface to three feet.

*ng/g = Nanograms per gram of parts per billion (ppb).

Average 2,3,7,8-TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt).

US EPA furan recommended preliminary residential soil remediation goal = 1.0 E+00 ng/g or 1ppb per Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

The 2,3,7,8-TCDF average two-foot depth concentration located six-feet from the pole was found to be significantly higher ($p<0.1$) when compared to the same depth at the three-inch distance. However, no significant difference was found ($p<0.05$) when comparing the two-foot depth at six-feet from the pole to the 12-foot background surface sample. No significant difference ($p<0.05$) was found comparing the three-foot depth at three-inches from the pole to the 12-foot background surface sample. This is a strong indication that all sample points were within the background level for this location.

Statistical testing was also conducted to determine if there was any significant difference between roadside and beach concentrations. Sampling points from various depths were compared with their counterparts from each location. Similar testing was conducted using distance as the variable tested. Most 2,3,7,8 TCDF samples collected along the roadside were higher, but not significantly higher, in concentration than samples collected in sandy beach areas. The 2,3,7,8 TCDF roadside sample concentrations at all distances, collected from the one-foot sampling depth were found to be significantly ($p<0.05$) higher than respective samples collected from the same depth in sandy beach areas. The surface, two-foot, and three-foot depth comparison of roadside to beach locations resulted in non-significant findings. Additional testing indicated that the 2,3,7,8 TCDF 12-foot roadside background concentration was significantly higher ($p<0.05$) than the 12-foot background concentration collected from the beach location. See Figures A-25 to A-28.

Creosote

Soil concentrations diminished as a function of distance from the pole. As noted below, results between the beach and roadside locations varied slightly but the basic trends remained the same.

Creosote Results Summary

Creosote Roadside

An elevated surface concentration was observed at three inches from the pole (see Table 3.11). All individual distance samples from three inches to six feet ranged from 6.79E+01 mg/kg to 4.48E+00 mg/kg with an average sample concentration of 1.32E+01 mg/kg.

CREOSOTE ROADSIDE DISTANCE(ft.)	DEPTH SURFACE Concentration mg/kg	DEPTH 1 FOOT Concentration mg/kg*	DEPTH 2 FEET Concentration mg/kg	DEPTH 3 FEET Concentration mg/kg
0.25	2.43E+01	3.99E+01	2.52E+01	3.61E+01
2	1.19E+01	1.05E+01	6.67E+00	6.16E+00
4	1.03E+01	6.36E+00	5.14E+00	4.52E+00
6	8.81E+00	6.18E+00	5.05E+00	6.12E+00
12	1.21E+01			

TABLE 3.11. Average creosote soil concentrations collected from roadside utility pole locations. Distance from pole is measured in feet at depths ranging from the surface to three feet.

*mg/kg = Milligrams per kilogram or parts per million (ppm).

US EPA Creosote Soil Remediation Action Level Action Level = 2.0E+02 mg/kg or 200ppm.

Average creosote laboratory limit of detection = 0.8E-01 mg/kg or 0.08ppm.

The total average roadside concentration at this distance (three inches) varied by a factor of 4.3 when compared to total average concentrations at the two, four, and six-foot depths. Elevated creosote concentrations were observed at the three-inch distance from the pole. Concentrations dropped off to their respective background levels at a distance of two feet from the pole. See Figure 3.4. Sample size was too small to permit statistical testing.

Creosote Beach

Creosote beach concentrations differed from their roadside counterparts with an elevated surface concentration observed at three inches from the pole (see Table 3.12). This sampling point varied by a factor of 1.6 in comparison to concentrations at the one, two, and three-foot depths from the same distance. Otherwise, the results followed the same pattern as the creosote roadside samples. All individual distance samples from three-inches to six-feet ranged from 1.40E+01 mg/kg to 2.65E+00 mg/kg with an average sample concentration of 5.01E+00 mg/kg. Elevated creosote concentrations were observed at the three-inch distance from the pole. Concentrations dropped off to their respective background levels at a distance of two feet from the pole. See Figure 3.5.

Sample size was too small to permit statistical testing. However, elevated creosote concentrations were observed at the three-inch distance from the pole. Concentrations dropped off to their respective background levels at a distance of two feet from the pole. See Figure 3.4.

Sampling points from various depths were compared with their counterparts from each location. Creosote samples collected from roadside surface, one-foot, and two-foot sampling depths were found to be higher in concentration than the corresponding samples collected from the sandy beach areas. As previously indicated, all samples from both beach and roadside locations dropped off to background levels on or about two feet from the pole. See Figures A-29 to A-32.

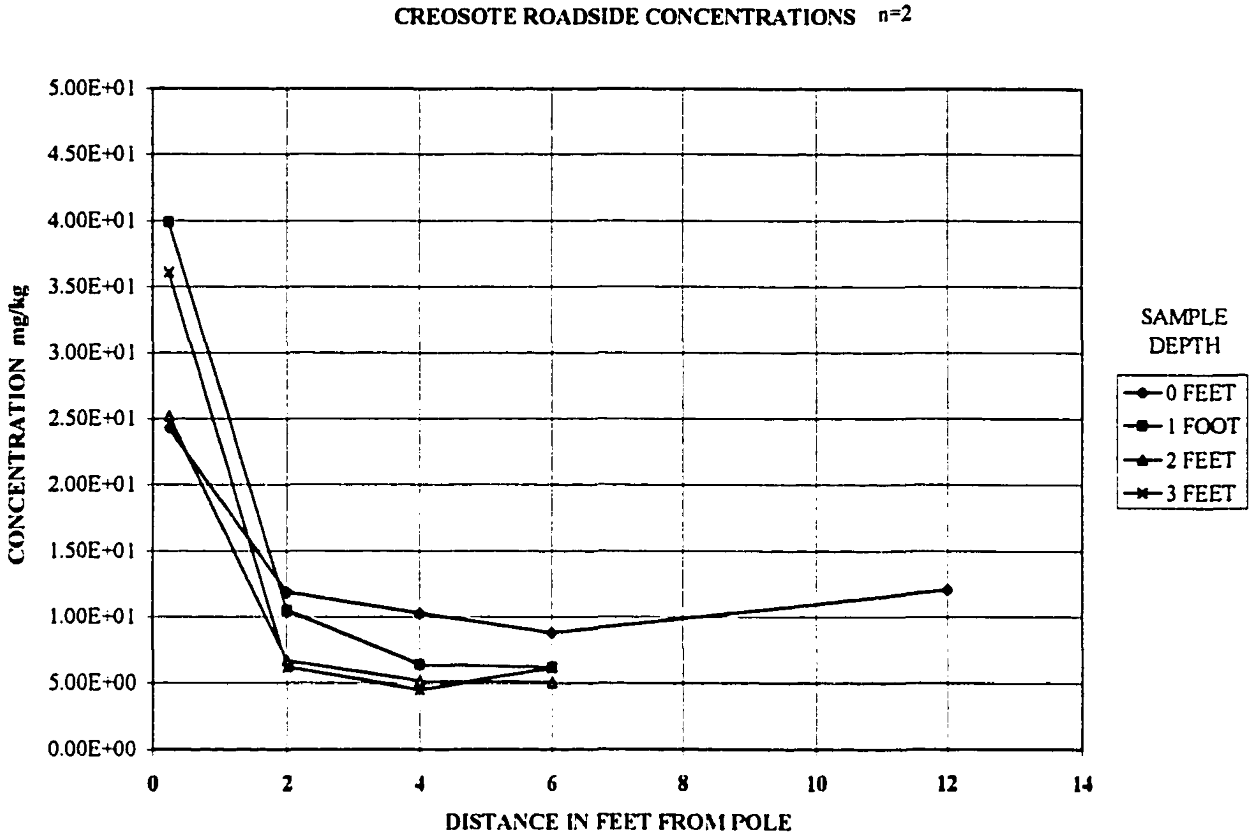


FIGURE 3.4. Creosote concentrations in silty/loam soil (roadside area) at depth varying by distance from the utility pole.

US EPA Soil Remediation Action Level for creosote = 200 milligrams per kilogram (mg/kg) or 200 parts per million (ppm). If the action level were plotted on this scale, the graph would be approximately one foot high.

Average laboratory creosote limit of detection = 0.8E-01 mg/kg or 0.08ppm. All graphed values are either at or above this limit.

CREOSOTE BEACH DISTANCE(ft.)	DEPTH SURFACE Concentration mg/kg	DEPTH 1 FOOT Concentration mg/kg	DEPTH 2 FEET Concentration mg/kg	DEPTH 3 FEET Concentration mg/kg
0.25	8.74E+00	4.46E+00	5.74E+00	6.59E+00
2	4.78E+00	4.76E+00	4.72E+00	4.85E+00
4	5.35E+00	5.53E+00	5.00E+00	4.61E+00
6	4.11E+00	4.01E+00	4.26E+00	3.93E+00
12	4.57E+00			

TABLE 3.12. Average creosote soil concentrations collected from beach utility pole locations. Distance from pole is measured in feet at depths ranging from the surface to three feet.

*mg/kg = Milligrams per kilogram or parts per million (ppm).

US EPA Creosote Soil Remediation Action Level = 2.0E+02 mg/kg or 200ppm.

Average creosote laboratory limit of detection = 0.8E-01 mg/kg or 0.08ppm.

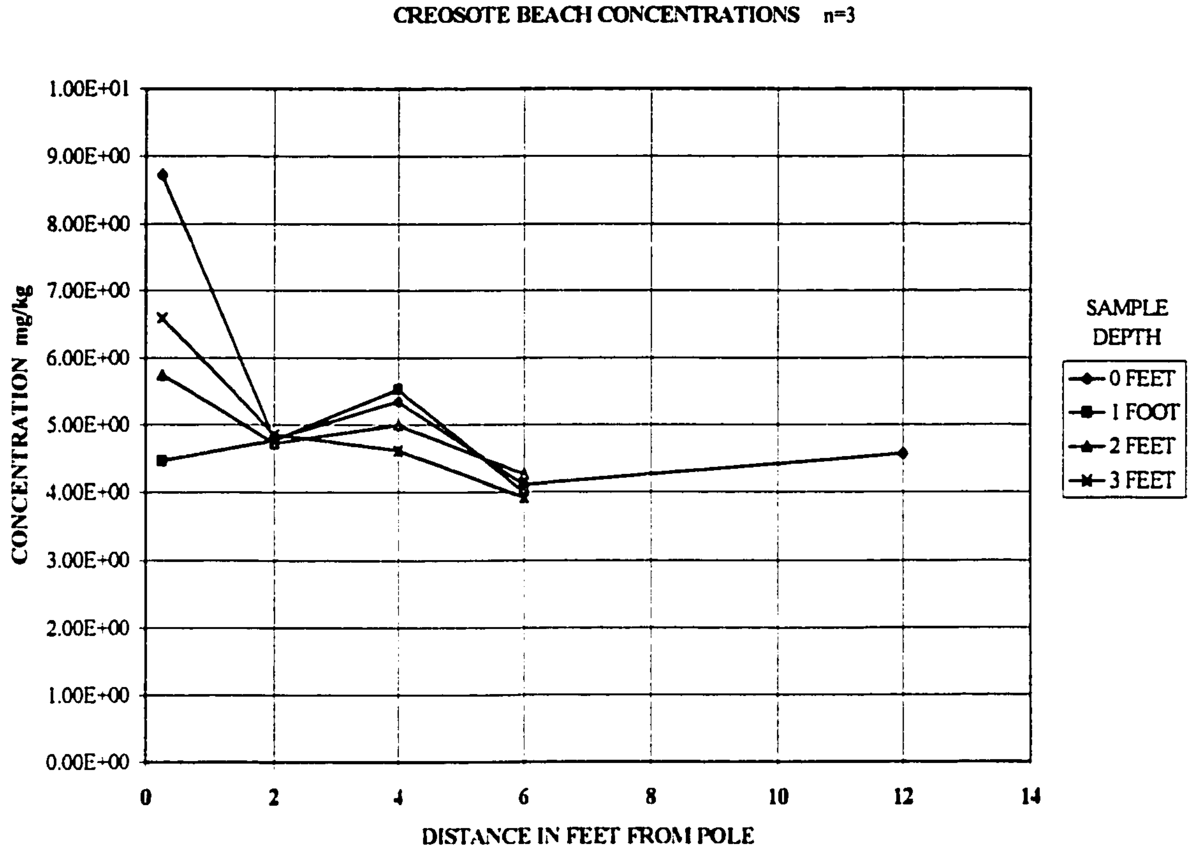


FIGURE 3.5. Creosote concentrations in sandy soil (beach area) at depth varying by distance from the utility pole.

US EPA Soil Remediation Action Level for creosote = 200 milligrams per kilogram (mg/kg) or 200 parts per million (ppm). If the action level were plotted on this scale, the graph would be approximately three feet high.

Average laboratory creosote limit of detection = 0.8E-01 mg/kg or 0.08ppm. All graphed values are either at or above this limit.

CONCLUSIONS

The results of this analysis indicate that the preservatives PCP and creosote can be detected within the first three-inches to two-feet from the in-service poles. Concentrations drop off rapidly from this point to background levels. This pattern of concentration can be attributed to preservative leaching from the pole over time caused by weathering, quality of preservative treatment process, and preservative concentration at time of application. However, due to creosote's small sampling size additional validation is recommended. Contamination due to periodic groundline treatment was not a factor. The vast majority of groundline treatment applicators use copper naphthenate (CN) or other non-PCP preservative for periodic treatment of areas where the pole interfaces with the soil. CN was not a variable tested for in this sampling sequence. Although PCP was in some isolated cases used for groundline treatment, PCP and creosote are not typically the preservatives of choice for groundline treatment and are not a likely source of contamination.

TCDD, 2,3,7,8-TCDD, TCDF, and 2,3,7,8-TCDF were found in the soil surrounding the pole. The most probable source of these compounds is the original wood preservative solution. These compounds were most likely in the preservative prior to treatment, since the PCP formulation process produces dioxins and furans as a by-product. However, the fact remains dioxins and furans were detected in soil surrounding PCP poles and in one location, TCDF concentrations were detected in soil surrounding a creosote treated pole.

The vast majority of contaminants (variables) tested were found to be well below their respective EPA action levels for soil remediation (see Table 3.13). The only exception was the PCP surface sample collected three-inches from the pole. The average concentration of PCP at this sampling location was 1.08E+02 mg/kg.

Preservative	Action Level
Creosote	200 ppm
PCP	100 ppm
TCDD	1.0 ppb (TEQ)*
2,3,7,8 TCDD	1.0 ppb (TEQ)
TCDF	1.0 ppb (TEQ)
2,3,7,8 TCDF	1.0 ppb (TEQ)

Table 3.13. US EPA Action Levels for Soil Remediation.

*TEQ = Toxicity Equivalency as per US EPA. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall TEQ mixture is the sum of the individual TEQ congener concentrations.

Dioxin/furan recommended residential soil clean up level is per the Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-26.

It is important to note that the concentrations found by the soil analyses are dependent on many factors including soil type and texture, initial level of pole treatment, pH, temperature, organic and moisture content of the soil, climate, topography, age of pole, and sunlight. The majority of these factors affecting the soil's capacity for preservative retention are geographic in nature. The soil composition is based on the parent rock found in the southeastern portion of New York State (which, in this case, is glacial outwash). The topography is dependent on the regional geology. The climate, local weather, and sunlight are variables dictated by their geographic location. All these factors play a significant role in soil attenuation and must be considered when attempting to interpret data resulting from this study.

Sampling results also indicate that preservative concentration along the roadside, where the soil composition was mostly silty loam, was in most cases significantly higher then their counterparts collected in sandy soils along the beach. This can be attributed to either a higher organic content of the roadside soils (silty loam) and/or the increase of leachability of sandy soils. The average roadside pH level was 7.09 in comparison to a pH of 7.20 representative of samples collected from beach locations, indicating that pH was not a significant factor.

TCDDs and TCDFs for the most part reached background levels at or about two feet from the pole. TCDD and 2,3,7,8 TCDD roadside concentrations reached background levels at slightly greater distances. However, this did not create a significant impact on the overall sampling results.

None of the poles tested in this study had any visible signs of preservative leaking from the pole. Poles with visible signs of extensive leaching will in all probability have concentrations of preservative in the surrounding soil higher than those detailed in this study. Although no poles with visible leaching were encountered, they would have been avoided in order not to bias this study.

Follow-up Research

Similar studies should be performed to determine if poles with a shorter in-service life than used in this study (i.e., less than 5 years), leach preservative at a faster rate, thereby significantly increasing the amount of preservative in the soil surrounding the pole. Studies should be performed in a variety of geographic locations, since changes in climate, topography, soil conditions, water table, and species type, to name just a few variables, may have a significant impact on pole leachability and soil attenuation, subsequently impacting the concentration of preservative in the soil.

One may interpret, based on the parameters used in this dissertation, that if soil were to be analyzed further north in a much colder climate the preservative soil attenuation rate would be somewhat slower and therefore contain a higher concentration of preservative. Conversely, soils analyzed further south in a hot humid setting, soil attenuation would be higher resulting in a lower concentration of preservative. One would also expect that further north in a colder environment the preservative would be subject to more physical factors attributing to its degradation, while in south the preservative would under go more biological and chemical degradation (see Figure 3.6). However, this interpretation should be subject to additional validation.

Using the results of this study, preservative concentration in soil can be predicted for specific compounds based on the parameters of this study. Adding to this, knowledge of pole age, its location and type of soil, one can make an educated guess as to the concentration of preservative in the soil surrounding the pole. The preservative contamination should fall within the range of sampling results detailed in this chapter.

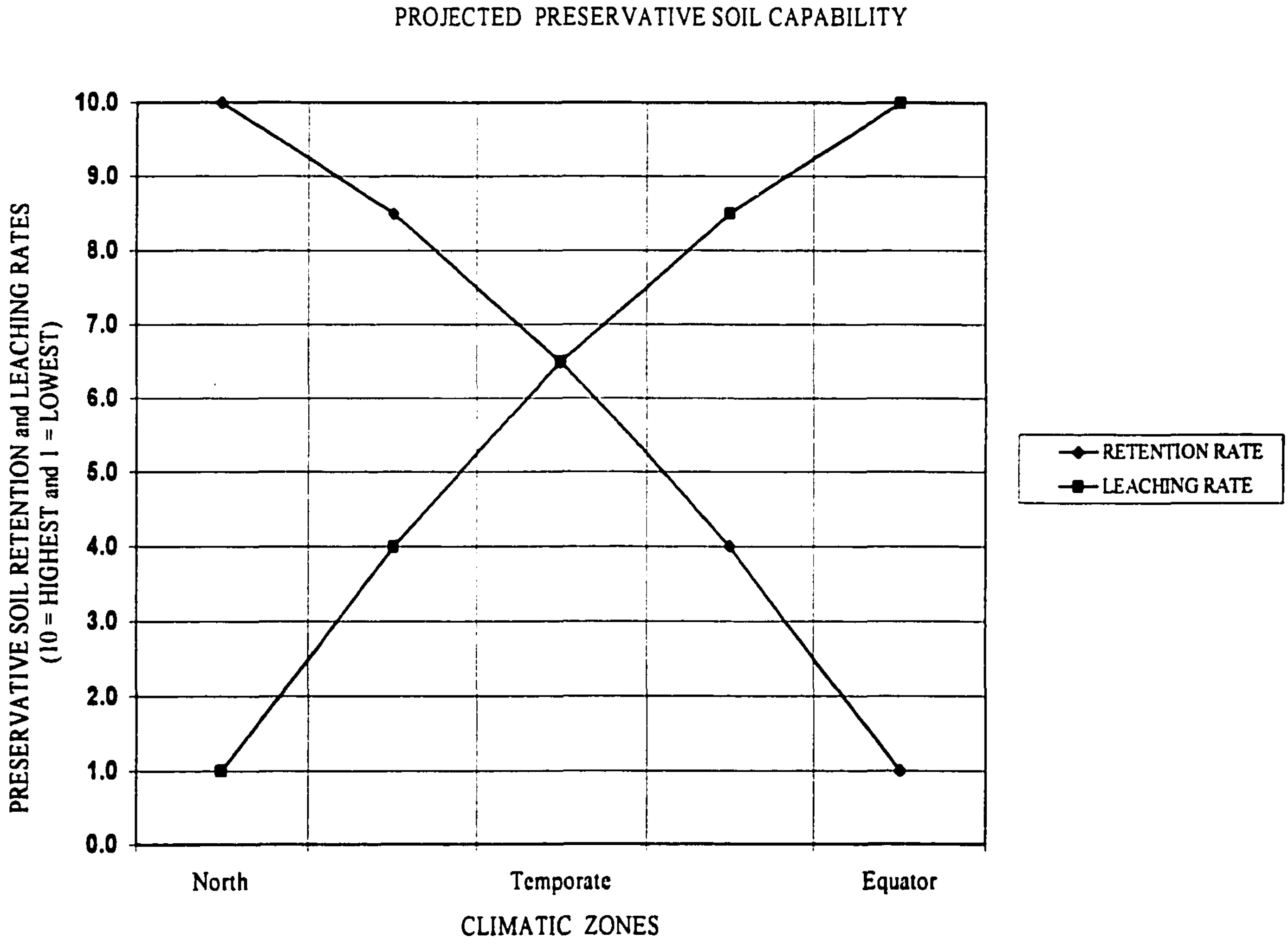


FIGURE 3.6. Preservative soil retention and leaching projections for climatic zones in the Northern Hemisphere ranging from the north pole to the equator.

The importance of this method of predicting preservative soil contamination is that it will significantly impact environmental policy of corporations regarding the usage of utility poles and remediation of surrounding soil. Improvements in the technology of wood preservative application, new preservative formulations, as well as close regulatory oversight, will also be contributing factors in corporate decision making regarding the non-wood alternative issue. Utilizing the results based on the methodology and parameters presented in this study, corporations and regulatory agencies will be able to reduce the costs associated with the testing, and remediation of potential contaminated sites.

CHAPTER 4

ENVIRONMENTAL AND HEALTH CONCERNS

This chapter will address the environmental and health-related issues regarding the usage and exposure to the three major types of wood preservatives, chromated copper arsenate (CCA), creosote, and pentachlorophenol (PCP). It is important to understand the impact of today's wood preservatives on the environment and human health. With this understanding, wood preservative users can acquire data to make better-informed decisions when deciding the type of preservative or pole to purchase. As with other types of exposure-related issues, the overall health and environmental impact is a result of exposure level (dose), exposure time (duration), route of entry (inhalation, ingestion, and skin absorption), individual characteristics (i.e., age, sex, nutritional status, family traits, and state of health), individual life style, habits, and potential synergies with other chemicals present. Regulatory concerns affecting future pesticide use, as well as utility pole usage, will be addressed in Chapter 5.

Information in this chapter was obtained from the US Department of Health and Human Services (US DHHS) - Agency for Toxic Substance and Disease Registry (ATSDR), United States Environmental Protection Agency (US EPA), and US DHHS, Public Health Service. Health risk information was taken directly from the US EPA's Integrated Risk Information System (IRIS) database. This database was developed by the US EPA for communication of chronic non-cancer and cancer health hazard information for over 500 substances. The hazard information contained in this database represents the EPA's technical evaluations developed through comprehensive review by Agency-specific experts. The health risk assessment information on chemical substances is included in this database only after a comprehensive review of chronic toxicity data. US EPA health scientists from several program offices and the Office of Research and Development perform this review. The rationale and methods used to develop the carcinogenicity information in IRIS are described in The Risk Assessment Guidelines of 1986 (EPA/600/8-87/045) and in the IRIS background document. IRIS summaries developed since the publication of EPA's more recent Proposed Guidelines for Carcinogen Risk Assessment also utilize those guidelines, where indicated (Federal Register, April 23, 1996).

The oral Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects, such as cellular necrosis (killing of living cells). It is expressed in units of milligrams per kilograms per day (mg/kg-day). In general, the RfD is an estimate, with uncertainty spanning perhaps an order of magnitude of a daily exposure to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime. For pole preservative in soil, the RfD of a preservative contaminant represents the potential exposure of a person coming in direct contact with the soil and being exposed. For example, a child ingesting surface soil contaminated with wood preservative. RfDs can also be derived for the noncarcinogenic health effects of substances that are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of these substances.

PRESERVATIVE INFORMATION

Chromated Copper Arsenicals (CCA)

CCA contains three elements, arsenic, chromium and copper. This chemical substance, also referred to as an inorganic arsenical, is registered for use as a wood preservative under FIFRA. Results of studies of chromium (VI) exposure have established a dose relationship for lung tumors. Epidemiological studies of workers in chromate production plants in Japan, Great Britain, West Germany, and the United States have revealed a correlation between occupational exposure to chromium and lung cancer. However, it is not clear which specific form of chromium responsible for the induction of cancer. It is suspected that hexavalent chromium (Chromium VI) has more of a mutagenic effect.

Arsenic is a naturally occurring element usually found in the environment at very low levels. It occurs as inorganic and organic forms of arsenic. Inorganic arsenic is combined with other elements such as oxygen, chlorine, and sulfur, and is much more toxic than organic arsenic, which is combined with carbon and hydrogen. Mainly inorganic arsenic compounds are mainly used as wood preservatives, insecticides and weed killers.

CCA Exposure Issues

Since arsenic is a naturally occurring element exposure can occur in almost any setting, therefore all humans are exposed to low levels of arsenic. The majority of people are exposed via ingestion of food products. Food constitutes the largest source of human arsenic intake, about 25 to 50 micrograms per day (µg/d), with lower amounts coming from drinking water and air. Some fish and shellfish contain elevated levels of arsenic, but this is predominantly in an organic form ("fish arsenic") which has low toxicity.

Sources of Exposure

The main use of arsenic in the United States of America is in pesticides and herbicides. Some products, mostly weed killers, use organic arsenic as the active ingredient. Other pesticides use inorganic forms of arsenic to kill plants, insects and rodents, or to preserve wood. The manufacturing or handling of these pesticides may result in arsenic exposure to humans unless adequate safety procedures are followed. Above-average levels of exposure are usually associated with one or more of the following situations:

Work Place

Exposure to arsenic can occur in the work place during the manufacturing (smelting) of copper and other metals. This process often releases inorganic arsenic into the air. Thus, workers in metal smelters and nearby residents are exposed to elevated airborne arsenic levels. The application of pesticides (e.g., in orchards and fields and along roadways) also may lead to water or soil contamination, creating the possibility for more widespread exposure to residents in the area.

Non-Occupational Settings

Since arsenic is a naturally occurring element, mineral deposits found in some geographic areas contain large quantities of arsenic. These mineral deposits may result in elevated levels of inorganic arsenic in water.

In the past, inorganic arsenic was contained in household products such as paints, dyes, and rat poisons, and in medicines for diseases such as asthma and psoriasis. These products are no longer in general use; therefore, exposure from these sources is now unlikely. However, Wolmanized lumber, which is used for outside decking and porches, contains CCA. This may be a potential source of exposure to the homeowner and their families.

In the Environment

Arsenic can also be found in some waste-chemical disposal sites; however, the chemical form found here (inorganic or organic) is often unknown. If the material is not properly stored or contained at the site, arsenic may escape into the soil or groundwater, thereby, increasing the probability of exposure to area residents. Elevated levels of arsenic in soil, due either to natural mineral deposits or from human activities, may lead to exposure from ingesting soil. This may be of particular concern for small children who swallow small amounts of soil while playing.

Additionally, low levels of arsenic are found in most fossil fuels (oil, coal, and gasoline). The burning of these materials in power stations, furnaces, stoves, and automobiles releases low levels of inorganic arsenic into the air.

Routes of Exposure

Arsenic can enter the body through ingestion, inhalation or skin absorption. Most ingested arsenic is quickly absorbed through the stomach and intestines where it enters the bloodstream, although this varies somewhat for different chemical forms of arsenic. Arsenic when is inhaled is also well absorbed through the lungs into the blood stream. Small amounts of arsenic may enter the body through the skin absorption. Most arsenic that is absorbed into the body is converted by the liver to a less-toxic form that is efficiently excreted in the urine. Consequently, arsenic does not have a strong tendency to accumulate in the body except at high exposure levels (dose).

Effects of Arsenic on Health

Inorganic arsenic is more toxic than the organic form. Arsenic in the inorganic form is a recognized human poison and large doses can result in death. Lower levels of exposure may result in detrimental systemic effects. Common symptoms related to ingestion are irritation of the digestive tract, which results in pain, nausea, vomiting, and diarrhea. Other effects typical of ingestion include decreased production of red and white blood cells, abnormal heart function (rhythm), blood vessel damage, liver and/or kidney injury, and impaired nerve function causing a "pins-and-needles" feeling in the feet and hands.

High levels of inorganic arsenic ingested via food sources or drinking water can be fatal. At high levels (60 ppm in food or water) arsenic damages many tissues including nerves, stomach and intestines, and skin. There is evidence from animal research that high oral doses during pregnancy may be damaging to the fetus, but this effect has not been studied in humans. Perhaps the single most characteristic systemic effect of oral exposure to inorganic arsenic is a pattern of skin abnormalities including the appearance of dark and light spots on the skin, and small "corns" on the palms, soles, and trunk. While these skin changes are not considered to be a health concern, some of the corns may ultimately progress to skin cancer. In addition, arsenic ingestion has been reported to increase the risk of cancer inside the body, especially in the liver, bladder, kidney, and lung. Inhalation exposure to inorganic arsenic (dusts or fumes) may produce the same types of systemic health effects as oral exposure. However, this is not common, and the effects are usually mild. Breathing high levels can result in sore throat and irritated lungs. Of much greater concern is the ability of inhaled arsenic to increase the risk of lung cancer. This has been observed mostly in humans exposed to high levels of airborne arsenic in or around smelters, but lower levels may increase lung cancer risk as well. Direct dermal contact with arsenic compounds, frequently from inorganic arsenic dusts in air, may result in mild to severe irritation of the skin, eyes, or throat.

Dose Response Relationships

Most studies indicate that humans are more sensitive to arsenic than animals, which means that studies in animals are of limited use in predicting exposure levels affecting humans (as in most animal studies). Studies in humans indicate that there is considerable variation among individuals, and it is difficult to identify with certainty the exposure ranges of concern. For example, some humans can ingest over 150 ug/kg/day without any apparent ill effects. However more sensitive individuals in exposed populations often begin to display one or more of the characteristic signs of arsenic toxicity at oral doses of approximately 20 ug/kg/day (about 1000 to 1500 ug/day for an adult).

Arsenic Health Risk Information

Effects are usually mild at 150 µg/kg/day, becoming more severe as the dose is increased. Doses of 600 to 700 µg kg/day (i.e., approximately 50,000 µg/day in an adult or 3,000 µg/day in an infant) have caused death in some cases. Exposure from water with concentrations of approximately 100 to 200 (ug/L) does not seem to produce significant (noncancer) health risks. However, typical signs of arsenic toxicity have been reported in several populations' drinking water with 400 µg/L of arsenic or greater. It is suggested that levels of arsenic ingested by most people (approximately 50 µg/day) do not pose a serious health concern.

Inhalation exposure to air concentrations of approximately 200 µg/m^3 is associated with irritation to nose, throat and exposed skin. Higher levels may occasionally lead to mild signs of systemic toxicity similar to oral exposure. Direct skin contact with arsenic compounds can cause mild to severe skin irritation, but no reliable dose estimates are available on the exposure levels at which these effects begin to appear. Studies of animals maintained on a diet with unusually low concentrations of arsenic did not attain their normal weight, and became pregnant less frequently than animals maintained on a diet containing a more normal (but low) concentration of arsenic. Also, the offspring from these animals tended to be smaller than normal and some died at an early age.

Bio-Testing

Arsenic exposure can be detected by measuring the levels of arsenic in urine. These tests must be performed within 1 to 2 days of exposure in order to determine an accurate level of exposure. Measurement of arsenic in hair or fingernails is sometimes used to detect chronic exposures, but this method is not very reliable for detecting low levels of arsenic exposure.

Carcinogenicity of Arsenic

The US Department of Health and Human Services (DHHS) has determined that arsenic and certain arsenic compounds are known carcinogens. It is believed that cancer-causing agents can increase risk even at very low exposures. Based in the US EPA IRIS database, Inorganic Arsenic's Classification is: A; Human Carcinogen. Using available data in humans (Tseng et al., 1968; & Tseng, 1977), the US EPA has calculated that the maximum likelihood estimate (MLE) of skin cancer risk. Risk for 70 kg person drinking 2 L of water per day ranged from 1E-3 to 2E-3 for an arsenic intake of 1 ug/kg/day (approximately 50 to 100 µg/day in an adult). Expressed as a single value, the cancer unit risk for drinking water is 5E-5 per (ug/L) and for inhalation its 4.3E-3 per (ug/m^3). Details of this assessment can be found in US EPA (1988). Since there is considerable uncertainty in the cancer risk assessment process, quantitative estimates of cancer risk such as these are intentionally conservative. The actual risks of cancer could be lower, but are unlikely to be higher. The following tables are quantitative estimates of carcinogenic risk derived from EPA data of oral and inhalation exposure.

TABLE 4.1. Drinking Water Concentrations at Specified Arsenic Risk Levels

Risk	Level	Concentration
E-4	1 in 10,000	2E+0 ug/L
E-5	1 in 100,000	2E-1 ug/L
E-6	1 in 1,000,000	2E-2 ug/L

Data retrieved from the US EPA IRIS Database for Arsenic (CASRN -- 7440-38-2)

TABLE 4.2. Air Concentrations at Specified Arsenic Risk Levels

Risk	Level	Concentration
E-4	1 in 10,000	2E-2 per (ug/m^3)
E-5	1 in 100,000	2E-3 per (ug/ m^3)
E-6	1 in 1,000,000	2E-4 per (ug/ m^3)

Data retrieved from the US EPA IRIS Database for Arsenic (CASRN -- 7440-38-2)

As stated, inorganic forms of arsenic are more toxic than organic forms. Forms of arsenic that dissolve easily in water (soluble forms of arsenic) tend to be more toxic than those that dissolve less readily in water. Also, toxicity depends somewhat on the oxidation state of the arsenic.

Health Issues Directly Related to the use of CCA as a Wood Preservative

CCA treated wood is sometimes known by its old trade name, Wolmanized Wood or Wolmanized Lumber. Inorganic arsenicals are most commonly used on treated wood found outside the home in the form of outdoor decks, walkways, fences, gazebos, boat docks, playground equipment, as well as for highway noise barriers, sign posts, utility posts, and retaining walls.

The US EPA reviewed the use of CCA in pressure treated wood extensively during the 1980s. Their conclusion was that pressure treated wood did not pose unreasonable risks to children or adults, either from direct contact with the wood, as used for playgrounds and decks or from contact with surrounding soil where some releases may have occurred. This conclusion is based on scientific data that EPA has since reviewed and the agency has not identified any significant health concerns from short or long-term exposure to arsenic residues from pressure-treated wood.

EPA reached this conclusion based on studies that evaluated dermal contact (absorption through the skin), inhalation, and ingestion for both children and adults. EPA also reviewed a study that concluded that CCA does not pose a short or long-term toxic hazard to children playing on playground equipment. However, the agency was concerned about the health effects of workers who come in contact with CCA on a daily basis. Based on these concerns, the agency issued new requirements for protecting workers.

Environmental Issues related to (CCA) Arsenic

Arsenic has specific characteristics when it enters the environment. It dissolves readily in water, does not evaporate and it does not break down. In the aquatic environment, fish and shellfish as part of the food chain can bioaccumulate arsenic (organic) in their tissues. Arsenic also has the potential to change from one form to another, and once air-borne, it can be spread over large areas. In this airborne state, it has the potential for entering the food chain through a variety of mediums.

Creosote

Coal tar creosote (CAS #8001-58-9) is the most common form of creosote in the workplace and at hazardous waste sites in the United States. It is referred to by the US EPA as creosote. It is a thick, oily liquid that is typically amber to black in color and is a distillation product of coal tar. As a wood preservative, it serves as a waterproofing agent for log homes, railroad ties, telephone poles, marine pilings, and fence posts. It is also a restricted-use pesticide, and is used as an animal and bird repellent, insecticide, animal dip, fungicide, and a pharmaceutical agent for the treatment of psoriasis. About 300 chemicals have been identified in coal tar creosote, but there may be as many as 10,000 other chemicals in the mixture. Coal tar creosote can easily be set on fire and contains some components that dissolve in water. Coal tar creosote components dissolved in water move through the soil to eventually reach and enter groundwater, where they may persist for years. Once creosote is dissolved in water, biodegradation may take months. Biodegradation of coal tar creosote in soils can take years to attenuate due to its complex chemical structure. Synonyms for coal tar creosote are creosote, creosote oil, dead oil, brick oil, coal tar oil, creosote P1, heavy oil, liquid pitch oil, wash oil, creosotum, cresylic creosote, naphthalene oil, and tar oil.

Wood creosote (CAS #8021-39-4) is a colorless to yellowish greasy liquid with a characteristic smoky odor and sharp burned taste. The major chemicals in wood creosote are phenol, cresols, and guaiacol. This form of creosote has been used as a disinfectant, a laxative, and a cough treatment; it is rarely used today in the United States, but is still used as an expectorant and a laxative in Japan. Wood creosote is relatively soluble in water and is miscible with alcohol, ether, and fixed or volatile oils. Its synonyms are beechwood creosote and creosote.

Coal tar (CAS #8007-45-2) and coal tar pitch (CAS #67996-93-2) are the by-products of high-temperature treatment of coal to make coke or natural gas. Its physical composition is usually thick, black or dark brown liquids or semi-solids with a naphthalene-like odor. Coal tar products are found in medicinal ingredients to treat skin diseases such as psoriasis; they are also used as animal and bird repellents, insecticides, animal dips, and fungicides. Coal tar, coal tar pitch, and coal tar pitch volatiles are used for roofing, road paving, aluminum smelting, and coking. Coal tar is slightly soluble in water. It mostly dissolves in benzene and it partially dissolves in alcohol, ether, chloroform, acetone, and pet.ether. Synonyms for coal tar are crude coal tar, and pixalbol.

All the above forms of creosotes, coal tar creosotes, coal tar, and coal tar pitch are similar in composition. Their major chemical constituents that can potentially cause harmful health effects are polycyclic aromatic hydrocarbons (PAH's), phenol, and cresols. For the purposes of this paper, the term creosote will be used to reference coal tar creosote. Some major components of creosote are acenaphthene, acenaphthylene, anthracene, carbazole, chrysene, dibenzofuran, fluoranthene, fluorene, 2-methylnaphthalene, naphthalene, phenanthrene, and pyrene (EPA, 1992). All of the above compounds are PAHs except for carbazole and dibenzofuran.

Creosote Exposure Issues

Exposure to creosote can occur in any number of settings. Ingestion of foods or drinking water with high levels of creosote may cause burning in the mouth and throat, stomach pains, severe skin irritation, convulsions, and kidney and liver problems. Environmental persistence, lipophilicity (ability to accumulate in fatty tissue), and genetic toxicity of individual PAHs usually increase with an increase in molecular weight.

Exposure to creosote at operating wood treatment facilities should be minimal because all of these facilities are subject to strict controls by the Occupational Safety and Health Administration (OSHA) and the US EPA. The exposure of the general population to creosote from these facilities is also minimal. However, exposure to creosote from abandoned wood treatment facilities is possible. To prevent exposure during application, creosote solutions used for wood treatment can only be sold to certified pesticide applicators.

Routes of Exposure

Creosote can enter your body through inhalation as a contaminant of air, through ingestion after eating contaminated food or drinking contaminated water, or through skin absorption due to splashing or poor personal hygiene. Although there is no information on how fast or how much of the creosote mixture is absorbed, many of the components of the creosote mixture (for example, PAHs) are rapidly absorbed through the lungs and the stomach and the intestines.

The major sources of human exposure to creosote are contaminated hazardous waste sites, wood treatment facilities, and wood products treated with creosote. Wood products that are typically treated with creosote are railroad ties used by the railroads and landscapers, utility poles, marine pilings, and fence posts. One can also be exposed to creosote through contact with soil, water or air contaminated as the result of releases from waste disposal sites, wood treatment facilities, treated wood products, burning of treated scrap wood, and drinking creosote contaminated water. Background levels of certain parts of the creosote mixture, such as PAHs, can be found in some soils and foods, but it is not known if these substances came from creosote.

Health Issues

Reports of coal-tar creosote poisoning in workers exposed to creosote indicate that brief exposures to high doses can cause harmful effects to the skin, eyes, nervous system, and kidneys, and may possibly result in death. Longer-term exposure to lower levels of coal-tar creosote can also result in reddening, blistering or peeling of the skin. Chemicals in coal-tar creosote appear to accumulate in the body, particularly in fat tissue. Most of the chemicals in creosote compounds that are taken into the body, but not stored in body tissues are excreted in the feces within a few days.

In animals, the skin and lungs are affected by longer-term exposure to lower levels of coal-tar creosote, whereas, in humans, only the skin has been observed to be affected under this type of exposure conditions. The inhalation of vapors of the creosotes, coal tar, coal tar pitch, and coal tar pitch volatiles can cause irritation of the respiratory tract. However, no substantive information is available on the health effects of inhaled creosote. Ingestion of large amounts of creosote may cause a burning in the mouth and throat and stomach pains. The above effects worsen as the dosage and exposure frequency increases. Studies involving animals, which were fed large amounts of wood creosote, resulted in convulsions and death; those fed lower levels had liver and kidney problems. Birth defects have been observed in livestock exposed to coal tar creosote-treated wood products.

Carcinogenicity of Creosote

The International Agency for Research on Cancer (IARC) has determined that coal tar creosote is probably carcinogenic to humans. The US EPA has also determined that coal tar creosote is a B1; probable human carcinogen, and that coal tar pitch is a human carcinogen. Skin cancer and cancer of the scrotum have resulted from long exposure to low levels of these chemical mixtures, especially through direct contact with skin during wood treatment, manufacture of coal tar creosote-treated products, or from working in coke or natural gas factories. Long-term (365 days or longer) exposure to lower levels of creosote by skin or air contact has resulted in skin cancer and cancer of the scrotum. Cancer of the scrotum in chimney sweeps has been associated particularly with prolonged skin exposure to soot and coal tar creosote.

Bio-Testing

At this time, there is no medical test to determine human exposure to the creosote mixture. However, chemicals contained in creosote such as, PAHs, can attach themselves to substances within the body. The presence of PAHs can be measured in body tissues or blood following exposure to creosote. In addition, chemicals contained in coal-tar creosote and their breakdown products can be measured in the urine of exposed individuals. Tests on the urine are commonly done to determine if a person has been exposed to coal tar creosote. This test is not routinely available at a doctor's office and would require special equipment for sampling and detection of the compound. Although these tests can confirm that a person has been exposed to chemicals contained in coal-tar creosote, it is not yet possible to use the test results to accurately predict the severity of possible health effects occurring from exposure. Furthermore, these tests are not specific for the chemicals contained in coal-tar creosote; the chemicals measured could have come from exposure to other sources.

The US EPA has not yet developed regulatory standards and guidelines to protect the public from the potential health effects of exposure to coal tar creosote in drinking water and food.

However, OSHA has developed regulatory standards and guidelines to protect workers from the potential health effects of coal-tar products in air. A legally enforceable permissible exposure limit (PEL) of 0.2 mg/m^3 coal-tar pitch volatiles in workroom air to protect workers during an 8-hour shift.

Federal regulatory standards and guidelines in air and water exist for the key individual PAHs and phenols contained in creosote. The EPA has declared creosote a restricted use pesticide, which means that it can only be bought and used by certified applicators and only for those uses, covered by the applicator's certification. EPA has concluded that any release of creosote to the environment in excess of 1 pound should be reported.

Environmental Issues Related to Creosote

Coal tar creosote can be found in water and soil primarily as a result of its use as a wood preservative in the wood industry. It has the capacity to dissolve in water, thereby, allowing it to move easily through the soil into the groundwater. Once in the groundwater, it may take many years for it to break down; providing for the process of bioaccumulation to occur in both plants and animals.

Clean Creosote

As a side note there is a product called "clean creosote". This product is basically the same (chemically) as coal tar creosote. The basic difference between creosote and clean creosote is that clean creosote is filtered prior to application and contains a higher concentration of high volatiles in the mixture. The result using clean creosote is a cleaner looking utility pole, since the filtration removes materials that traditionally left a dark residue on the outside of the pole. With respect to the environment and health-related issues, there is no significant difference between the two just aesthetics.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are found in creosote. They are a group of chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. Some PAHs are manufactured. Other forms of PAHs are found in coal tar, crude oil, creosote, and roofing tar, and a few are used in medicines or to make dyes, plastics, and pesticides. There are more than 100 different PAH compounds found throughout the environment in the air, water, and soil. Although the health effects of the individual PAHs are not exactly alike, the following 15 PAHs found in creosote are considered as a group, some of which are considered to be probable human carcinogens (see TABLE 4.3):

- acenaphthene
- acenaphthylene
- anthracene
- Benz(a)anthracene
- benzo(a)pyrene
- benzo(b)fluoranthene
- benzo(ghi)perylene
- benzo(k)fluoranthene
- chrysene
- dibenzo(a,h)anthracene
- fluoranthene
- fluorene
- indeno(1,2,3-cd)pyrene

- phenanthrene
- pyrene

As pure chemicals, PAHs generally exist as colorless, white, or pale yellow-green solids. Most PAHs do not occur alone in the environment, including those found at hazardous waste sites. Rather they are found as mixtures of two or more PAHs. They can either occur in the air attached to dust particles, in soil, or in sediment as solids. Most PAHs do not dissolve easily in water, but some PAHs readily evaporate into the air. PAHs generally do not burn easily and they will last in the environment for months to years.

TABLE 4.3. Components of Creosote Identified as Probable Human Carcinogens

Benz(a)anthracene
Benzo(b)fluoranthene
Benzo(k) fluoranthene
Benzo(a)pyrene
Chrysene
Dibenzo(a,h)anthracene
Indeno(1,2,3-cd)pyrene

Table 4.3. Lists seven PAHs that have been determined by The EPA Office of Health and Environmental Assessment (OHEA) to be probable human carcinogens.

Source: Information Extracted from the US EPA IRIS Database

PAH Health Issues

Source of Exposure

PAHs are present throughout the environment and exposure can occur at home, outdoors or in the workplace. Above-average levels of exposure are usually associated with one or more of the following situations:

Work Place

The work place is the source of the greatest exposure to PAHs. PAHs have been found in coal-tar production plants, coking plants, bitumen and asphalt production plants, coal-gasification sites, smoke houses, aluminum production plants, coal-tarring activities, and municipal trash incinerators. PAHs have also been found in other facilities where petroleum, petroleum products, or coal are used or where wood, cellulose, corn, or oil is burned.

Non-Occupational Settings

In the home, PAHs are present in tobacco smoke, smoke from fireplaces and wood burning stoves, creosote-treated wood products, cereals, grains, flour, bread, vegetables, fruits, meat, processed or pickled foods, and beverages. Food grown in contaminated soil or air may also contain PAHs. Cooking meat or other food at high temperatures, (which happens during grilling or charring) increases the amount of PAHs in the food. Drinking contaminated water or cow's milk. Nursing infants of mothers living near hazardous waste sites may be exposed to PAHs through their mother's milk. The level of PAHs in the typical U.S. diet is less than 2 ppb.

In the Environment

PAHs can become attached to dust and other particles in the air we breathe. Some typical sources include vehicle exhausts, asphalt roads, coal, coal tar, wildfires, agricultural burning, and hazardous waste sites, former manufactured-gas sites and wood-preserving facilities. Background levels of PAHs in the air are reported to be 0.02-1.2 mg/m^3 in rural areas and 0.15-19.3 mg/m^3 in urban areas. PAHs are found in soils in areas where coal, wood, gasoline, or other products have been burned. PAHs have been found in some drinking water supplies in the United States indicating its link to groundwater. The background level of PAHs in drinking water ranges from 4 to 24 nanograms per liter (ng/L).

Routes of Exposure

PAHs can enter the body quickly and easily by all routes of exposure (i.e., through inhalation, ingestion, and skin absorption). Inhalation is one of the most significant routes of exposure for people living near a hazardous waste site. Ingestion can occur when drinking contaminated water or eating contaminated food, soil, or dust particles that contain PAHs. PAHs can also enter the body via skin adsorption. Contact with PAHs can occur near a hazardous waste site, working with heavy oils or other products (such as coal tar, roofing tar, or creosote). The rate at which PAHs enter your body is increased when they are present in oily mixtures. They tend to be stored mostly in your kidneys, liver, and fat, with smaller amounts in the spleen, adrenal glands, and ovaries. Results from animal studies indicate that PAHs do not tend to be stored in your body for a long time; most PAHs that enter the body leave within a few days, primarily in the feces and urine.

Health Effects

Studies in animals have shown that PAHs can cause harmful effects on skin, body fluids, and a reduction in the body's immune system for fighting disease after both short and long-term exposure. It must be noted that, these effects have not been reported in humans.

Mice fed high levels of benzo(a)pyrene during pregnancy had difficulty reproducing and so did their offspring. The offspring from pregnant mice fed benzo(a)pyrene also showed other harmful effects, such as birth defects and decreased body weight. It is expected that similar effects could occur in humans, but there is no data available to show that these effects occur.

There is no information available from human studies to determine health effects resulting from exposure to specific levels of the individual PAHs, although inhalation and skin exposure to mixtures containing PAHs has been associated with cancer in humans.

If a person is exposed to PAHs at an amount below the MRL, it is not expected that harmful (noncancer) health effects will occur. Because this level is based only on information currently available, there is always some uncertainty associated with it. Also, because the method for deriving MRLs does not use any information about cancer, an MRL does not imply anything about the presence, absence, or level of risk for cancer.

Carcinogenicity of PAHs

The US Department of Health and Human Services has determined that PAHs may reasonably be anticipated to be carcinogenic. Several of the PAHs, including Benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, have caused tumors in laboratory animals when inhaled air containing PAHs (lung cancer), ingested PAHs in food (stomach cancer), or had them applied to their skin (skin cancer) all exposures were over long periods of time. Reports in humans indicate that individuals exposed by inhalation or skin contact for long periods of time to mixtures with PAHs can also develop cancer. Some PAHs have caused cancer in laboratory animals

Bio-Testing

Once introduced into the body, PAHs are changed into chemicals that can attach to substances within the body. There are special tests that can detect the presence of PAHs attached to these substances in body tissues or blood. However, these tests are currently being developed and it is not known yet how well they work. PAHs and/or their breakdown products can be measured in urine. Although these tests can determine if one has been exposed to PAHs, it is not yet possible to use these tests to predict the severity of any health effects that might occur or to determine the extent of your exposure to the PAHs.

Environmental Issues related to PAHs

As mentioned PAHs can enter the environment as releases from volcanoes, forest fires, burning coal, creosote, automobile exhaust, and hazardous wastes sites. The resulting PAHs attach themselves to airborne dust particles, and transported to other locations at varying distances from their original source. This transport mechanism provides an excellent route for deposition on soils or surface water. Some PAH particles can readily evaporate into the air from soil or surface waters. Others can break down by reacting with sunlight and other chemicals in the air, this can occur over a period of days to weeks. PAHs also enter the environment through contaminated groundwater flows where they can adhere tightly to particles and move through soil to contaminate local aquifers. Once PAHs enter the water they are not easily dissolved. They attach to solid particles and settle to the bottoms of lakes or rivers; it is here where the cycle of bioaccumulation begins. Through the action of bioaccumulation, contents of plants and animals tend to be much higher than PAH contents of surrounding soil or water environment.

Pentachlorophenol (PCP)

PCP, like creosote, is a manufactured chemical not naturally occurring in the environment. Pure PCP is a colorless crystal. The impure form of PCP is dark gray to brown occurring as dust, beads, or flakes. It has a sharp chemical odor when hot, but not easily detected using the sense of smell at room temperature. PCP is widely used as a biocide and wood preservative, and it was one of the most heavily used pesticides in the United States. It is still used in industry as a wood preservative for utility poles, railroad ties, cross arms, and fence posts; however, only certified applicators can purchase and use PCP. It is no longer found in wood preserving solutions or insecticides and herbicides that can be purchased for home and garden use.

Chlorodibenzofurans (CDFs)

Pentachlorophenol contains chlorinated dibenzofurans (CDFs). CDFs are a family of chemicals that contain one to eight chlorine atoms attached to the carbon atoms of the parent chemical, dibenzofuran. There are 135 different types of CDFs with varying harmful health and environmental effects. The compounds that contain chlorine atoms at the 2,3,7,8-positions of the dibenzofuran molecule are known to be especially harmful. Not all of the different types have been found in large enough quantities to study the physical properties. However, of those that have been studied, they do not dissolve in water easily and appear to be in the form of colorless solids. There is no known use for these chemicals other than for research purposes. Most CDFs occur in small amounts as undesirable by-products of certain processes, such as the manufacturing other chemicals or bleaching at paper and pulp mills. CDFs can also be released into the environment via incineration.

Polychlorodibenzo-*p*-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) are two components in PCP solution that is of most concern. These components are formed as by-products during the production of specific chlorophenolic chemicals. Of the PCDDs present the primary congeners are octachlorodibenzo-*p*-dioxins (OCDDs) with traces of hexa- and heptachlorodibenzo-*p*-dioxins (HxCDDs and HpCDDs) (EPA, 1990). The PCDD congener of most concern is 2, 3, 7, 8-tetrachlorodibenzo-*p*-dioxin (TCDD).

TCDD not usually found in PCP solutions can be formed during incomplete combustion of PCP (EPA, 1992). The best temperature for the formation of TCDD is approximately 750^0 and 900^0 but formations can be found at temperatures as low as 350^0. PCDDs and PCDFs have a very low solubility in water, but are significantly more soluble in non-polar organic solvents. These compounds adsorb to organic matter and are persistent under ambient environmental conditions. Their migration is predominantly via the movement of particulate matter, such as dust, soils, and rock particles, and through the migration of organic solvents and carrier oils. The EPA's concern lies with the potentially hazardous effects of PCDDs and PCDFs on human health as well as the environment.

Toxicity Equivalency Factors (TEF)

Dioxin-like compounds are defined to include those compounds with non-zero Toxicity Equivalency Factor (TEF) values are defined in a 1989 international scheme (I-TEFs/89) and have received international endorsement (Ahlborg, et.al., 1994). In order to develop a dioxin risk assessment process, a Toxic Equivalency (TEQ) procedure was designed in an attempt to define the cumulative toxicity for dioxin like mixtures. The congener 2,3,7,8-TCDD is assigned a TEF of 1.0. All other congeners have lower TEFs ranging from 0.5 to 0.00001. Generally, accepted TEF values for CDD/Fs are shown in Table 4.4. The calculation of the TEQ of a mixture involves multiplying the concentration of individual congeners by their respective TEF. The sum of the TEQ concentrations for the individual congeners results in the overall TEQ concentration for the mixture.

This procedure was developed under the auspices of the North Atlantic Treaty Organization's Committee on Challenges of Modern Society (NATO-CCMS, 1988; 1988b) to promote international consistency in addressing contamination involving CDDs and CDFs.

The EPA has adopted the I-TEFs/89 as an interim procedure for assessing the risks associated with exposures to complex mixtures of CDDs and CDFs (EPA, 1989). As shown in Table 4.4, this TEF scheme assigns nonzero values to all chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs) with chlorine substituted in the 2,3,7,8 positions. Additionally, the analogous brominated compounds (BDDs and BDFs) and certain polychlorinated biphenyls have recently been identified as having dioxin-like toxicity (EPA, 1994); and, thus are included in the definition of dioxin-like compounds. However, EPA has not assigned TEF values for BDDs, and BDFs. The nomenclature adopted here for purposes of describing these compounds is summarized in Table 4.4.

Source of Exposure

Work Place

Exposure to PCP to workers usually occurs at lumber mills, wood-treatment facilities where it is used as a wood preservative, at or near hazardous waste sites, sites of accidental spills, and other related work sites.

Non-Occupational Settings

Exposure to PCP can also occur by residing in log homes made from pentachlorophenol-treated logs, drinking contaminated water near waste sites, sites of accidental spills, and PCP production work sites. Eating contaminated foods, such as meat, fish, and milk (90% of daily exposure, which is only a few picograms [pg], results from eating contaminated food). These exposures are low and are not very common.

In the Environment

Exposure can occur by coming into contact with contaminated soil, hazardous waste sites and landfills, treated utility poles, railroad ties, cross arms, and fence posts.

Routes of Exposure

As with other preservatives exposure can occur via inhalation, ingestion or skin absorption. Inhalation of contaminated air while at some of the above locations. Ingestion of PCP contaminated food and/or water. Absorption through the skin by touching contaminated soil or treated lumber in wood-treatment facilities, lumber mills, utility poles, and in construction or farming.

Health Effects

Most of the information on the adverse health effects comes from studies of people who were accidentally exposed to food contaminated with CDFs. The amounts that these

TABLE 4.4. Toxicity Equivalency Factors (TEF) for CDDs and CDFs.

COMPOUND	TEF
Mono-, Di-, and Tri-CDDs	0.0
2,3,7,8-TCDD	1.0
Other TCDDs	0.0
2,3,7,8-PeCDD	0.5
Other PeCDDs	0.0
2,3,7,8-HxCDD	0.1
Other HxCDDs	0.0
2,3,7,8-HpCDD	0.01
Other HpCDDs	0.0
OCDD	0.001
Mono-, Di-, and Tri-CDFs	0.0
2,3,7,8-TCDF	0.1
Other TCDFs	0.0
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
Other PeCDFs	0.0
2,3,7,8-HxCDF	0.1
Other HxCDFs	0.0
2,3,7,8-HpCDF	0.01
Other HpCDFs	0.0
OCDF	0.001

Source: US EPA, 1989.

people were exposed to were much higher than background levels obtained from a normal diet. Short-term exposures to high levels of PCP or long-term exposure to low levels can harm the liver, kidneys, blood, lungs, nervous system, immune system, and gastrointestinal tract. It can also irritate the skin and eyes. Exposure to (CDFs) occurs mainly by eating certain contaminated foods. In humans exposure to CDFs is most likely to cause skin and eye irritation increased vulnerability to respiratory infection and can potentially effect nervous system. Researchers have seen similar effects in animals. Impurities in commercial PCP may be responsible for some, but not all, of its harmful effects. It is not known if PCP is responsible for birth defects in humans. However, exposure has caused a decrease in the number of offspring born to animals that were exposed while they were pregnant, as well as, an increase in skin irritation and difficulty in learning ability.

Carcinogenicity

The Department of Health and Human Services, the International Agency for Research on Cancer, and the US EPA have not officially classified CDFs for carcinogenicity. The International Agency for Research on Cancer has determined that pentachlorophenol is possibly carcinogenic to humans. This conclusion is based on animal studies that resulted in an increased risk of cancer, specifically in the livers and adrenal glands of mice. However, there is no conclusive evidence that PCP can cause cancer in humans.

SUMMARY OF RISK ESTIMATES

TABLE 4.5. Drinking Water Concentrations at Specified Risk Levels

Risk Level		Concentration
E-4	1 in 10,000	3E+l ug/L
E-5	1 in 100,000	3E+O ug/L
E-6	1 in 1,000,000	3E-l ug/L

US EPA - Quantitative estimate of carcinogenic risk from oral exposure. Last updated 5 May 1998. Oral Slope Factor -- 1.2E-1 per (mg/kg)/day

Drinking Water Unit Risk -- 3E-6 per (ug/L)

TABLE 4.6. Dose Response Data (PCP Carcinogenicity for Oral Exposure)

Technical Grade PCP

Human Equiv-Pooled

Hepatocellular ppm	Hemangiosarcoma (mg/kg)/day	Administered Dose (mg/kg)/day	alent Dose Tumor Incidence
0.0	0.0	0.0	5/31
100.0	17.0	1.4	12/48
200.0	35.0	2.7	15/46

US EPA - Quantitative estimate of carcinogenic risk from oral exposure.

Bio-Testing

Laboratory tests have been developed that can measure CDFs in the blood, urine, breast milk and body tissues. These tests are only useful shortly after exposure because CDFs

leaves the body fairly quickly. These tests can not indicate the concentration of the initial pentachlorophenol exposure, length of exposure or if an individual's health will be effected by the exposure. Nearly everyone in the United States and other industrialized countries has been exposed to low levels of CDFs because they are in the environment.

Environmental Issues related to (PCP)

As indicated when PCP enters the environment it adheres to particles in the air, soil and water. Airborne transport via air currents can deposit PCP on to soils or surface waters. Once deposited it may last from days to years depending on existing environmental conditions. In soil it will adhere to particles and its residency time will depend on acidity and climate conditions. In surface waters particles containing PCP will settle to the bottom. If microorganisms are present and the conditions are right, PCP in soils and surface waters can be broken down into other compounds. They accumulate in fish by a factor of tens of thousands times higher levels than in the surrounding water or sediment; thus starting the bioaccumulation cycle.

DISCUSSION

The concerns of the impact of preservatives on human health as well as the environment are well documented. The US regulatory agencies are re-reviewing CCA, PCP and creosote in an attempt to quantify the overall impact of these three preservatives. The evidence presented in this chapter briefly touches upon issues that have affected people and the environment. PCP, creosote and CCA are either carcinogenic or are characterized as "probably" carcinogenic to humans and animals. Lifecycle exposure studies must be performed to accurately depict the overall impact of these preservatives as well as their individual components.

Based on the collected environmental and health data, it is the by-products or components of the preservative that present the hazards facing us today. PCP contains dioxins and furans (a manufacturing by-product), creosote contains PAHs, some of which are potential human carcinogens, and CCA contains arsenic, a known human carcinogen.

The initial processing of the preservatives or additives needed to make them effective may create a significant potential for a health or environmentally related risk, even if the practical use of the chemical is innocuous. The disposition of the chemical or its residue in soil may be very costly if the federal government declares it a hazardous waste.

Another potential hazard related to wood utility poles is from the preservatives used for periodic remedial treatment. A popular form of remedial treatment is the use of cigar shaped canisters containing sodium fluoride, sodium dichromate and tri-sodium arsenate a known carcinogen. These canisters are inserted into one-inch drilled holes approximately one to two feet from the groundline. Once placed into the pole the drilled holes are sealed with a dowel type plug. This preservative can be accidentally released into the environment via physical damage to the pole and or vandalism. In either case, this concentrated wood preserving compound can result in a severe health hazard if it is misused. There are a number of alternatives to this specific product; however, all have a potential for negatively impacting individual health and the environment.

As indicated, preservatives are present in soil at the 15 pole sites sampled. The overall impact on human health is contingent on duration of exposure and concentration of preservative. The extent of the effect on health and the environment is also contingent on the geology/topography and soil type of the area. The number and location of underground streams are indicative of the geology and topography of a specific area. In addition, the soil type dictates the rate in which the leachate can reach available groundwater. The proximity of underground streams also plays an important role since many of them feed drinking water supplies and drain into lakes and rivers where they effect the quality local drinking water aquifers and farmland using local aquifers for irrigation.

The presence of preservatives in soil alone does not itself present an immediate hazard to health. However, the mere presence of preservative in soil may still be an issue for public concern even if it's below the regulatory action level. The concern arises due to the possibility that repeated exposure (contact) to preservative contaminated soil (even at low concentrations) may result in a health hazard. This is especially true if those exposed are young children whose biological defense mechanisms are not fully developed to handle this type of daily exposure. In the case of children playing, the preservative treated pole itself may be the source of exposure.

The challenge facing us today is to discover a procedure that will minimize the overall health and environmental impact of these preservatives. The combined effect of a lifecycle approach will substantially reduce the overall corporate cost while significantly reducing the amounts of contaminants in the environment. Both are equally important if we are to seriously attempt to minimize the production and introduction of hazardous materials/waste into the environment.

This dissertation will not only serve to quantify the concentration of preservative in soil it will also present a clear alternative to preservative treated utility poles. This alternative will minimize exposure of preservative to the population as well as slowly decrease the volume released into the environment.

CHAPTER 5

REGULATORY REVIEW

Federal, state and local regulations regarding the use of wood preserving chemicals are still under review. Through the US EPA and OSHA, the federal government has put into place guidelines to protect workers and the environment from exposure to preservatives. These guidelines focus on the handling, application and disposal of CCA, creosote (and PAHs), and PCP (and dioxins and furans). The following is a history of the development of regulatory guidelines and the current regulations. This information is presented by preservative type and components.

Chromated Copper Arsenate (CCA)

In 1988, the US EPA initiated a special review of inorganic arsenicals. As a result of this special review, the agency required new protective measures for workers using inorganic arsenical wood preservatives to reduce their exposure and subsequent health risks. These protective measures included the following:

1) CCA was classified as a "Restricted Use" pesticide, meaning that this chemical is for sale and use only by certified pesticide applicators or persons under their direct supervision and only for those uses covered by the applicator's certification.

2) Protective clothing requirements for workers must be specified on labels. All exposed arsenic treatment plant workers are required to wear a respirator if the level of

ambient arsenic is unknown or exceeds the permissible exposure limit (PEL) of 10 ug/m^3. OSHA PEL's are set for an 8-hour workday, during a 40-hour workweek.

3) Manufacturers and formulators must use a closed system for mixing powdered inorganic arsenicals. Applicators may not eat, drink, or use tobacco products during the application process. Applicators must also wash thoroughly after contact with the pesticide.

4) A Consumer Awareness Program was instituted requiring wood pressure-treaters to provide Consumer Information Sheets to all lumberyards and other retailers. The information sheets instruct consumers about handling procedures regarding the use of protective gloves, coveralls and facemasks when sawing treated wood products.

The EPA also registers individual products containing CCA used for treating wood. As part of this registration process, EPA has required specific guidelines for using these products. These instructions require the use of dilute solutions (eg., 0.5 - 10%) only in closed, vacuum-sealed cylinders. Industry treatment standards must be strictly adhered to in order to minimize worker exposure and environmental contamination.

CCA will be reassessed as part of EPA's ongoing re-registration program. All pesticides initially registered before November 1984 must undergo re-registration review to ensure that the data supporting their use meet current standards. As part of the re-registration review, EPA is requiring manufacturers (a.k.a., registrants) to submit additional data, including exposure data on wood treatment plant employees and surrounding populations. Once the required studies are submitted and reviewed, EPA will complete its analyses and issue a Re-registration Eligibility Decision (RED) on the continued uses of CCA.

Disposition of CCA

D. Regulatory Exemption for Arsenically Treated Wood Products

Arsenically treated wood products disposed by the end user are exempt from classification as a federal hazardous waste regardless of the TCLP results for specified constituents from any individual sample. (If the wood exceeds the TCLP regulatory levels for any other constituent, it would be classified as a hazardous waste). In July 1992, the EPA published in the Federal Register a correction to the hazardous waste rules reaffirming an exclusion from hazardous waste designation for arsenical-treated wood. The exclusion reads:

> *"40 C.F.R. Section 261.4(b). Solid Wastes which are not hazardous wastes: The following solid wastes are not hazardous wastes:*
>
> *(9)Solid wastes which consists of discarded arsenical-treated wood or wood products which fails the test for the Toxicity Characteristics for Hazardous Waste Codes D004 through D017 (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, endrin, lindane, methoxychlor, toxaphene, 2-4-D; and Silvex] and which is not a hazardous waste for any other reason in the waste is generated by persons who utilize the arsenical-treated wood and wood products for these materials' intended end use. [57 Fed. Reg. 30658, July 10, 1992, codified at 40 CFR Section 261.4 (B9)] "*

Future of CCA Regulations

It has not been determined if wood treated with CCA poses a significant risk to human health and the environment; therefore, the EPA does not recommend replacement of this preservative solely on this basis. When selecting materials to use for decks, playgrounds, and other outdoor uses, consumers and communities should consider other factors in addition to the environment, such as cost, strength, and durability.

The EPA has reviewed a recent study conducted by Stilwell and Gorney (1997) of the Connecticut Agricultural Experiment Station in New Haven, Connecticut. The result of this study indicates that arsenic is being released from decks and playground equipment treated with CCA into the surrounding soil. The EPA has requested for review all the data generated as part of this study. It is worth noting that, over long periods of time, almost any wood preservative may be released in minute amounts as the wood weathers. In addition, any finding of arsenic in soil must take into account the variability of naturally occurring levels of arsenic already present in the soil. Following EPA's review of the complete study, the Agency will be in a better position to determine its significance and to take any action necessary to protect public health.

Creosote

The federal government has not developed regulatory standards and guidelines to protect people from the potential health effects of exposure to coal-tar creosote in drinking water and food. However, regulatory standards and guidelines in air and water exist for the key individual PAHs and phenols contained in creosote. The EPA has declared creosote a

"Restricted Use" pesticide, which means that it can only be bought and used by certified applicators and only for those uses, covered by the applicator's certification. EPA also requires that a release to the environment in excess of one pound be reported.

In the workplace, the Occupational Safety and Health Administration (OSHA) regulates Coal tar creosote releases into the air. OSHA has set an airborne PEL of 0.2 mg/m^3 for coal tar pitch. The National Institute for Occupational Safety and Health (NIOSH) has concluded that occupational exposure to coal products can increase the risk of lung and skin cancer in workers and recommended an occupational exposure limit for coal tar products of 0.1 mg/m^3 of coal tar pitch volatiles for up to a 10-hour workday, during a 40-hour workweek

Coal tar creosote is also regulated by EPA's Offices of Emergency and Remedial Response, Air and Radiation, Chemical Emergency Preparedness and Prevention, Solid Waste, and Pesticide Registration Standards. In addition, coal tar creosote is subject to the following Federal environmental laws: Comprehensive Environmental Response, Communication, and Liability Act (CERCLA); Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); and Resource Conservation and Recovery Act (RCRA).

EPA regulations specifically require that releases of coal tar creosote into the air, water, or soil and must be reported annually and entered into the Toxic Release Inventory (TRI). The following is an example found in the 1992 TRI: 1,308,038 pounds of coal tar creosote were released by 85 facilities. Those releases ranked 84th of the TRI's 322 chemicals. Of those releases, 565,353 pounds were fugitive or nonpoint air emissions, 728,211 pounds were stack or point air emissions, 11,835 pounds were surface water discharges, 5 pounds were released by underground injection, and 2,634 pounds were released into soil. In 1992, 1,841,011 pounds of coal tar creosote were reported as being transferred to recycling, energy recovery, treatment, publicly owned treatment works, disposal, or other off-site locations.

Disposition of Creosote Treated Wood

The TCLP for disposition of creosote waste products including wood and soil is 200 ppm. This TCLP is comprised of a variable mixture of hundreds of polycyclic aromatic compounds (PAHs) and semi-volatile organic compounds (SVOCs). These compounds make up approximately 85% of the chemical constituents of undiluted creosote (EPA, 1992).

PAH Regulatory Issues

Based on benzo(a)pyrene data, the federal government has developed regulatory standards and guidelines to protect individuals from the potential health effects of PAHs in drinking water. The US EPA has provided estimates of levels of total cancer-causing PAHs in lakes and streams associated with various risks of developing cancer in humans. The EPA requires reporting of a release of PAHs of more than one pound. It should be noted that, PAHs are generally not produced commercially in the United States except as research chemicals. OSHA has set an airborne PEL for PAHs of 0.2 mg/m^3 of PAHs (per cubic meter of air) for up to a 10-hour workday, during a 40-hour workweek.

Pentachlorophenol (PCP)

The Environmental Protection Agency has set regulatory standards and guidelines to protect people from the possible health effects of PCP in drinking water. The EPA's limit for PCP in drinking water is 1 part per billion (ppb). The EPA recommends that children do not drink water containing more than 0.3 ppm of PCP for periods greater than one day. Adults should avoid drinking water with more than 1 ppm. EPA also estimates that for an average-weight adult, exposure to 0.03 mg PCP/kg of body weight/day will probably not cause any noncancer human health effects. The EPA also requires that spills and accidental releases of PCP into the environment equal to or greater than 10 pounds must be reported to the EPA. The Agency is now working to measure the levels of PCP found at abandoned waste sites.

In order to protect working individuals from the possible health effects of airborne PCP, OSHA has set an airborne PEL of 0.5 mg/m^3 (0.05 ppm) PCP in the work area. This standard is has also been recommended by NIOSH and the American Conference of Governmental and Industrial Hygienists (ACGIH).

Disposition of PCP Treated Wood/Soil

The TCLP for disposition of PCP waste products including wood and soil is 100 ppm.

ChlorinatedDibenzoFuran (CDF) Issues

Presently there are no federal guidelines or recommendations for protecting human health or the environment from exposure to CDFs in an occupational setting. However, beginning 1 JAN 2000 the EPA has lowered the reporting thresholds for certain persistent bioaccumulative toxic (PBT) chemicals subject to reporting under 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and section 6607 of the Pollution Prevention Act of 1990 (PPA). Along with this change the EPA has also added the category of dioxin and dioxin-like components to the EPRCA section 313 list of toxic chemicals and established a 0.1 gram reporting threshold for the category. This addition to the EPCRA section is based on the carcinogenicity or other chronic human health effects and/or significant effects on the environment.

Disposition of CDFs

The US EPA recommended action level for disposition of wood and soil containing TCDDs and 2,3,7,8 TCDD is 1 ppb.

Preservative Disposal Methods

Treated wood removed from service that is not destined for reuse and is not a hazardous waste can be disposed as solid waste. It is the responsibility of the generator of the used treated wood to determine whether the preservatives contain any TCLP constituents. State and local jurisdictions may have particular guidelines of which generators must be aware and must follow. The Consumer Information Sheets also contain information on disposal practices, including warnings never to burn treated wood in fireplaces, open fires, or wood stoves, or to permit haphazard or random disposal. The following are some disposal practices for treated wood:

Landfilling. As a non-hazardous material., discarded treated wood and construction wastes may generally be disposed at municipal landfills approved to receive the material by the state and/or local authorities. Some non-hazardous waste landfills may classify treated wood as a "special waste" and require documentation of its status.

Energy Recovery. Treated wood removed from service has energy value and therefore can be considered an energy resource. There are facilities that utilize untreated as well as treated wood waste as fuel. The treated wood waste is generally creosote or penta-treated materials. This option is currently expanding and offers the advantages of permanent disposal and increased utilization of our timber resources in meeting our country's energy needs.

Bioremediation. Some research and development efforts are taking place in the area of bioremediation, in which biological processes are used to remove and/or reclaim the preservative chemical and render the wood product suitable as fiber. While such technologies are welcomed and encouraged, they are generally not available on a large-scale basis for the management of non-hazardous treated wood wastes.

Hazardous Waste Facilities. Although treated wood is not designated as a hazardous waste, disposal in hazardous waste incinerators or landfills is an available option. However, the high cost and unnecessary use of a limited resource for the disposal of non-hazardous materials make this option generally inappropriate. In examining the disposal of penta-treated utility poles alone, the Electric Power Research Institute (EPRI, 1992) has estimated that "by avoiding the hazardous waste designation, the utility industry will save $15 billion between 1989 and 1993". When expanded to all treated wood, the savings could exceed several billions of dollars each year. The conclusion reached by the EPRI study does not mention that, although there is a higher cost for incineration (energy recovery), it does present an excellent means for reducing landfill demand and the potential for hazardous waste minimization. Changes in the Federal Drinking Water standard as well as soil clean-up criteria could trigger Superfund cleanups.

A concern associated with the incineration of waste wood is the waste wood ash. This ash is the residue resulting from high temperature incineration. Treated wood products have a higher sulfur, heat, metals and/or chlorine content (on a dry basis), than clean virgin wood. They also tend to contain a higher level of metals (eg. lead and zinc) which have a relatively low volatilization temperature and vapor pressure. As a result, treated waste wood streams have approximately 3 to 10 times higher concentrations of these metals in the fly ash fraction. In most cases the incineration residue is bound together with cement or asphalt and used in construction. High temperature incineration is the disposal method of choice for this type of hazardous waste and is a much better alternative than land filling used utility poles.

DISCUSSION

Corporate user concerns regarding in-service wood utility poles are based on the cost of extending in-service pole life, pole disposition and remediation of the soil surrounding the pole. Cost of replacing the pole has increased, pushing the need for more research to find economical methods for pole preparation, preservative treatment, periodic in-service treatment, and disposition. These studies are expected to yield methods that will extend the life of existing in-service poles which would resulting in the delay of pole replacement, disposition and soil clean up.

There is a growing need in today's competitive corporate environment to find more efficient methods of conducting business. The decision for pole purchase should be based on the life cycle cost of the utility pole, which incorporates both environmental and regulatory issues, not just the initial cost.

The following information on federal laws impacting wood preservatives was obtained from the US EPA web site.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA/SUPERFUND)

This law enacted on December 11, 1980 created a tax on the chemical and petroleum industries and provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. Over five years, $1.6 billion was collected and the tax went to a trust fund for cleaning up abandoned or uncontrolled hazardous waste sites.

CERCLA established prohibitions and requirements concerning closed and abandoned hazardous waste sites. It has provided for liability of persons responsible for releases of hazardous waste at these sites and established a trust fund to provide for cleanup when no responsible party could be identified. The law authorizes two kinds of response actions: Short-term removals where actions may be taken to address releases or threatened releases requiring prompt response. Long-term remedial response actions that permanently and significantly reduce the dangers associated with releases or threats of releases of hazardous substances that are serious, but not immediately life threatening. These actions can be conducted only at sites listed on EPA's National Priorities List (NPL). CERCLA also enabled the revision of the National Contingency Plan (NCP). The NCP provided the guidelines and procedures needed to respond to releases and threatened releases of hazardous substances, pollutants, or contaminants. The NCP also provided the NPL. CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) on October 17, 1986. This amendment reflected EPA's experience in administering the complex Superfund program during its first six years and made several important changes and additions to the program. It stressed the importance of permanent remedies and innovative treatment technologies for cleaning up hazardous waste sites, required Superfund actions to consider the standards and requirements found in other State and Federal environmental laws and regulations, provided new enforcement authorities and settlement tools, increased State involvement in every phase of the Superfund program, increased the focus on human health problems posed by hazardous waste sites, encouraged greater citizen participation in making decisions on how sites should be cleaned up, and increased the size of the trust fund to $8.5 billion. SARA also required the EPA to revise the Hazard Ranking System (HRS) to make sure that it accurately assessed the relative degree of risk to human health and the environment posed by uncontrolled hazardous waste sites that may be placed on the National Priorities List (NPL).

Federal Water Pollution Control Act (Clean Water Act)

The Clean Water Act is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating discharges of pollutants to waters of the United States. CWA was enacted by Congress to restore and maintain the chemical, physical, and biological integrity of the nation's waters by establishing limits on the discharge of pollutants into the waters of the United States. It also provides for immediate notification of an onshore or offshore discharge of harmful quantities of oil or reportable quantities of hazardous substances into or upon the navigable waters of the US or adjoining shoreline.

In 1987, the CWA was reauthorized and again focused on toxic substances, authorized citizen suit provisions, and funded sewage treatment plants (POTW's) under the Construction Grants Program.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

The primary focus of FIFRA was to provide federal control of pesticide distribution, sale, and use. EPA was given authority under FIFRA not only to study the consequences of pesticide usage but also to require users (farmers, utility companies, and others) to register when purchasing pesticides. Through later amendments to the law, users also must take exams for certification as applicators of pesticides. All pesticides used in the U.S. must be registered (licensed) by EPA. Registration assures that pesticides will be properly labeled and will not cause unreasonable harm to the environment.

Resource Conservation and Recovery Act (RCRA)

All listed hazardous wastes under RCRA are also CERCLA hazardous substances and are subject to both laws. This act gave EPA the authority to control hazardous waste from the "cradle-to-grave." This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also set forth a framework for the management of non-hazardous wastes. It also requires small quantity generators storing between 100 to 1000kg of hazardous waste per month are required to notify the NRC in the event of a release that threatens human health outside the facility or reaches surface water. Large quantity generators have up to 15 days to report the incident in writing.

Toxic Substance Control Act (TSCA)

The Toxic Substances Control Act of 1976 was enacted by Congress to test, regulate, and screen all chemicals produced or imported into the United States. Many thousands of chemicals and their compounds are developed each year with unknown toxic or dangerous characteristics. To prevent tragic consequences, TSCA requires that any chemical that reaches the consumer marketplace be tested for possible toxic effects prior to commercial manufacture.

Any existing chemical that poses health and environmental hazards is tracked and reported under TSCA. Procedures also are authorized for corrective action under TSCA in cases of cleanup of toxic materials contamination. TSCA supplements other federal statutes, including the Clean Air Act and the Toxic Release Inventory under EPCRA.

It also requires emergency notification to the appropriate EPA regional office of an emergency incident of environmental contamination by a chemical substance or mixture regulated under TSCA. Reporting under TSCA is required when a spill:

1. Seriously threatens humans with cancer, birth defects, mutation, death or serious prolonged incapacitation, or
2. Seriously threatens non-human organisms with a large scale or ecologically significant population destruction.

SUMMARY

To date, federal environmental laws and regulations impact both use and disposal of creosote and PCP. The US EPA is currently reviewing CCA to determine its effect on health and the environment. A significant determining factor in the EPA's decision making process, is the US Department of Health and Human Service's determination that arsenic and certain arsine compounds are known human carcinogens.

The potential exists for the federal government to enact more stringent preservative application and disposition guidelines. This potential increases as additional research indicates the potential correlation between preservative exposures and detrimental health and environmental effects. This trend in federal guidelines may significantly increase the costs for wood utility pole usage in comparison to other material alternatives. The inclusion of dioxin and dioxin–like compounds to EPCRA and section 6607 of the PPA on 1 JAN 2000 is a strong indication that regulations are beginning to move in a more conservative direction regarding the use and disposal of waste containing these compounds.

CHAPTER 6

ECONOMICS OF UTILITY POLE USEAGE

The overall cost associated with the use of utility poles is an important utility industry issue. Cost of replacing the pole has increased, creating the need for more research to find better methods for pole preparation, preservative treatment, periodic in-service treatment, and disposition. After reviewing the variables associated with the use and operations of utility poles, cost appears to be the primary factor for corporate purchasing decisions. Some considerations for purchasing utility poles are the type of preservative to be used, cost of periodic maintenance, soil remediation cost, frequency of replacement cost, pole disposition cost and the impact on joint use agreements.

Another purchasing selection parameter is the decision on the type of pole to be used, i.e., non-wood alternative vs. wood. This critical decision should depend on the overall life cycle cost, as well as the company's environmental policy approach. There is a need for the life-cycle costs to be factored into the purchase price; otherwise, the initial cost will be the only deciding parameter. This could result in an incorrect assessment of the total pole cost, resulting in the continued purchase of only wood poles.

The revision of current federal and state environmental regulations will have a significant impact on pole life cycle costs. Any change resulting in a lowering of the preservative remediation action level will have the potential to significantly impact life-cycle costs. Additionally, if hazardous material reduction and minimization of hazardous wastes remains an issue of major concern, then the use of non-wood alternatives should strongly be considered.

Wood vs. Fiberglass Poles

The initial purchase price of a wood pole is significantly less than that of the fiberglass alternative. See Table 6.1. In some cases, two wood poles could be purchased for the price of one fiberglass pole.

TABLE 6.1. Illustrates the Initial Price difference between Wood Utility Poles and Fiberglass Utility Poles.

Pole Class/Height	Initial Price of Wood Utility Pole	Initial Price of Fiberglass Utility Pole*	Price Difference
Class 3-35 foot	$207.00	$849.00	$642.00
Class 3-40 foot	$300.00	$949.00	$649.00
Class 4-35 foot	$207.00	$649.00	$442.00
Class 4-40 foot	$300.00	$749.00	$449.00

*Fiberglass pricing is from Shakespeare Composites and Electronics. Prices are per truckload freight allowed; F.O.B. Newberry, South Carolina. Wood prices are derived from an average of a major utility's wood pole costs for 1996).

The initial cost difference between using treated wood poles vs. fiberglass result in a saving of $442 to $649 per pole.

Subsequent Maintenance Costs

Wood poles can incur additional costs for periodic groundline treatment. This treatment requires a vendor (licensed pesticide applicator) to visit each pole once every 10 years and apply pesticide to the soil surrounding the pole or to treat the pole itself with pesticide cores drilled into the pole. This process by its very nature could inadvertently add pesticide into the soil surrounding the pole. This additional preservative in the soil increases the hazard and could substantially increase the soil disposition cost when the pole is either remover or replaced. If the soil surrounding the pole exceeds the US EPA soil remediation standard, it must be disposed of as a hazardous waste. This would increase the life-cycle cost of the wood pole by as much as four times the initial price of a fiberglass pole. See Table 6.2.

TABLE 6.2. Comparison of Subsequent Utility Pole Costs after Installation.

Type of Poles	Inspection/Remedial Treatment per Pole	Disposal Cost per Ton	Approximate Soil Remediation* Cost
Pentachlorophenol	$25.00	$93.00	$3,500.00
Creosote	$25.00	$93.00	$3,500.00
Fiberglass Reinforced Composite	$0.0	Recycled	$0.0

***Soil remediation should be performed only if the soil concentration exceeds the EPA soil remediation standard.**

Pole Disposition/Soil Remediation

Using first costs, the wood pole appears to be much less expensive. However, not factored into the initial price are periodic groundline treatment, wood pole disposition and soil disposition costs. Currently, wood pole disposition is approximately $93.00 per ton for incineration. The average weight of a class 4-40 foot utility pole is 1400 pounds. This breakdown equates to approximately $65.00 per pole for disposition. Still much less expensive than a fiberglass pole.

Excessive leaching of preservative has resulted in soil concentrations exceeding the US EPA remediation action level for soil (PCP 100 ppm and creosote 200 ppm). These incidents have an average soil clean up cost of $3,500 per pole. This soil remediation cost comprises labor, sampling, soil excavating, soil transportation and disposal, thus negating all savings calculated in the initial cost of the pole. The frequency of pole removal and remediation efforts when soil preservative concentrations are above the EPA's action level must also be evaluated in order to determine if a change to a non-wood alternative would reduce the corporation's utility pole life-cycle cost.

If the utility pole lifecycle cost were calculated on an average annual basis, presuming that the average in-service life for a wood utility pole was 15 years and 70 years for a fiberglass utility pole, the lifecycle cost for the fiberglass pole would be almost half that of a wood pole. If during a pole removal the soil surrounding the utility pole is found to contain preservative exceeding the US EPA action level for soil remediation, then the yearly cost for using wood utility poles becomes 17 times that of Fiberglass. This significant increase in cost is due to the added cost of the soil remediation. See Table 6.3.

TABLE 6.3. Average Annual Lifecycle Cost Comparison of Wood vs. Fiberglass Utility Poles

Pole Type	Initial Cost	Maintenance	Disposal	Time In-Service	Cost per pole/year
Wood	$300	$25	$65	15 yrs.	$25.00
Fiberglass	$950	0	$65*	70 yrs.	$14.50
Wood	$300	$25	$3,500	15 yrs.	$255.00**

*Disposal cost for Fiberglass should not exceed the disposal cost for wood poles since wood poles are handled as a hazardous waste and are incinerated.

**Average cost per year presuming the soil surrounding the pole surpasses the US EPA action level for preservative in soil resulting in the soil being handled as a hazardous waste.

On the average, utilities replace only 1 to 5 percent of their in-service poles each year, which amounts to tens of thousands of poles for a large utility. As long as the surrounding soil levels are below the EPA action level for remediation, it can be used as fill during replacement of the pole. If it exceeds the EPA action level it must be handled and disposed of as a hazardous waste. An alternative to soil disposal is in situ remediation using microbes. This process can be effective under the proper conditions, however, it requires more time than may be practical under most applications.

Future Regulatory Changes

Any regulatory change by the federal government governing the handling and disposition of wood and soil containing preservatives has the potential to impact utility pole user policy regarding utility poles and soil disposition. Regulations are dynamic and are regularly reviewed for needed changes based on factors such as new toxicity evaluations. These changes can significantly impact the way a company does business, e.g., simply by requiring utility poles and/or preservative contaminated soil to be disposed of as a hazardous waste. If this happens (and probably only then) will there be a shift to non-wood alternatives. Any future environmental regulatory changes can influence disposal costs 10 to 20 years down the road, thus, significantly impacting life-cycle costs by requiring utility poles or surrounding soil to be disposed of as hazardous wastes.

DISCUSSION

An overall objective in business operations is to reduce operating costs and minimize waste, thereby, resulting in a higher net profit. This is true for utilities where the wood pole issues are a prime candidate for cost analysis, since their aerial plant can represent up to 25 percent of the utility's capital investment. There are many routes a corporation can take to minimize cost of purchasing, maintaining and disposing of treated wood poles. A proactive utility pole policy has the potential to minimize environmental waste, avoid costly environmental clean-up fees, as well as reduce corporate liability. The policy should contain detailed information regarding processes for in-house remedial treatment and vendor manufacturing specifications as a guideline for detailing the level of pole quality expected from the pole manufacturing companies.

Cost Reduction Techniques

Periodic maintenance and remedial treatment are designed primarily to extend the in-service life of a utility pole. Programs of this type are very cost effective when compared with the costs of pole replacement, repair costs, and customer down time. The application of remedial chemical treatment can have a significant effect on longevity, directly affecting cost savings for the utility. One northeastern utility in the United States, with approximately 180,000 in-service poles, estimated that it saved almost 7 million dollars annually as a result of their inspection/maintenance program. This program included the use of internal and external treatments of the poles. The combination of regular utility pole inspections and aggressive remedial treatments can provide added dividends in terms of improved worker safety and pole reliability that further enhances profitability. It is beneficial for the utility companies to research innovative ways to optimize the in-services life of their wood poles.

Pole Restoration

Pole restoration has been a low cost option to pole replacement for quite some time. Recently the utilities have begun to take a closer look at the cost effectiveness of their utility pole policy. These reviews have resulted in an immediate implementation of cost savings processes. Some companies have developed databases to assist in making decisions regarding the maintenance or replacement of poles. Inspection programs have been designed to review the condition of in-service poles in order to effect repairs that will maintain the integrity of wood poles, thereby, extending their in-service life. Under normal circumstances, decay affects only 5% of the pole length. The remaining portion of the pole is usually in satisfactory condition. To replace a pole that could have been restored, is a very expensive and inefficient process. If the pole's structure can be restored, the overall repair cost will be only a fraction of the replacement cost. The immediate saving from restoration is calculated to be approximately 50% to 60%.

The most commonly used restoration methods are the steel truss and fiberglass composites. The steel truss is the most economical and widely used system in the United States today. The fiberglass system is more costly due to the need for excavation and increased application time. It is used in specific situations where the steel truss cannot be effective. This system is used where internal decay continues into areas of the pole where the steel truss would no longer be effective.

Reuse of Wood Utility Poles as an Alternative Fuel/Energy Source

The concept of using wood utility poles as a fuel positively impacts environmental and economic concerns. Atkins (1995) has developed rationale detailing the positive result of burning waste wood products. The burning of waste wood results in lower SO_2 and NO emissions than most other fossil fuels, reduces the demand on landfill space and the production of methane gas, tempers the economic fluctuations of fossil fuel prices, and has the potential for alleviating the increase of greenhouse gases. In addition, the US Department of Energy is attempting to establish a nationwide renewable energy base and has established tax credits for using biomass-based fuel.

A utility pole has a specific set of characteristics associated with its use as a fuel. Generally, treated waste wood materials have better combustion properties, with the exception of those containing water-borne preservatives. Oil-borne treated wood is more efficient as a boiler fuel with a much lower moisture content and higher heat content than the clean waste wood from virgin wood operations. Waste wood from manufacturing operations such as pallets, spools, and shipping crates also offer power generators an ideal combination of low moisture, high heat content and low metals emissions.

Non-Wood Alternatives to Wood Poles

In recent years, a combination of high wood prices and technical advances in non-wood products have accelerated the introduction of several non-wood alternatives to wood poles. These recent technical advances, along with the significant increase in wood pole cost, have lowered the cost of alternative material production, making them more cost effective and appealing to the utility. However, the availability of compatible poleline hardware remains a significant issue in choosing a non-wood alternative. The environmental liability associated with their use, handling, transportation, maintenance, disposition, has increased the justification for utilities to switch to non-wood utility poles.

There are a variety of non-wood alternatives to choose from for pole replacement. Depending on the application and life cycle cost analysis, the current choices include spuncast pre-stressed concrete poles, steel distribution poles, and fiberglass composite poles. The following information will give basic physical comparisons between non-wood poles and wood poles.

Concrete poles are, in most cases, the same size at the bottom as the wood poles with a slight taper at the tip. Its weight is usually twice that of a comparable wood pole. The benefits derived from substituting concrete for wood are its ability to resist weather, bio-degradation, very little insect infestation, airborne corrosives, and physical damage to the pole. The concrete pole has a life expectancy of 80 years. Additional cost saving benefits are the elimination of wood pole maintenance costs for groundline treatments, physical inspection and damage repair, contaminated soil remediation, hazardous material disposition costs, customer down time (during more frequent pole repair or replacement), and reduction in employee man-hours. The concrete pole is completely recyclable minimizing environmental liability making it more attractive from an environmental conservation/waste minimization point of view (Bull, 1996).

Steel distribution poles have recently become a cost effective alternative to wood poles. Studies in life-cycle cost analysis concluded that the steel pole has a longer in-service life than wood. The steel pole in-service life expectancy is approximately 80 years compared to the wood pole's 20 - 30 years. The benefits of using a steel pole are in most cases similar to the concrete pole with the following additions: they are more price competitive with wood, less expensive than fiberglass or concrete, have an in-service life of approximately 80 years, can be prepared/fitted for hardware at the factory, and have a recyclable salvage value. It must be noted that the one major concern associated with the use of steel poles is conductivity (Hartman, 1996).

Fiberglass reinforced composite (FRC) Distribution Poles contain three basic ingredients: fiberglass, resins and additives. The fiberglass pole in-service life expectancy is approximately 80 years putting it in the same range as concrete and steel poles. The benefits of using a fiberglass pole are similar to concrete and steel with the following additions: fiberglass is light and easy to handle lowering field construction cost, has a high strength to weight ratio (ex. 45 ft Class 4 pole weighs 520lbs.) making it easier to handle and transport, resists corrosion, is easily repaired in the field with FRC bonding, is electrically insulated, maintains consistent strength over the life of the pole, can be manufactured to Wood Pole Specifications, allows for climbability (has factory fitted attachments for removable steel steps), is environmentally safe to manufacture, and are fully recyclable (Derrick, 1996). See Table 6.4.

CONCLUSION

During the past few years a series of wood utility pole conferences have been organized conducted throughout the United States by the wood preserving industry in cooperation with research institutions and utilities. Their objective was to consolidate information regarding the use of wood utility poles and to discuss the most recent research on the subject of wood preservatives, usage of wood utility poles, perception of environmental action groups, upcoming environmental regulations and alternatives to wood poles.

One common concern that surfaced as an issue in the majority of presentations was the indication that the production and use of wood utility poles may have peaked. The reason for this conclusion was an analysis of economic issues concerning wood poles and competition from non-wood utility pole companies. The impetus for this shift in pole type usage appears to be the corporate need to drive down the cost of treating and maintenance of in service utility poles.

In response, wood manufacturers, in order to remain competitive in the utility pole industry, are developing new techniques for the preparation of utility poles for treatment, new techniques for the application of preservatives, new chemical variations of wood preservatives, as well as testing

TABLE 6.4. Benefits of using non-wood utility poles

- Elimination of wood pole maintenance costs for periodic groundline treatments
- Reduction in cost for physical inspection and damage repair
- Elimination of contaminated soil remediation
- In most cases are price competitive with wood; all are manufactured to wood pole specifications as per the AWPA
- Reduction of customer down time during pole repair or replacement
- Longer in-service life of approximately 80 years
- Light and easy to handle lowering field construction costs (fiberglass only)
- Easy to climb. Attachments can be prepared/fitted at the factory
- Resistant to bio-degradation and resists corrosion
- Does not succumb to woodpeckers, termites, carpenter ants, and groundline decay
- More appropriate for use in hurricane prone areas
- Easily repaired in the field
- Electrically insulated; (except steel)
- Consistent strength over the life of the pole
- Can be fully recycled eliminating hazardous material disposition costs; some even have a recyclable salvage value
- Minimization of environmental liability in the areas of safety and regulatory compliance.

and early detection of decay methodologies for in-service-poles. These factors combined with best management practices (BMPs) for care of in-service poles are designed to extend the potential life expectancy of wood poles. Wood pole manufacturers now estimate that under ideal environmental conditions the in-service life of wood utility poles is 75 to 85 years as a result of these innovations. However, the average in-service life for most wood utility poles is between 15 and 20 years.

All of the above factors have reduced the need for an increase in wood pole production. Wood utility pole maintenance programs, new advances in fiberglass composite pole development as well as the light duty steel poles and spuncast reinforced concrete poles have created strong concern among wood utility pole manufacturers. The increase in running utility cable underground for aesthetic purposes has also contributed to the decline in the purchase of new wood utility poles. It is clear that the wood pole industry which includes the preservative manufacturers, need to work hard to meet the standards both structurally as well as environmentally to maintain pace with the fast-approaching competition from the non-wood pole sector. The choice between wood and non-wood poles will depend on the specific need of the utility, the climate, soil conditions, product availability, and result of a detailed life-cycle cost analysis.

Based on the information above, user specific usage as well as the annual lifecycle cost comparison of wood vs. fiberglass utility poles in TABLE 6.3, it may be beneficial for corporations to perform a detailed comparison study between wood utility poles and non-wood utility poles. Corporations can no longer afford the luxury of a "bottomless" capital budget especially in today's climate where "corporate reorganizations", mergers and extensive downsizing are a way of life. Successful utilities are those who can operate at lower costs while still maintaining superior customer service. Based on this growing need, there should be a corporate focus to replace old "wasteful" practices with new technology and cost savings initiatives. While present day operations and maintenance plans reduce costs for wood utility poles, creative changes in corporate policy will ultimately make the difference for optimizing the continued use of the utility pole for future generations. As indicated, studies are constantly being conducted to find more effective and economical treatment processes, or cost effective alternative materials for replacement of wood utility poles. Decisions made today will significantly impact corporations in years to come.

CHAPTER 7

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

DISCUSSION

The soil sampling and analyses indicate that there are significant concentrations of PCP in roadside soil samples within three inches of in-service utility poles. This concentration may exceed the US EPA soil clean-up standard of 100 ppm PCP, indicating the need for the soil to be handled and disposed of as a hazardous waste. At the two through six-foot sample locations, the preservative concentration drops off to background levels similar to the 12-foot surface sample concentrations. For all other PCP sampling points, the level of PCP contamination was well below the US EPA's action level for soil remediation. All soil sample concentrations for creosote, dioxins and furans were below their respective US EPA soil clean-up standards, indicating that the soil does not need to be handled as a hazardous waste.

Soil samples were collected from sandy beach locations and roadside locations consisting of silty loam. The rationale for sampling from two different soil mediums was to determine if there was any difference in their preservative retention properties. Results indicated that PCP and creosote samples collected from beach locations were lower in concentration than samples collected along the roadside. This demonstrates the inability of sandy soil to retain preservative leachate compared to samples collected from roadside soils.

Although the geography, climate, soil types and number of poles surveyed were limited, there are global implications, which are detailed in this chapter. Using the data collected, soil preservative concentrations can be estimated to determine the proper soil disposal method for geographic regions with similar climatic and soil parameters as found in the southeastern section of New York State. This predictability of preservative soil contamination will significantly impact environmental policy of utility pole users regarding the usage of utility poles and remediation of surrounding soil. The improvements in technology of wood preservative application, new preservative formulations, as well as close regulatory oversight, will also be a factor in corporate decision making regarding the non-wood pole alternative issue.

Regulatory Concerns

The concerns of the impact of preservatives on human health, as well as the environment, are real. Presently, United States regulatory agencies are reviewing CCA, PCP and creosote in an attempt to quantify the overall impact of these preservatives on health and the environment. PCP, creosote and CCA have been characterized as either carcinogenic or as “probably” carcinogenic to humans. Detailed studies must be performed to accurately depict the overall environmental and health impact of these preservatives as well as their individual components.

The initial processing of the preservative(s) or additives needed to make them effective may in themselves have a significant impact on peoples health and the environment. This is true even if the intended usage of the preservative proves to be innocuous. The disposition of preservative treated utility poles, as well as the surrounding soil, is also of serious concern.

Disposition of Utility Poles

Following current federal regulations, utility poles preserved with creosote and PCP are not considered a hazardous waste and can be disposed of in an industrial landfill. However, many corporations are being proactive and are having their poles incinerated. High temperature incineration of utility poles has resulted in both environmental and socio-economic benefits. Some of the environmental benefits of high temperature incineration are reduction in atmospheric SO_2 and NOx emissions, as well as a reduction of waste entering already diminishing landfill space. In addition, the use of wood as a source of fuel optimizes the economic risks that are associated with fluctuations in fossil fuel production.

Disposition of Soil

Soil containing preservatives are of concern if concentrations exceed federal or state clean-up action levels that require special handling as hazardous waste. However, a question arises. If some corporations are being proactive by treating poles as a hazardous waste, then, why is the soil surrounding the pole not treated in a similar manner?

If the federal government classifies specific preservative containing materials as a hazardous waste, or if the hazardous waste guideline concentrations are lowered, then, the disposition of wood preservatives or surrounding soils may become very costly. This will be especially true if the result of changing guidelines increase the number of preservative contaminated Superfund sites.

Health Concerns

There are many health concerns associated with wood preservatives. This study has established that PCP leachate in soil contains dioxin and furan components. Specifically, tetrachlorodibenzo-*p*-dioxins (TCDD) and tetrachlorodibenzo-furans (TCDFs) and the congeners 2,3,7,8-TCDD and 2,3,7,8-TCDF. These two compounds, 2,3,7,8-TCDD and 2, 3, 7, 8-TCDF, are classified as probable human carcinogens and may pose a serious health hazard. Creosote contains PAHs, which are also classified as probable human carcinogens posing serious health and environmental concerns. Inorganic arsenic and certain arsenic formulations (CCA) are recognized as known human carcinogens.

However, the presence of these preservatives alone does not present a health hazard. Health hazards are determined by exposure potential (location) and dose/time relationships. To accurately assess if a hazard truly exists, one must look at the public accessibility (i.e., contaminant's potential for exposure), length of exposure, preservative concentration, and the general health of individuals exposed.

Environmental Concerns

If the preservative remains fixed in the treated wood or in the adjacent soils, concerns for environmental contamination are reduced. Environmental and health concerns arise when the preservative migrates from the application site towards ground or surface water affecting drinking water and irrigation. The migration of preservative through soil is dependent on a number of variables. These variables are determined according to geologic parent material, geography, soil type and pH, vegetation types, precipitation acidity and volume, and local industry discharges. As an example, in the desorption experiments, the precipitated PCP dissolved readily when saturated soil was washed with deionized water. PCP adsorbed clay was also released, however at a much slower rate. These findings show the potential exists for PCP to migrate through soil into local aquifers as well as nearby rivers and streams.

Preservative release from soil can have very deleterious effects on the environment. The toxicity of PCP is much greater for aquatic biota than for terrestrial biota. The solubility of PCP in an aqueous environment was found to increase exponentially with pH, thus, increasing the probability for a release into the groundwater and underground streams.

PCP's effect on wildlife in the aquatic environment is clearly indicated by its direct effect on the food chain (e.g., zooplankton) affecting fish growth and survival. PCP also has a toxic effect on filamentous algae, resulting in decreased levels of dissolved oxygen (DO) as algae decays. Dissolved oxygen is necessary to sustain life in the aqueous environment. If this reduction in DO occurs within an estuarine or coastal environment, the results could very well effect spawning grounds, and ultimately the size of local fish populations, thus impacting the fishing industry, as well as the trickle down effect to the rest of the economy. This is just one example detailing the probable impact pollution can have on the environment. Creosote, PCP, and CCA are the three predominant wood preservatives in today's market. These preservatives are found in the soil surrounding the pole, thereby, creating concerns of potential soil and ground water contamination.

Economics

Wood utility poles need to be periodically treated to maintain their integrity against decay. This remedial treatment adds more preservative to the environment and may be a factor in soil disposition costs. However, not treating the poles would result in a higher frequency of pole replacement resulting in a greater expense to the corporation, as well as a greater loss of living trees from the forest resource each year. Therefore, not treating these poles would be out of the question.

Utilities have incorporated best management practices (BMPs) for care of their in-service wood poles. These practices include periodic treatment of the poles as well as the soil in direct contact with the poles. Their main purpose is to extend the life expectancy of the wood pole. However, this periodic follow-up of remedial groundline treatment also adds to soil contamination. The mere existence of a wood pole in the ground eventually requires the treatment of soil which already contains preservative, thus, increasing soil contamination and disposition costs.

New advances in fiberglass composite pole development, light duty steel poles, and spuncast reinforced concrete poles have created competition for wood utility pole manufacturers. The increase in running utility cable underground for aesthetic purposes is also of some concern since it has contributed to the decline in the purchase of new wood utility poles. The increase in use of bucket trucks may also be a significant factor in minimizing the need to outfit non-wood poles for climbing.

Economic issues that need to be considered:

- frequency of pole replacement
- frequency of soil preservative concentrations exceeding the hazardous waste cleanup standard for disposal requiring the soil to be handled as a hazardous waste
- additional costs for groundline treatment which in itself adds soil contaminates
- frequency/type of in-service repairs
- potential new regulatory changes impacting disposal costs for both the utility pole as well as the surrounding soil
- lifecycle costs for non-wood alternatives
    - field studies to determine ease of use for non-wood alternatives
    - increase in use of bucket trucks minimizing hardware/training transition costs for non-wood alternatives
    - health and environmental impact of non-wood alternatives.

These are the major factors needed for inclusion in a study before seriously considering a transition to non-wood alternatives.

CONCLUSIONS

Disposition of Soil

This research has measured PCP soil contamination above the federal guidelines within three-inches from the in-service pole at the surface. This indicates that poles within the age group of six to 41 years of age leach a significant amount of preservative into the soil. On the basis of these results, it is suggested that a database be established that will have information from which one can to determine the proper method for soil disposal. As a precaution, soil should be tested whenever PCP treated poles are removed or replaced. Soil should always be analyzed if it is visibly stained due to preservative leaching from the pole. These procedures will insure proper disposal of the surrounding soil, if contamination exceeds the US EPA clean-up standards. Some utilities have already considered this issue and are making plans to minimize its impact by having used pole incinerated in place of landfilling. In addition, studies should be performed on wood utility poles five years old and younger to determine the rate of preservative leachate. Due to the small number of creosote treated utility pole sites surveyed, additional validation should be performed on soil surrounding creosote treated poles.

Health Concerns

Migratory movement of preservative and their constituents into groundwater can affect crop and drinking water aquifers. Direct contact with a treated pole in playgrounds or backyards can possibly effect the health of the local population. Further studies should be performed to determine if there is a direct relationship between the use of wood preservatives and adverse affects on human health.

Environmental Concerns

The more porous sandy soils did not retain the preservatives as well as soils composed of silty loam, thereby, creating a greater potential for migratory movement of preservatives and their constituents. The latter displayed significantly better retention properties for PCP, creosote, dioxins and furans. Further studies are needed to accurately measure this migratory movement. Preservatives and their constituents can potentially migrate from the pole or application site toward ground or surface water contaminating local drinking water and crop irrigation.

Economics

Economics plays a significant role in corporate decision making in choosing between a wood utility pole and a non-wood alternative. Wood utility poles need to be periodically treated to maintain their integrity against decay. The remedial treatment adds more preservative to the environment and may be a factor in disposition costs. However, not treating the poles would result in a higher frequency of pole replacement resulting in a greater expense to the corporation as well as a greater loss of living trees from the forests. Therefore, not treating these poles would be out of the question.

As US EPA guidelines become more stringent, there is a potential for a significant increase in soil remediation costs due to the lowering of current regulatory soil cleanup action levels. There is a potential for PCP, specifically the dioxin/furan component (TCDDs, TCDFs, and their 2,3,7,8 congeners), to incur disposal concerns in the near future. Dioxin and furan concentrations found in this study were only a one order of magnitude lower than the EPA action level of one part per billion.

If a wood pole exhibits excessive leaching of preservative into the surrounding soil the life cycle cost, from this alone, will significantly exceed the cost of the fiberglass non-wood alternative. Excessive leaching of preservative can result in preservative soil concentrations above the US EPA remediation action level for soil (PCP 100 ppm and creosote 200 ppm). If preservative soil concentrations are above the US EPA remediation action level the soil must be handled as a hazardous waste, significantly increasing the cost for handling, transporting and disposing of the soil. This special handling of soil significantly increases the lifecycle cost to approximately $3,500 per pole. This cost comprises specially trained labor, soil excavating, soil transportation and disposal, thus negating all savings calculated in the initial and subsequent costs of the pole.

The average in-service life of a wood utility pole in many urban areas is 10 to 20 years. This frequency is primarily due to increase in population, construction, physical damage and in some cases degradation due to infestation. These areas would need to continue using wood utility poles due to the frequency of replacement. Fiberglass would be cost prohibitive at such a high frequency. Areas of low pole replacement frequency would make fiberglass a prime candidate for replacement. Fiberglass poles would perhaps last three times longer than wood poles as well as minimize environmental and health liability concerns.

Additionally, any future changes making federal regulations more stringent will result in an increase in contaminated soil disposition costs or violations for the improper disposition of a hazardous waste.

Therefore, corporations may soon have to make crucial decisions regarding the choice between wood and non-wood utility pole alternatives. This choice would be clear if the review only focused on environmental issues. The minimization of preservative soil pollution can be accomplished by switching to non-wood alternatives, thus eliminating it at the source. However, looking at the issue from an economic perspective the decision needs to be well thought out. A detailed tailored lifecycle cost analysis for each utility will be necessary to determine the economics for choosing between wood poles and their non-wood alternatives.

The life-cycle review undertaken here indicated that fiberglass should be the pole of choice in most areas. Although the installation cost of a fiberglass pole is approximately three times the price of wood, when calculating the lifecycle cost of PCP preserved poles as well as soil cleanup costs, fiberglass is approximately one half the price. This life-cycle cost comparison makes the assumption that: a) there will be some form of soil remediation for the majority of PCP preserved pole removals, resulting in the disposition of soil in direct contact to the pole as a hazardous waste, and, b) that the fiberglass pole composite utility poles also have a potential in-service life expectancy of 70 to 80 years, compared to an average in-service life of wood utility poles of 25 to 35 years. It is also expected with recent technical advances in the production of fiberglass poles that the price of fiberglass pole manufacturing will decrease. This would be an additional incentive for corporations to consider when choosing the type of pole to purchase.

RECOMMENDATIONS

As previously discussed, PCP pole treatments have leached into soil within two feet of the utility poles located in the southeastern portion of New York State. The average surface sample concentration within three inches of the utility pole was above current federal PCP action level of 100 ppm. Soil with a PCP concentration above 100 ppm requires that the soil be handled as a hazardous waste. All soil sample concentrations for creosote, doixins and furans were found to be below their respective federal action levels. The following are recommendations based on the conclusions reached as a result of this research:

First, to minimize the environmental and regulatory impact a sampling protocol should be implemented to establish an industry baseline for soil concentrations within three inches to two feet of the utility pole for both PCP and creosote. This baseline would eliminate the need for sampling each time a pole is removed or replaced by establishing a precedent based on soil data collected categorized by specific criteria. This database would document soil concentrations collected under a specific set of conditions (eg. soil type, type of preservative, pH, climatic conditions and geography). By correlating the specific factors in the database with matching field soil criteria, it can be determined if the soil in question should be treated as a hazardous waste. This industry baseline should be utilized whenever a wood preserved pole is either replaced or removed from service. In addition, soil sampling should always be conducted whenever visible leaching is present. This will insure regulatory compliance with federal soil clean-up standards, as well as proper disposition of the soil. Clearly, if corporations are disposing of utility poles using methods reserved for hazardous wastes (i.e., incineration) it seems only reasonable that contaminated soil should be identified and disposed of in a similar manner.

Second, in an attempt to minimize available concentrations of hazardous material in the environment, it is recommended that serious consideration should be given to switching to a non-wood alternative. The impetus for this shift would be the corporate need to drive down the life cycle cost of in service utility poles, as well as potential Superfund liability. It may be in the best interest of the corporation to be proactive in this regard. A sensible approach for a transition of this magnitude would be replacing the poles through attrition. This would substantially reduce the amount of wood preservative leachate in the soil, reducing the probability of human exposure as well as environmental contamination. There would also be a significant impact on corporate disposition costs as well. The federal government should add an additional incentive to facilitate this attrition process in the form of monetary (tax) or regulatory compensation to the corporation.

Third, it is recommended that fiberglass poles should be used to replace wood preservative poles through attrition in areas where replacement of this type is most practical. The replacement through attrition will ease the economic impact to the corporation and allow for a slow transition from preservative treated poles to fiberglass. The use of fiberglass will also decrease Superfund liability for the corporation as well as reduce the amount of leachable preservative in the environment. This will minimize the economic impact of soil contamination and clean-up, pole disposal, and remediation of groundwater contamination.

Fourth, intensive health related research should be conducted studying the effects of wood preservative soil contamination on human health and the fragile ecosystem.

Fifth, a challenge should be proposed to all corporations using utility poles to find a procedure that will minimize the overall adverse impact to human health and the environment. The objective should be to combine the cost savings effect of a life-cycle approach with a substantial effort to reduce the amounts of contaminants being introduced into the environment. Both approaches are equally important if we, as a society, are to seriously attempt to bolster our national economy as well as minimize the production and introduction of hazardous materials/waste into the environment.

Sixth, Corporate environmental policies should be developed that will honor a commitment to minimize the generation of hazardous waste, recycle using the most up to date technology, and to reuse whenever possible. This process should be dynamic in nature consistently improving upon itself. This won't happen by just meeting minimum standards. The setting of minimum standards will insure that only the very minimum will be met.

It is the responsibility of all of us, as individuals or as corporate giants, to make the quality of life better for our children and generations yet to come. We must place into motion a template for a self-sustaining management process that will conserve our natural resources and minimize the production and use of any form of hazardous materials, thus, reducing hazardous waste and its effect on human health and our environment.

APPENDIX 1

GRAPHS

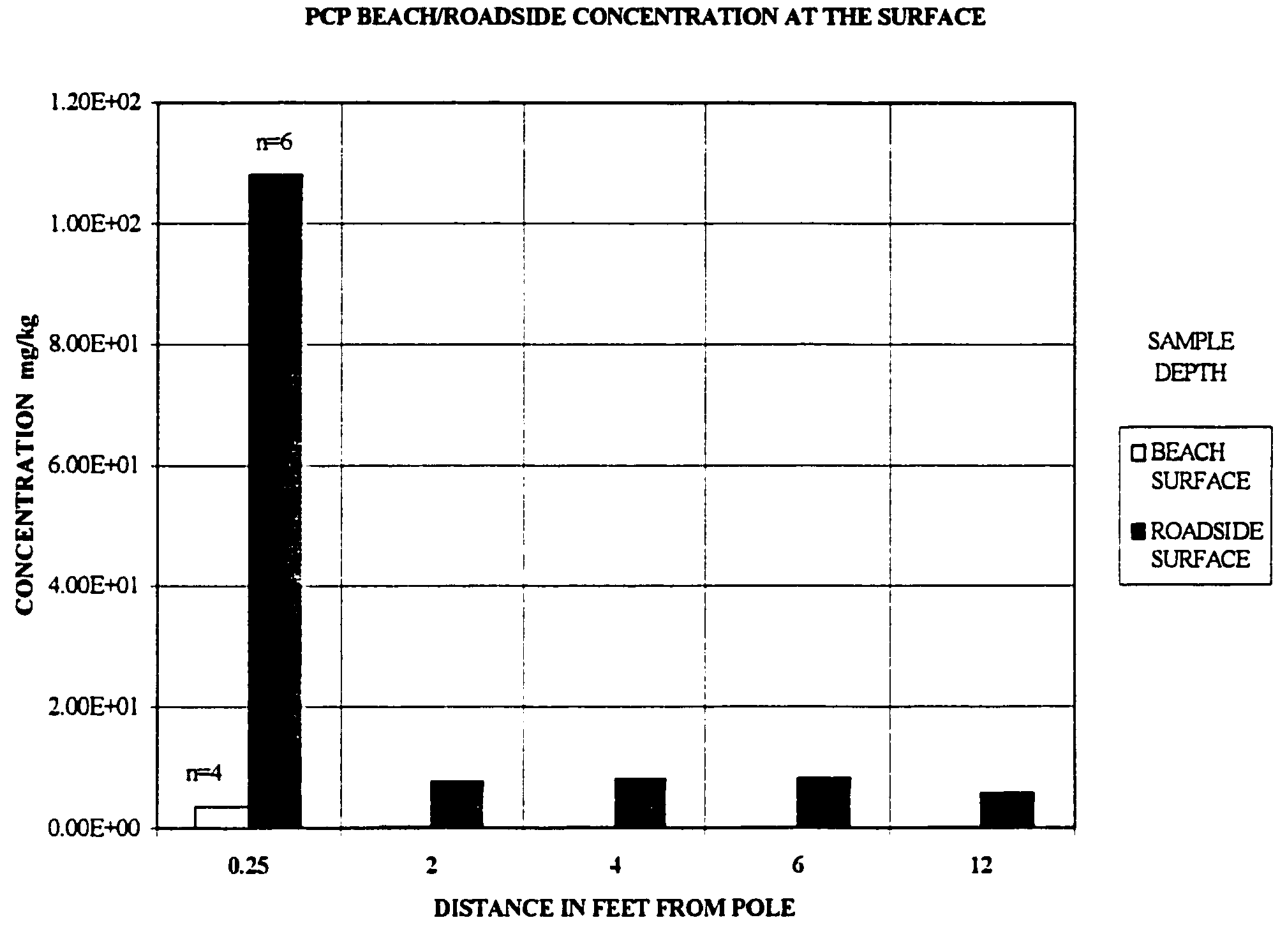


FIGURE A-1. PCP surface concentrations comparing samples of silty/loam soil (roadside area) concentrations to sandy soil (beach area) varying by distance.

US EPA Action Level for Soil Remediation = 1.00E+02 mg/kg or 100 parts per million (ppm).

Average PCP laboratory limit of detection = 1.9E-01 mg/kg or 0.19 ppm. All graphed values are either at or above this limit.

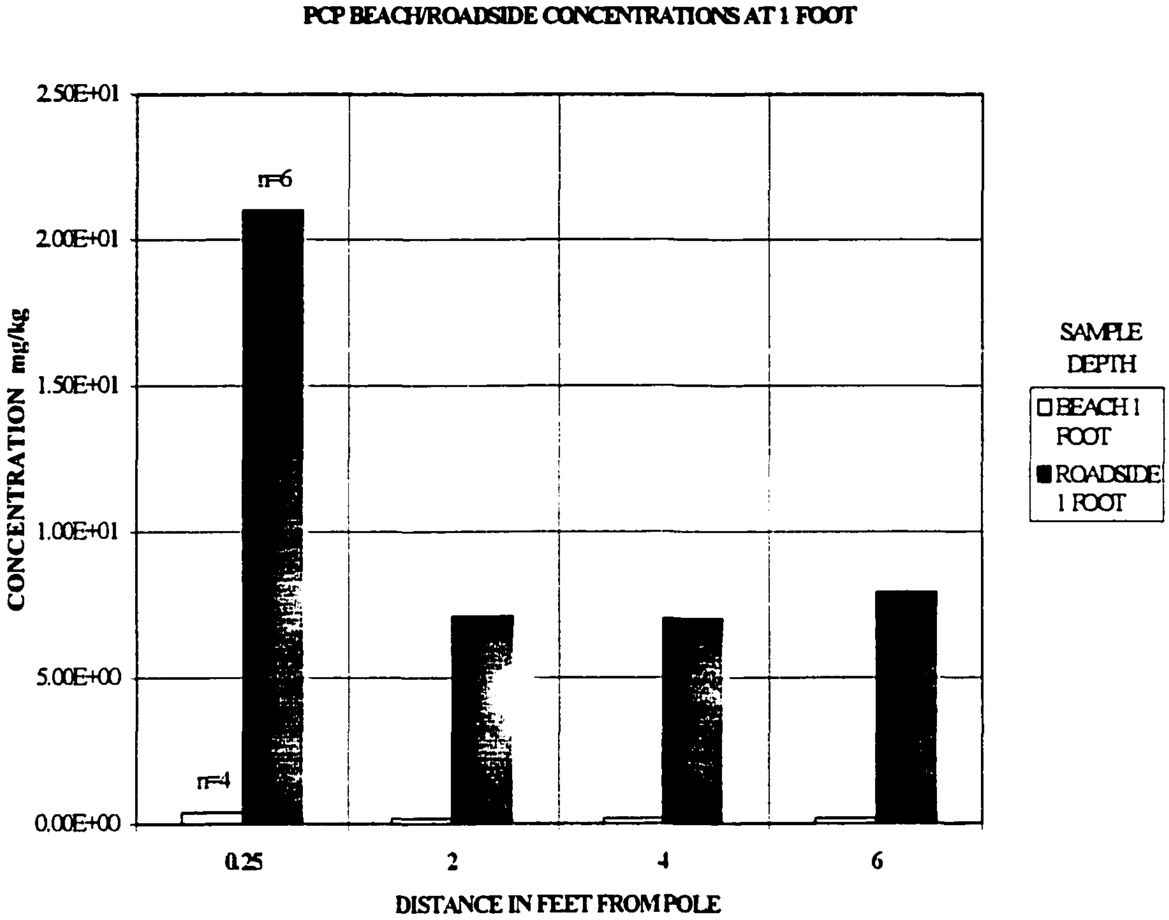


FIGURE A-2. PCP beach and roadside concentrations at a depth of one foot from the surface varying by distance.

US EPA Action Level for Soil Remediation = 1.00E+02 mg/kg or 100 parts per million (ppm).

Average PCP laboratory limit of detection = 1.9E-01 mg/kg or 0.19 ppm. All graphed values are either at or above this limit.

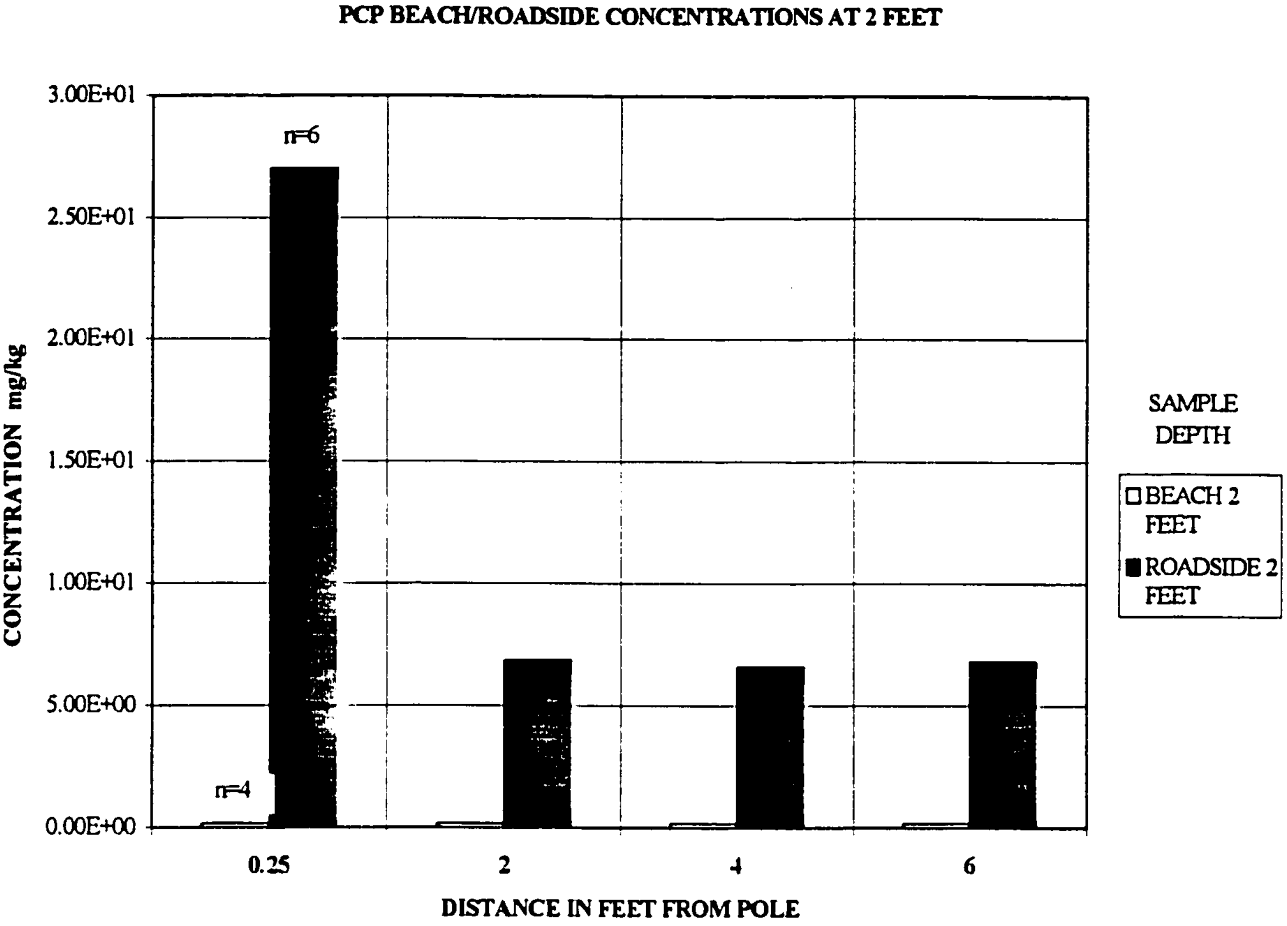


FIGURE A-3. PCP beach and roadside concentrations at a depth of two feet from the surface varying by distance.

US EPA Action Level for Soil Remediation = 1.00E+02 mg/kg or 100 parts per million (ppm).

Average PCP laboratory limit of detection = 1.9E-01 mg/kg or 0.19 ppm. All graphed values are either at or above this limit.

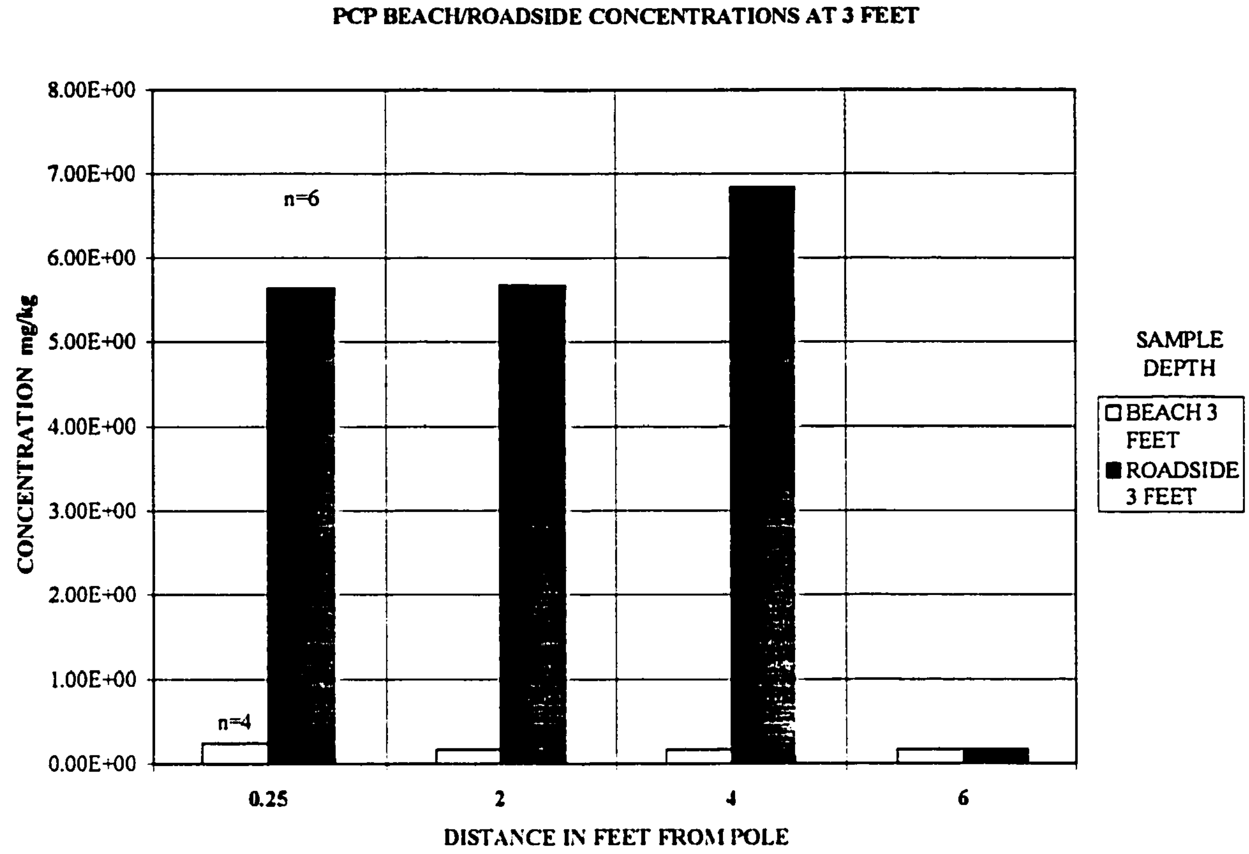


FIGURE A-4. PCP beach and roadside concentrations at a depth of three feet from the surface varying by distance.

US EPA Action Level for Soil Remediation = 1.00E+02 mg/kg or 100 parts per million (ppm).

Average PCP laboratory limit of detection = 1.9E-01 mg/kg or 0.19 ppm. All graphed values are either at or above this limit.

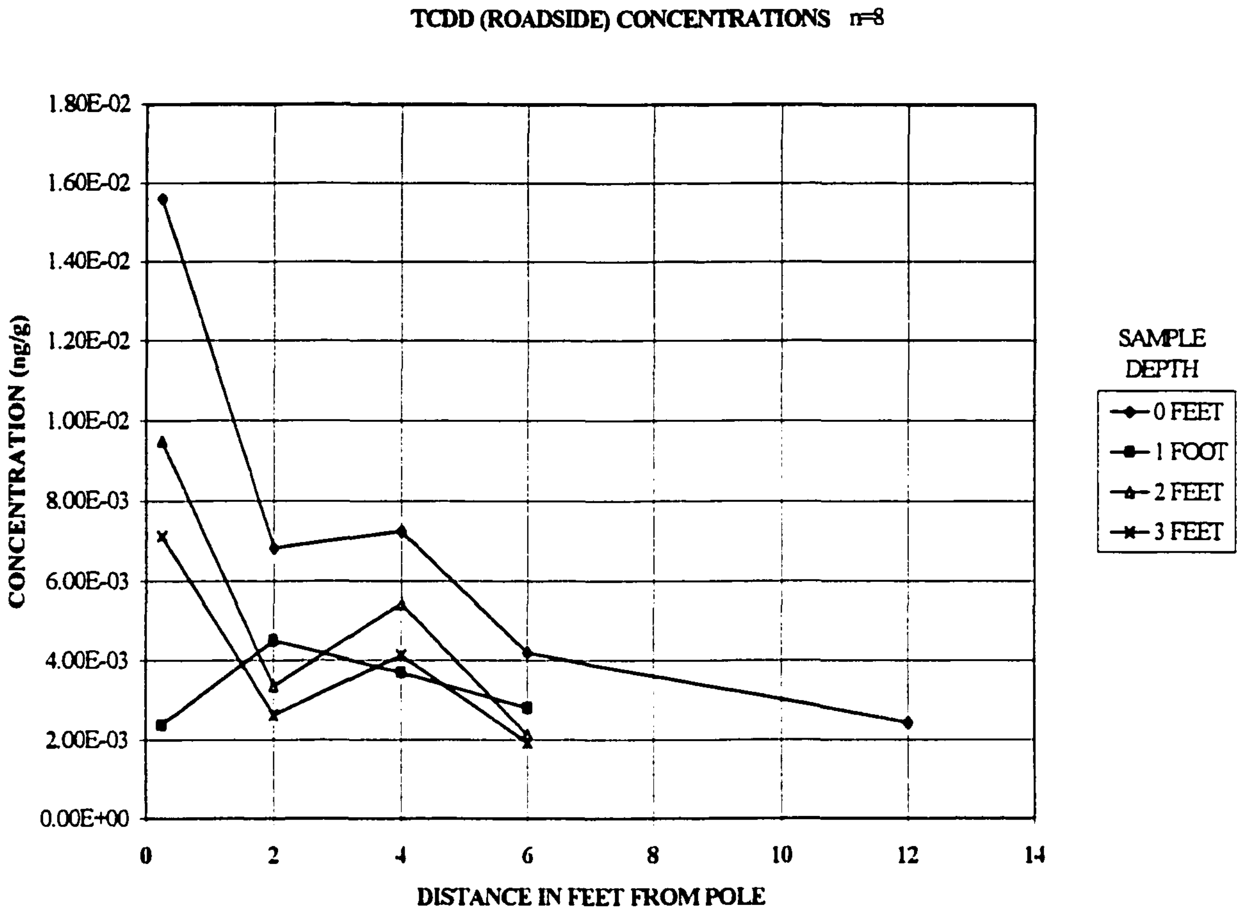


FIGURE A-5. TCDD concentrations in silty/loam soil (roadside area) at depth varying by distance from the utility pole.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDD Toxic Equivalency Factor (TEF) = 1.0. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately 3 feet high.

Average TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

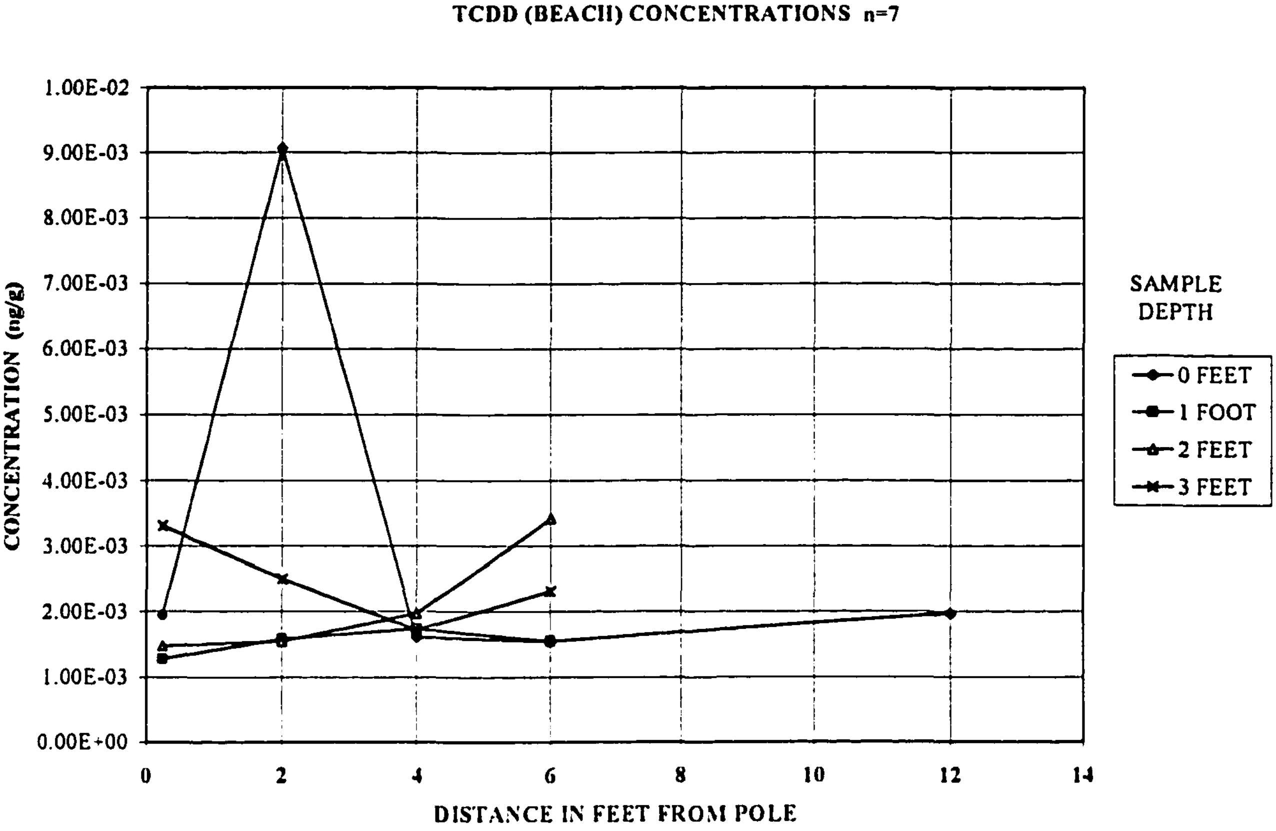


FIGURE A-6. TCDD concentrations in sandy soil (beach area) at depth varying by distance from the utility pole.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ.

US EPA TCDD Toxic Equivalency Factor (TEF) = 1.0. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be one foot high.

Average TCDD laboratory limit of detection = 1.1E-03 ng/g or 1.1 parts per trillion (ppt). All graphed values are either at or above this limit.

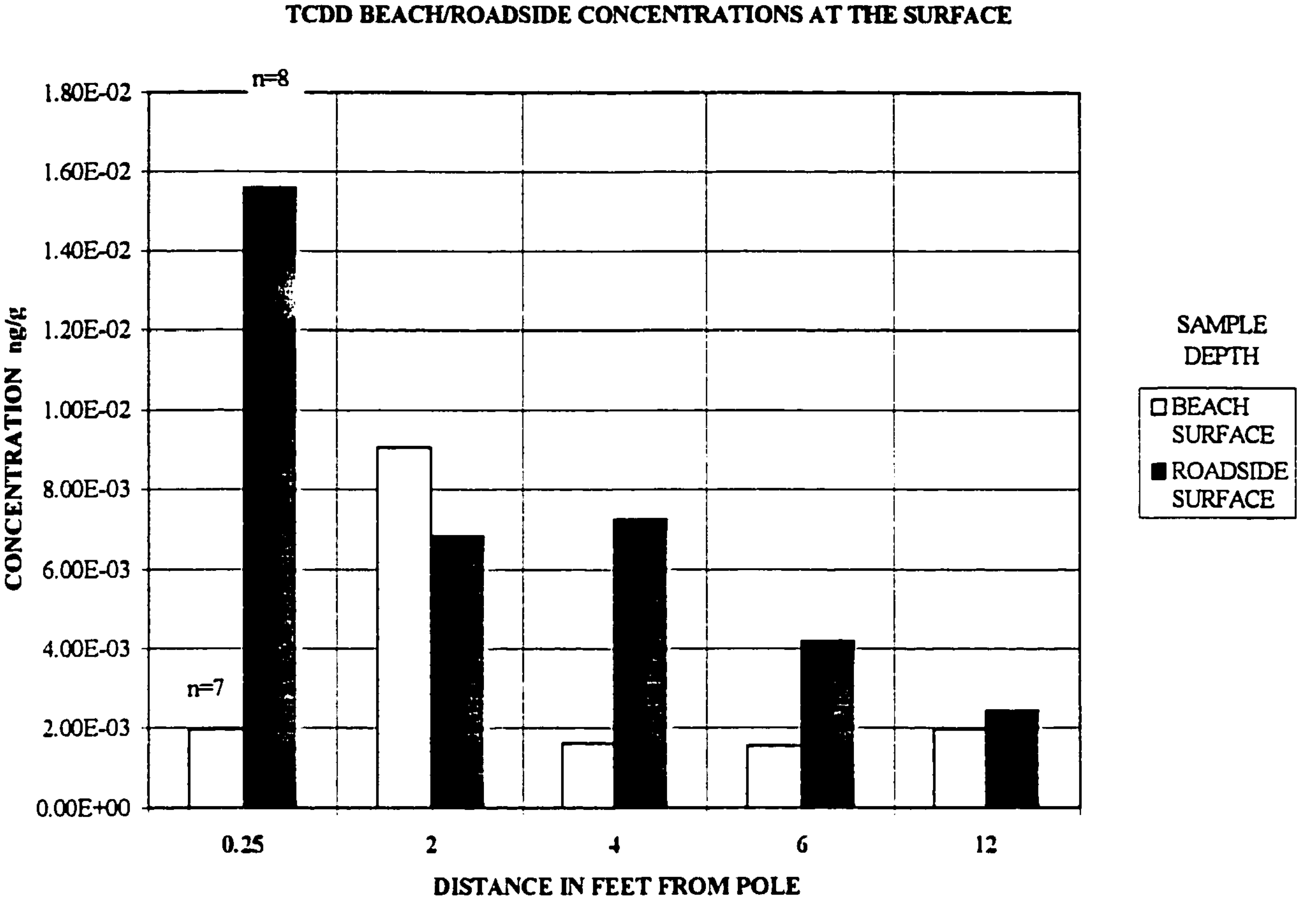


FIGURE A-7. TCDD beach and roadside concentrations at the surface varying by distance. The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDD Toxic Equivalency Factor (TEF) = 1.0. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately three feet high.

Average TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

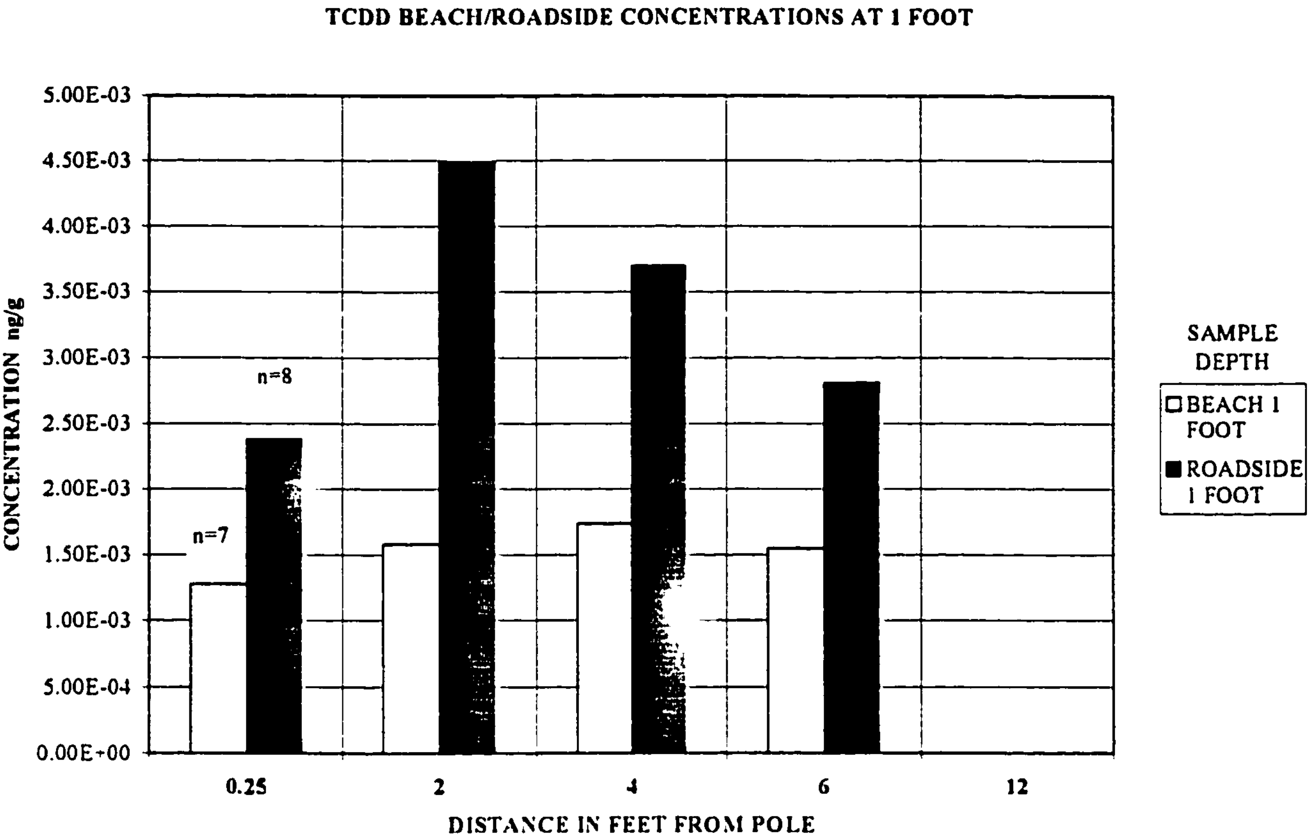


FIGURE A-8. TCDD beach and roadside concentrations at a depth of one foot from the pole surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDD Toxic Equivalency Factor (TEF) = 1.0. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average TCDD laboratory limit of detection = 1.1E-03 ng/g or 1.1 parts per trillion (ppt). All graphed values are either at or above this limit.

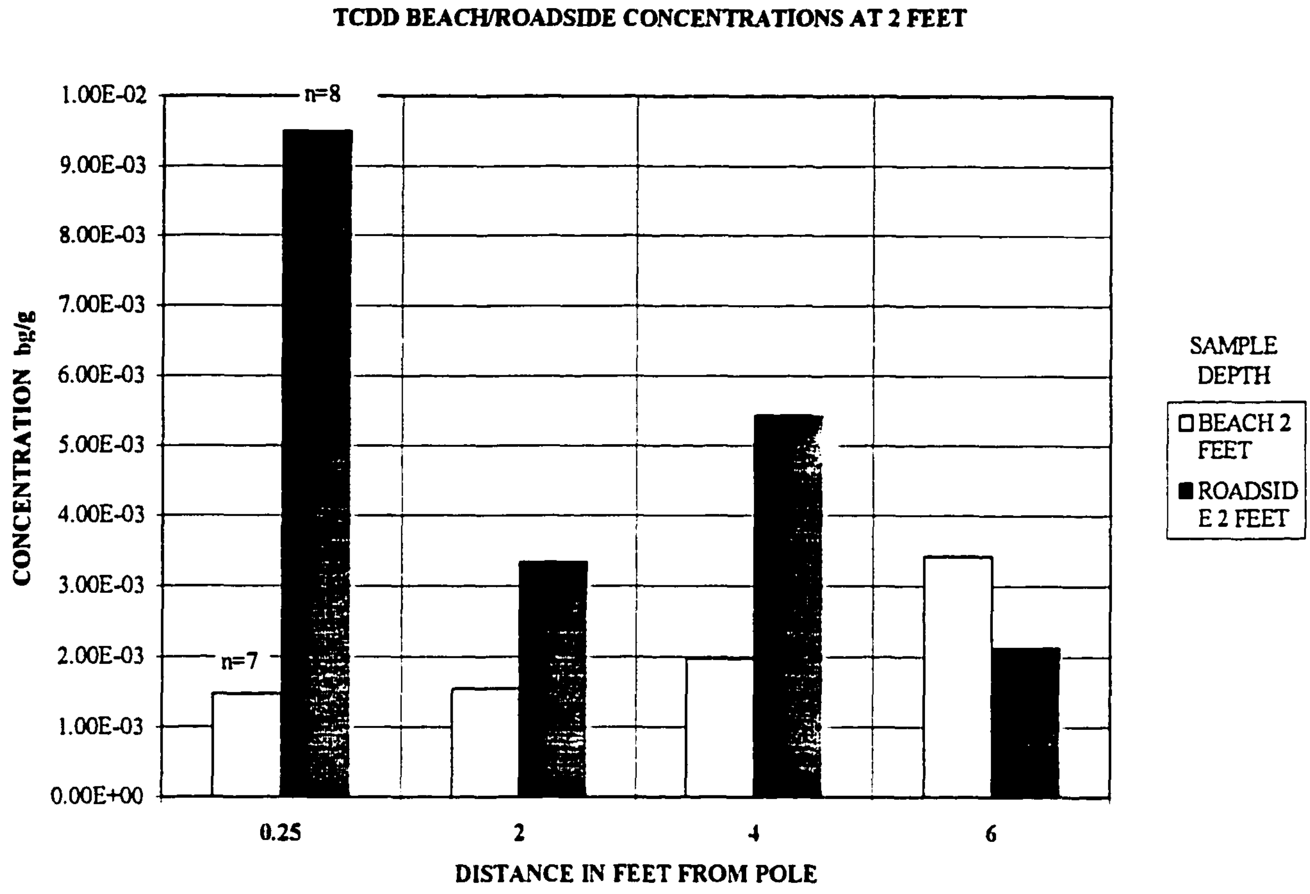


FIGURE A-9. TCDD beach and roadside concentrations at a depth of two feet from the pole surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDD Toxic Equivalency Factor (TEF) = 1.0. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately one foot high.

Average TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

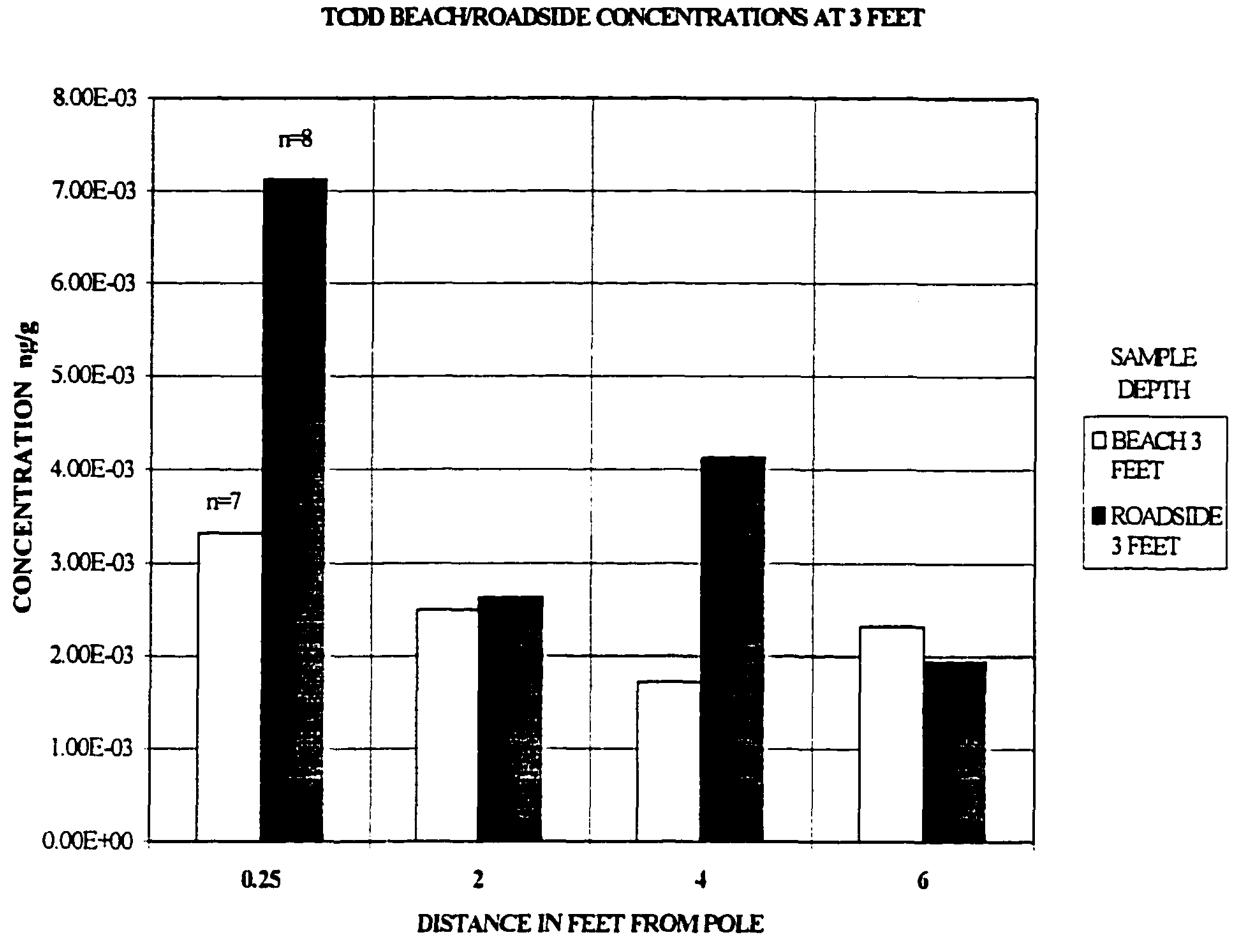


FIGURE A-10. TCDD beach and roadside concentrations at a depth of three feet from the pole surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDD Toxic Equivalency Factor (TEF) = 1.0. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

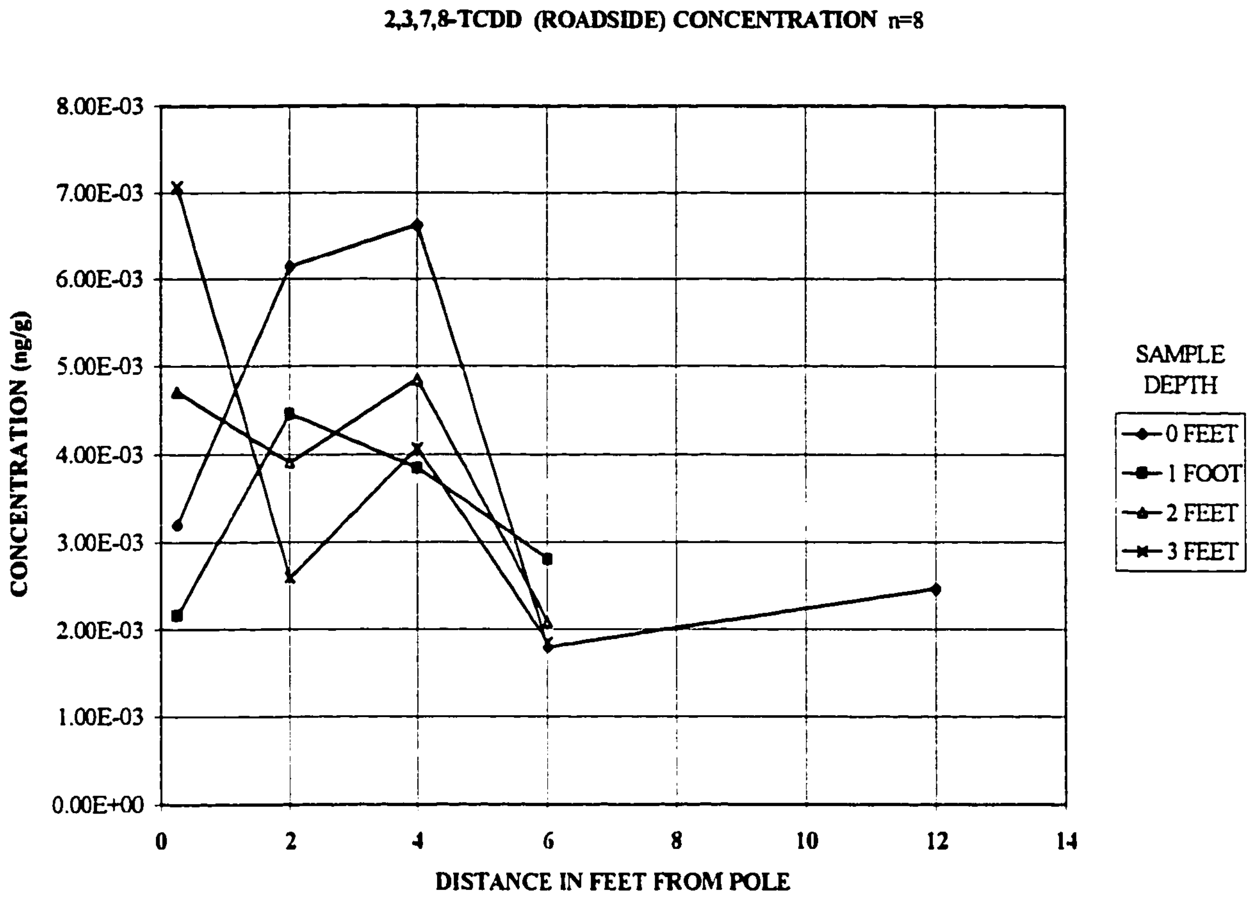


FIGURE A-11. 2,3,7,8 TCDD concentrations in silty/loam soil (roadside area) at depth varying by distance from the utility pole.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDD Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average 2,3,7,8-TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

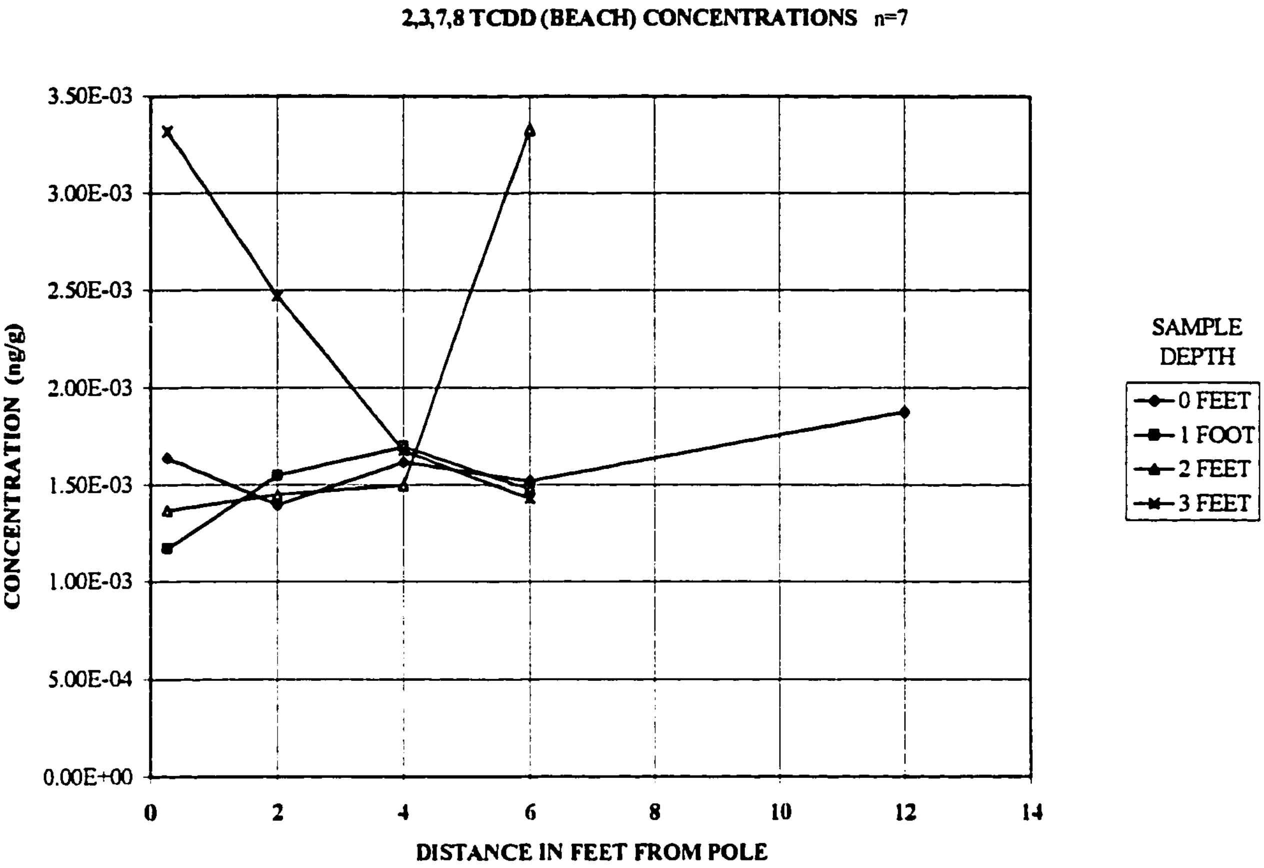


FIGURE A-12. 2,3,7,8 TCDD concentrations in sandy soil (beach area) at depth varying by distance from the utility pole.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDD Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately five feet high.

Average 2,3,7,8-TCDD laboratory limit of detection = 1.1E-03 ng/g or 1.1 parts per trillion (ppt). All graphed values are either at or above this limit.

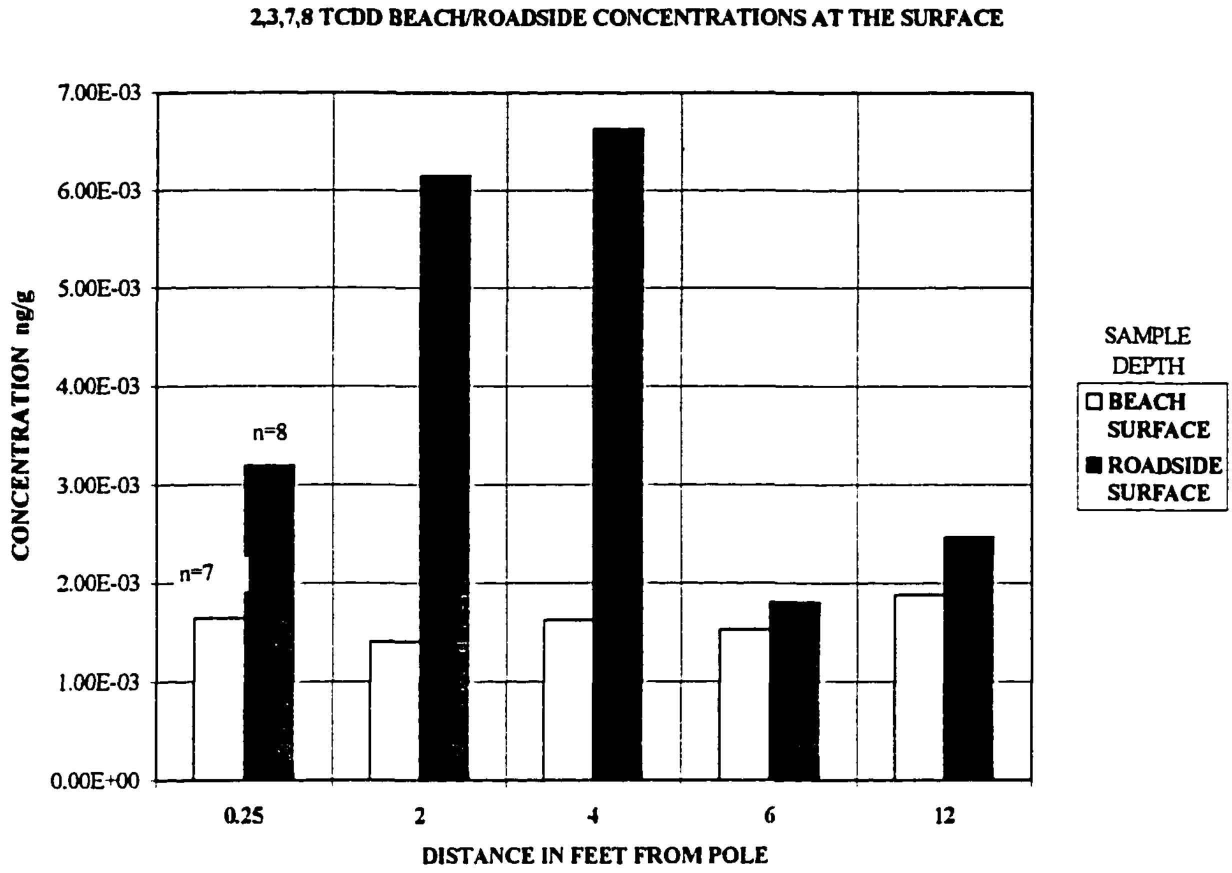


FIGURE A-13. 2,3,7,8 TCDD surface concentrations comparing samples of sandy soil (beach area) concentrations to silty/loam soil (roadside area) varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDD Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately three feet high.

Average 2,3,7,8-TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

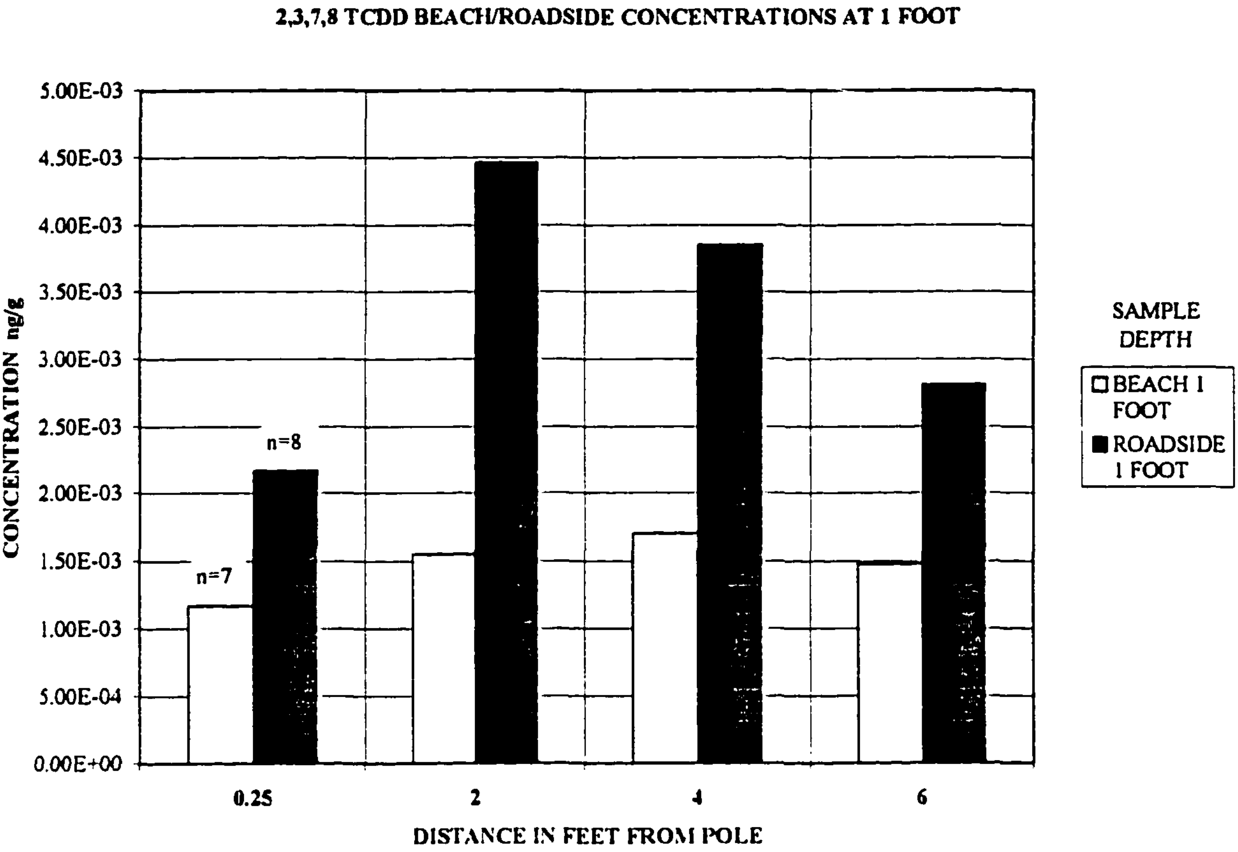


FIGURE A-14. 2,3,7,8 TCDD beach and roadside concentrations at a depth of one foot from the surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDD Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately three feet high.

Average 2,3,7,8-TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

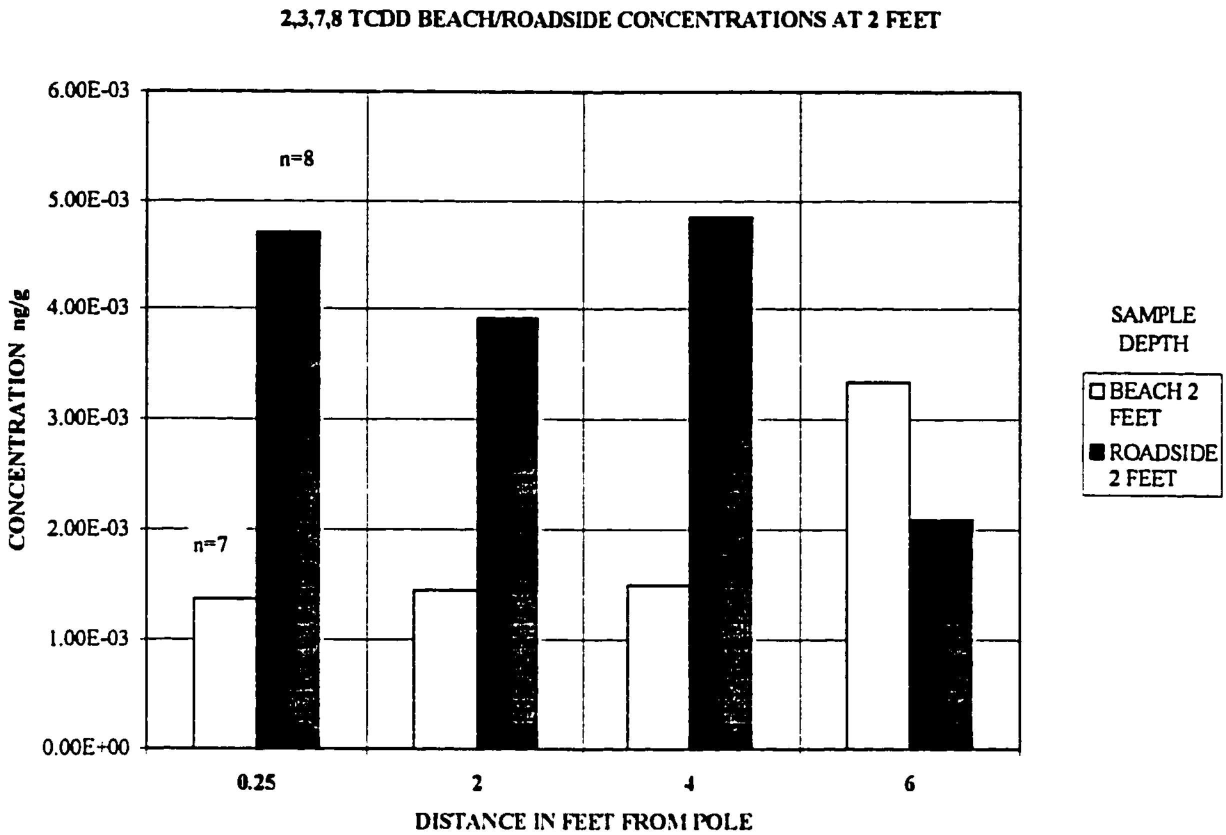


FIGURE A-15. 2,3,7,8 TCDD beach and roadside concentrations at a depth of two feet from the surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDD Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average 2,3,7,8-TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

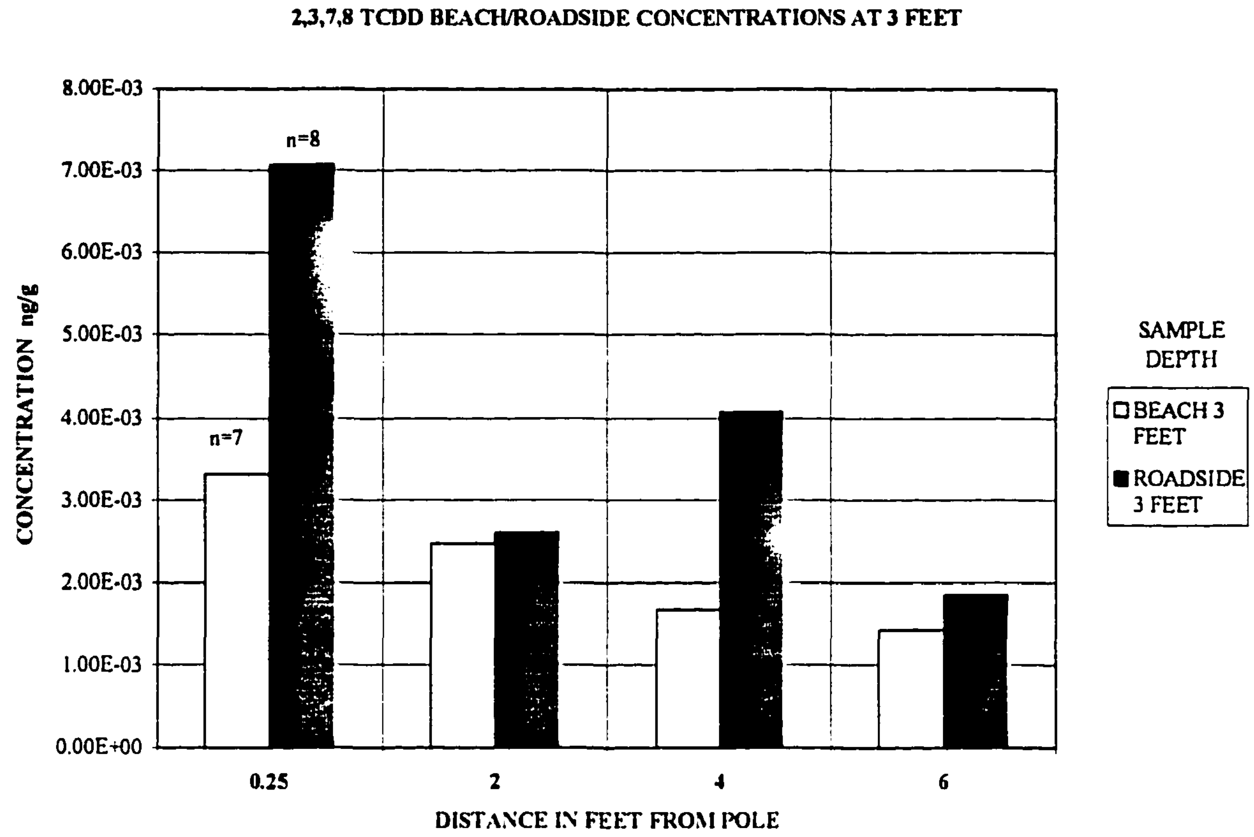


FIGURE A-16. 2,3,7,8 TCDD beach and roadside concentrations at a depth of three feet from the surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDD Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average 2,3,7,8-TCDD laboratory limit of detection = 1.5E-03 ng/g or 1.5 parts per trillion (ppt). All graphed values are either at or above this limit.

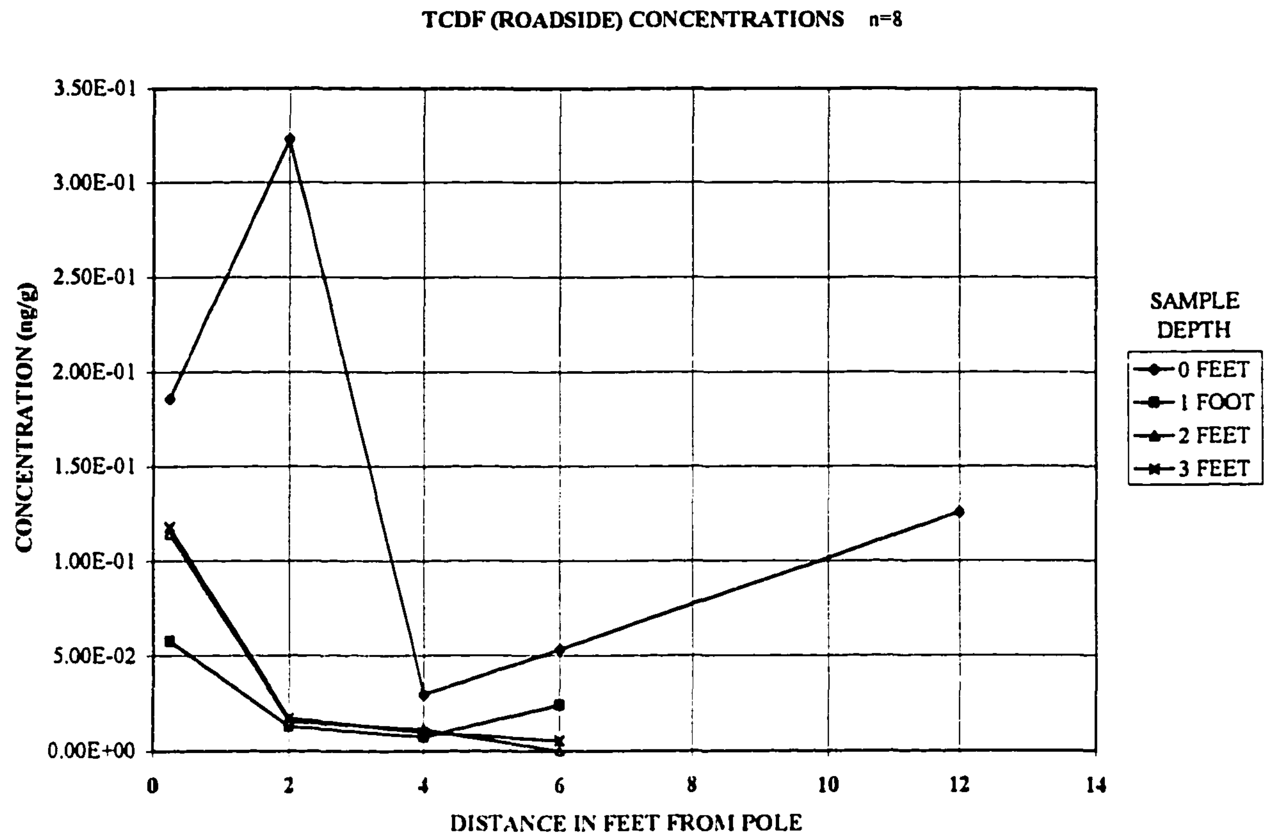


FIGURE A-17. TCDF concentrations in silty/loam soil (roadside area) at depth varying by distance from the utility pole.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

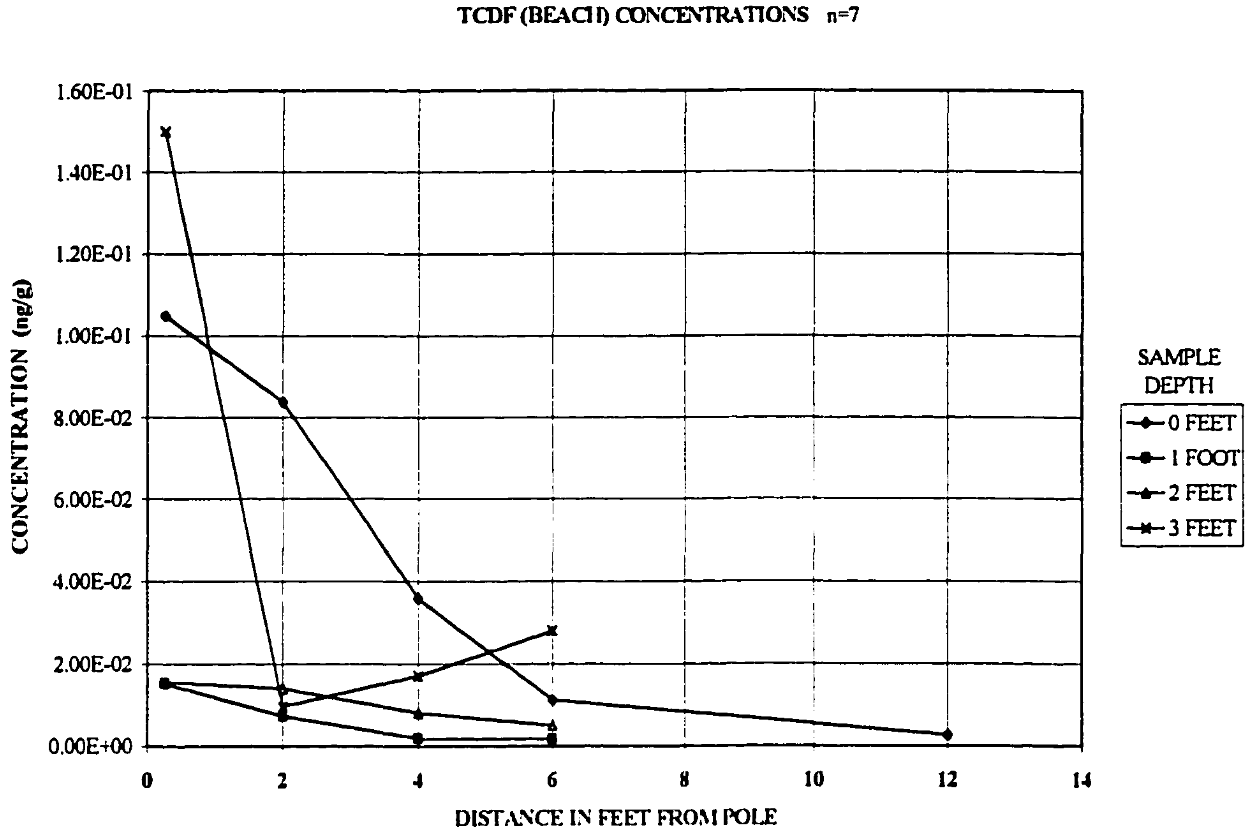


FIGURE A-18. TCDF concentrations in sandy soil (beach area) at depth varying by distance from the utility pole.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately three feet high.

Average TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

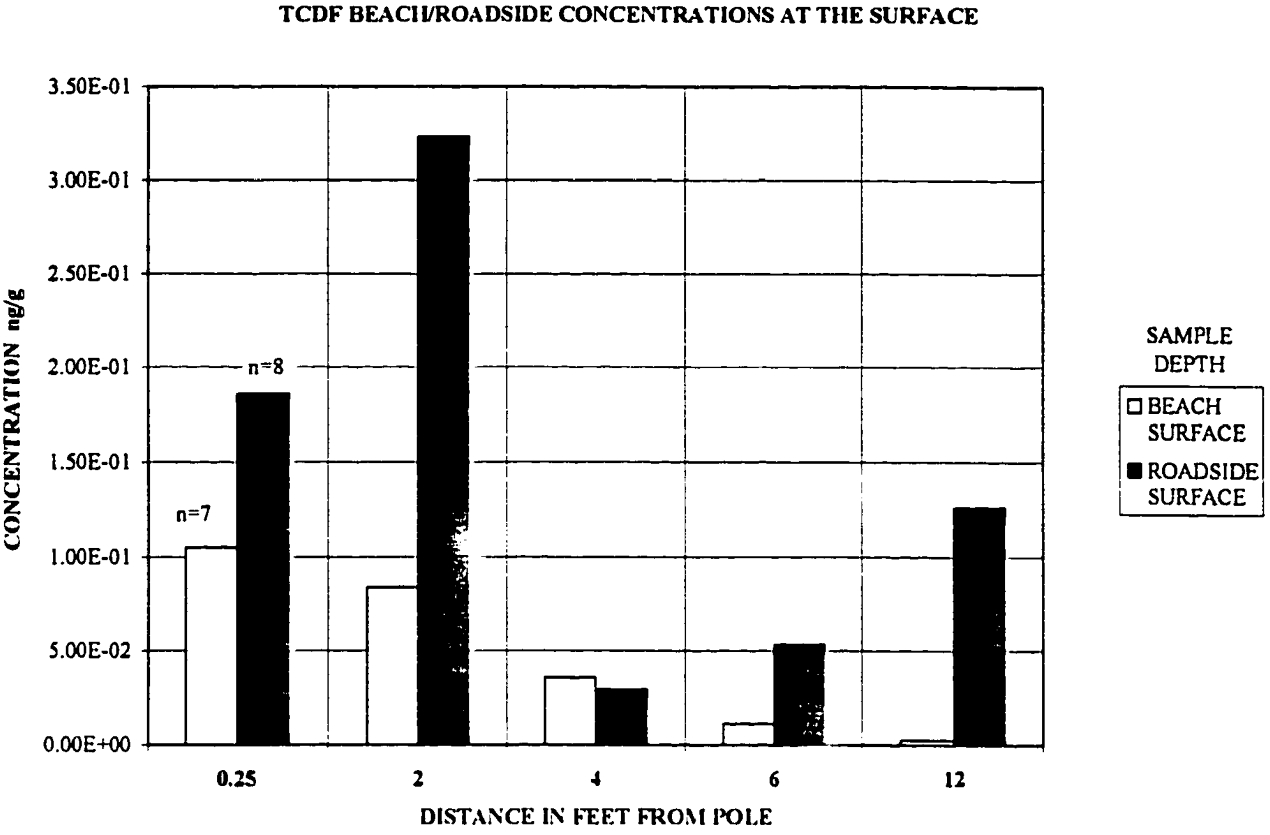


FIGURE A-19. TCDF surface concentrations comparing samples of sandy soil (beach area) concentrations to silty/loam soil (roadside area) varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

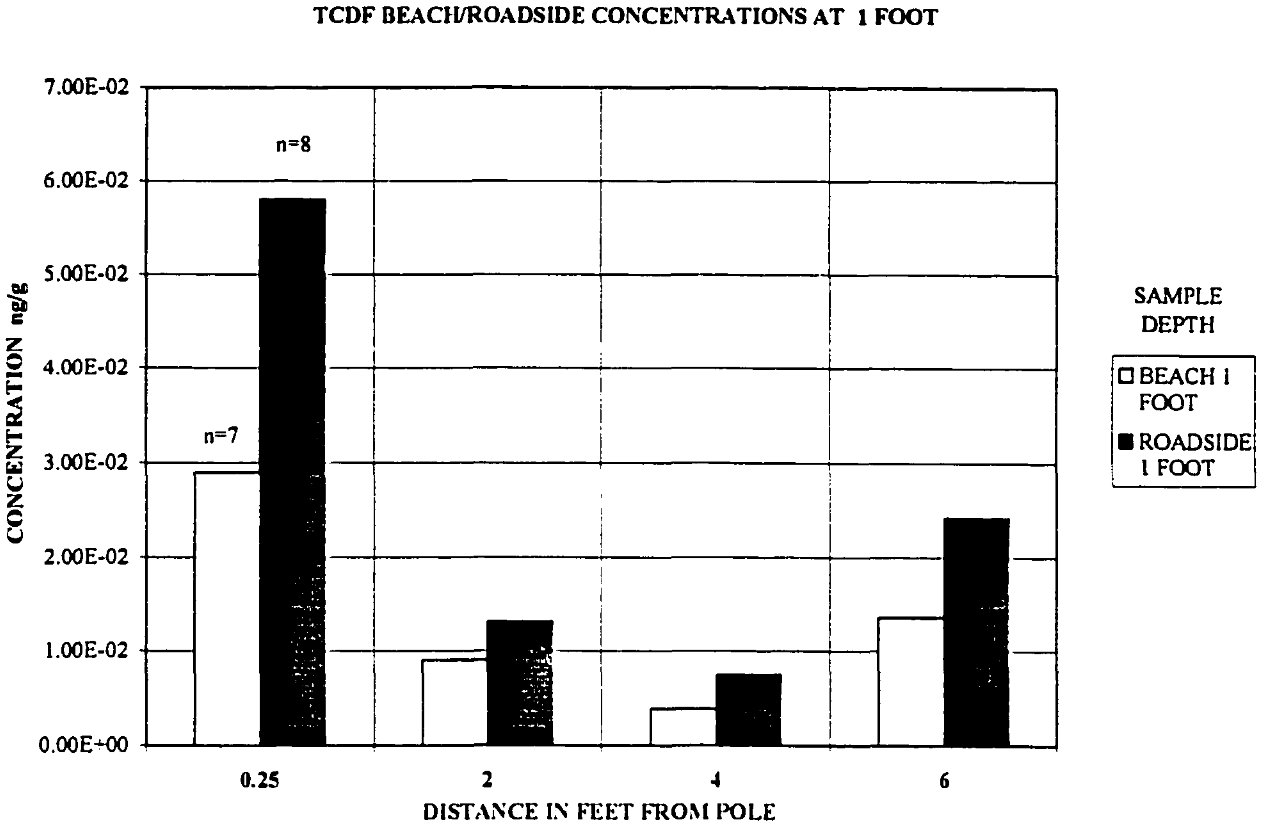


FIGURE A-20. TCDF beach and roadside concentrations at a depth of one foot from the surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

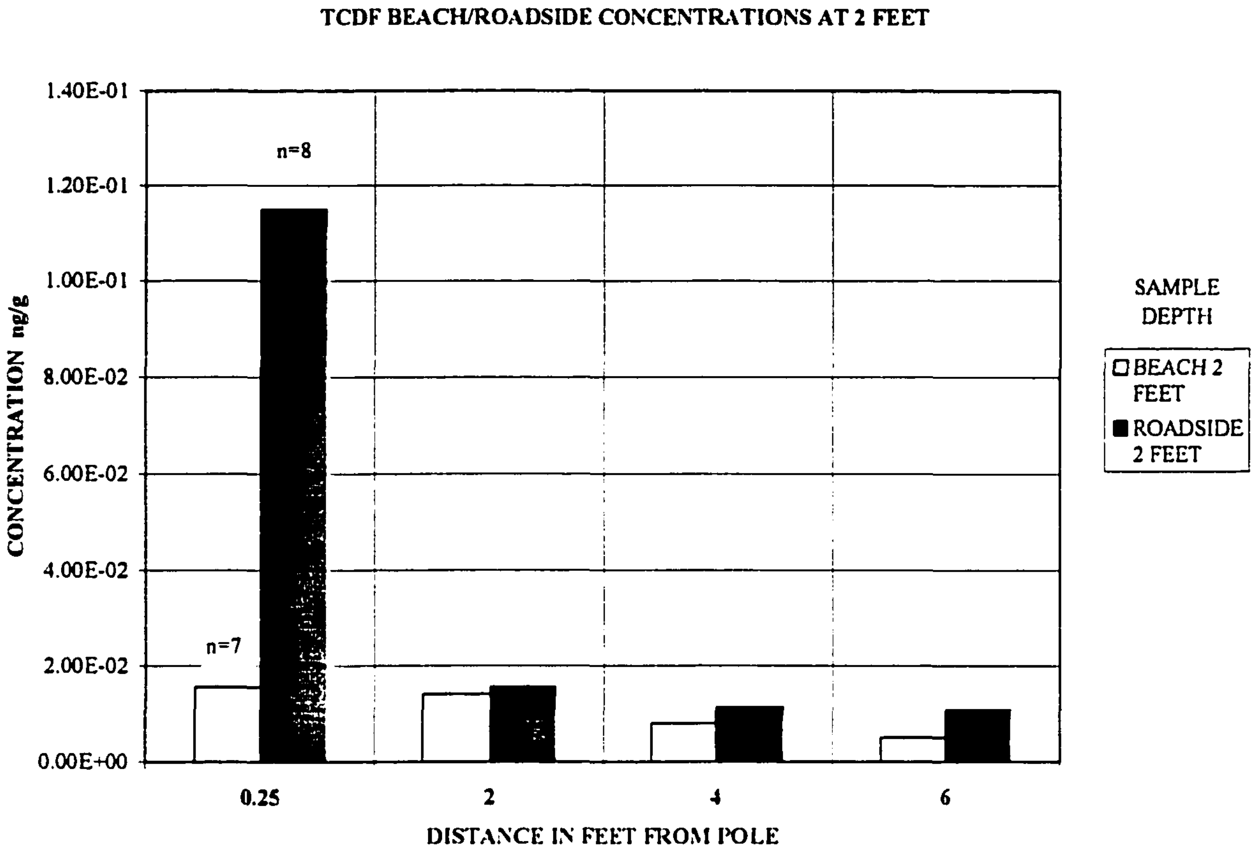


FIGURE A-21. TCDF beach and roadside concentrations at a depth of two feet from the surface varying by distance

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately three feet high.

Average TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

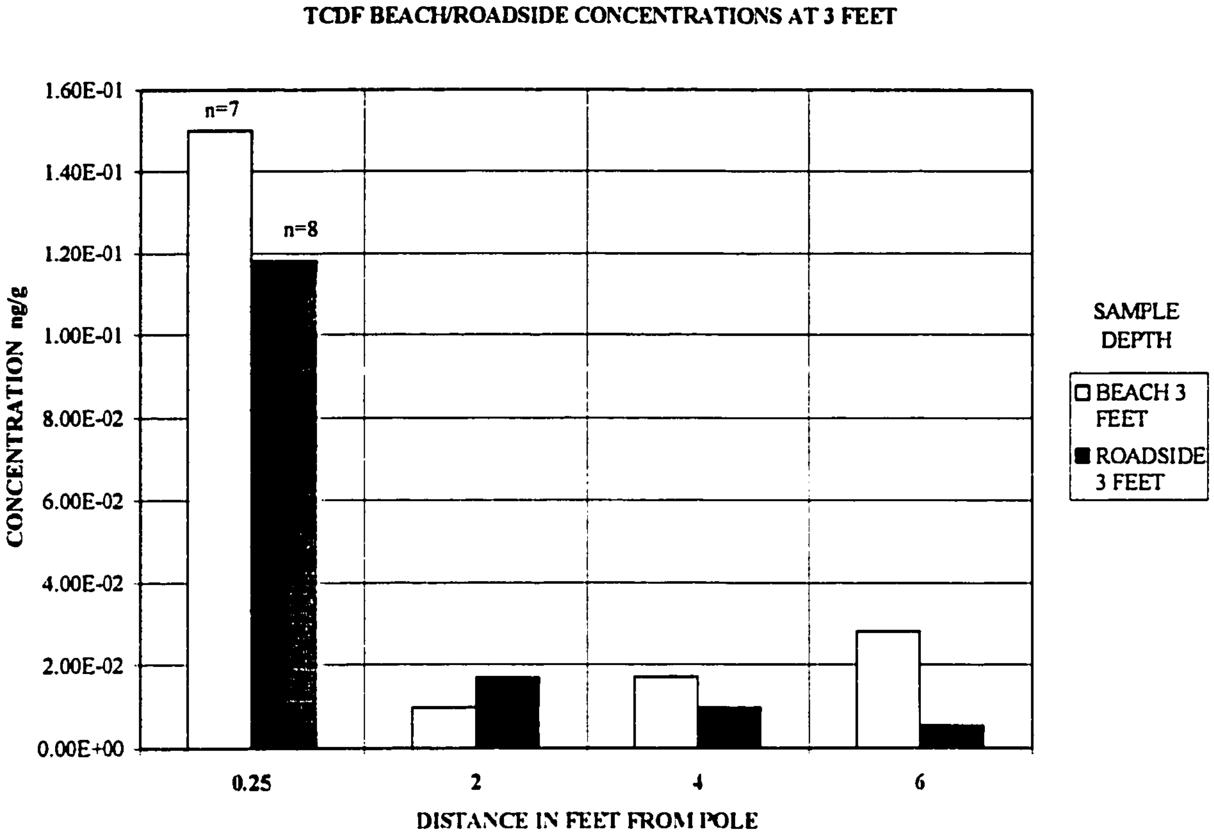


FIGURE A-22. TCDF beach and roadside concentrations at a depth of three feet from the surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately three feet high.

Average TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

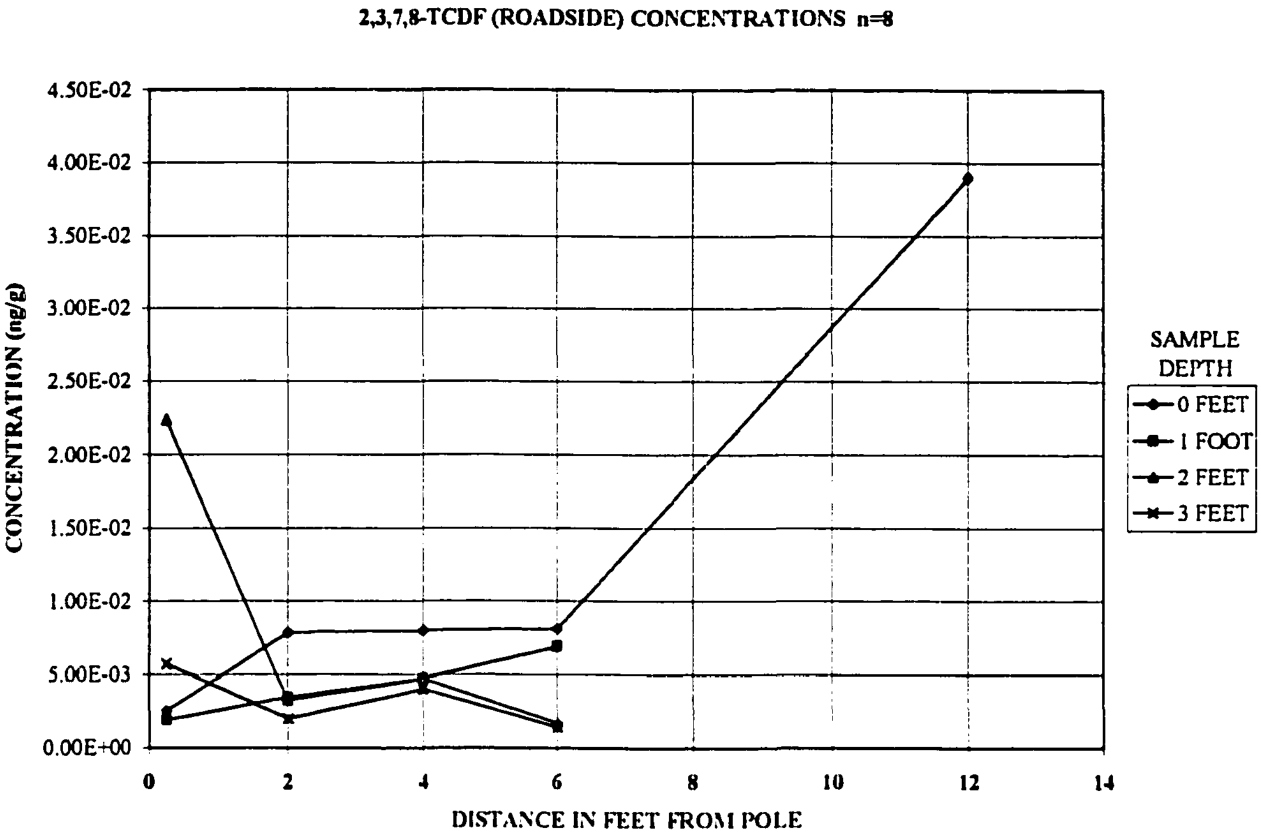


FIGURE A-23. 2,3,7,8 TCDF concentrations in silty/loam soil (roadside area) at depth varying by distance from the utility pole.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average 2,3,7,8-TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

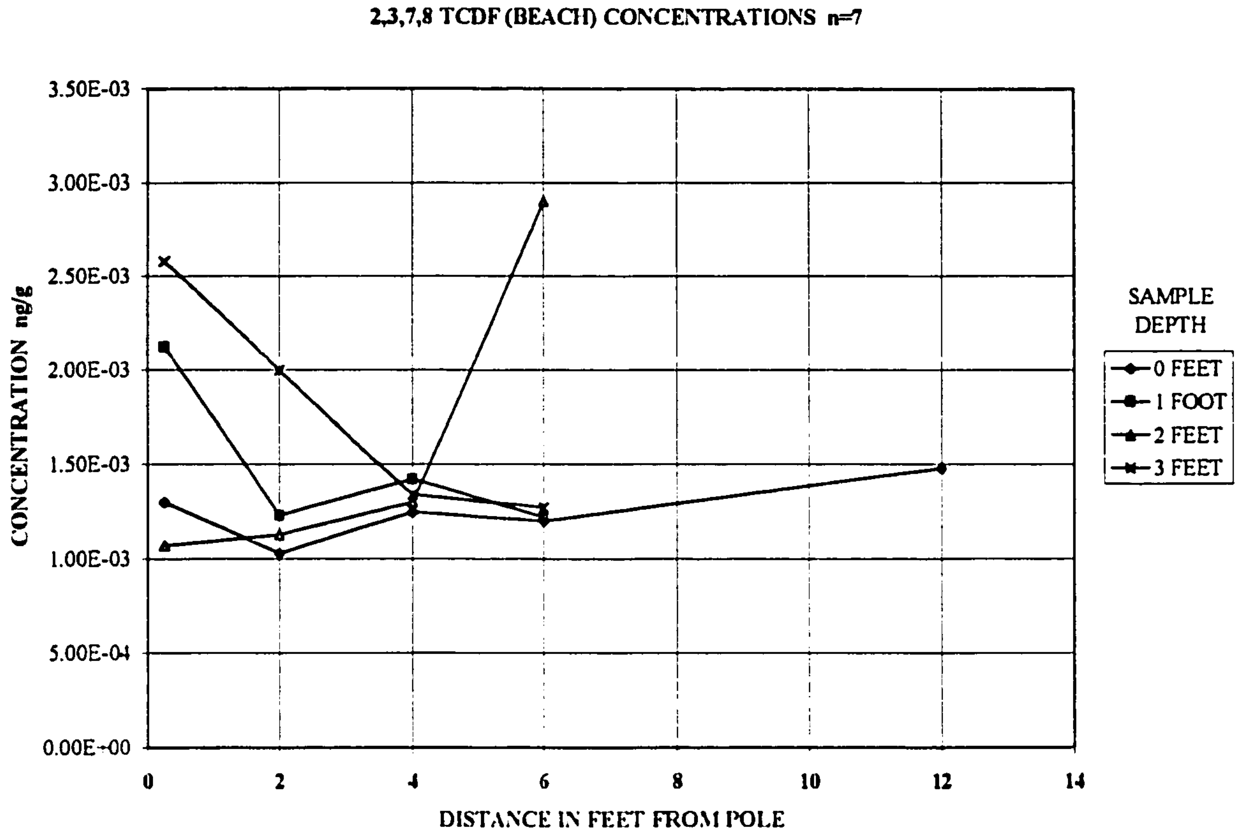


FIGURE A-24. 2,3,7,8 TCDF concentrations in sandy soil (beach area) at depth varying by distance from the utility pole.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately three feet high.

Average 2,3,7,8-TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

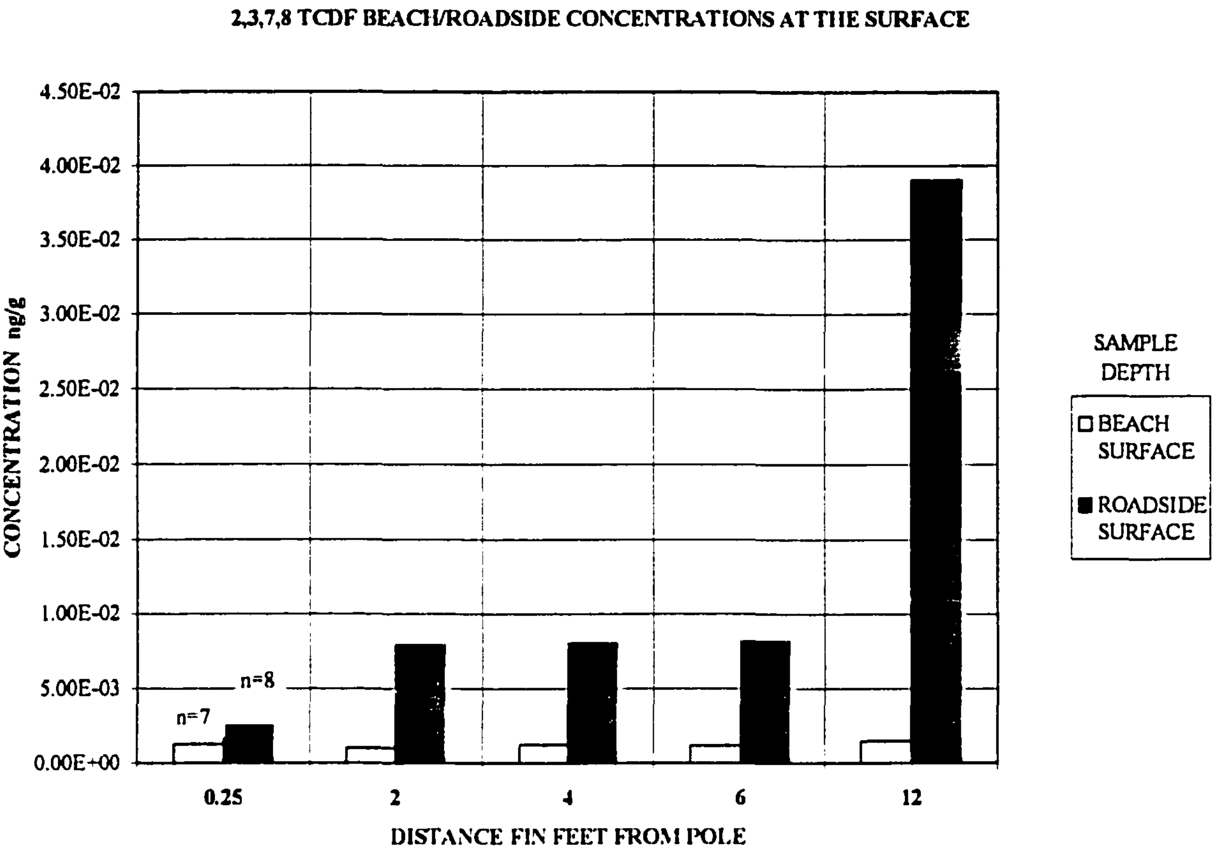


FIGURE A-25. 2,3,7,8 TCDF surface concentrations comparing samples of sandy soil (beach area) concentrations to silty/loam soil (roadside area) varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average 2,3,7,8-TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

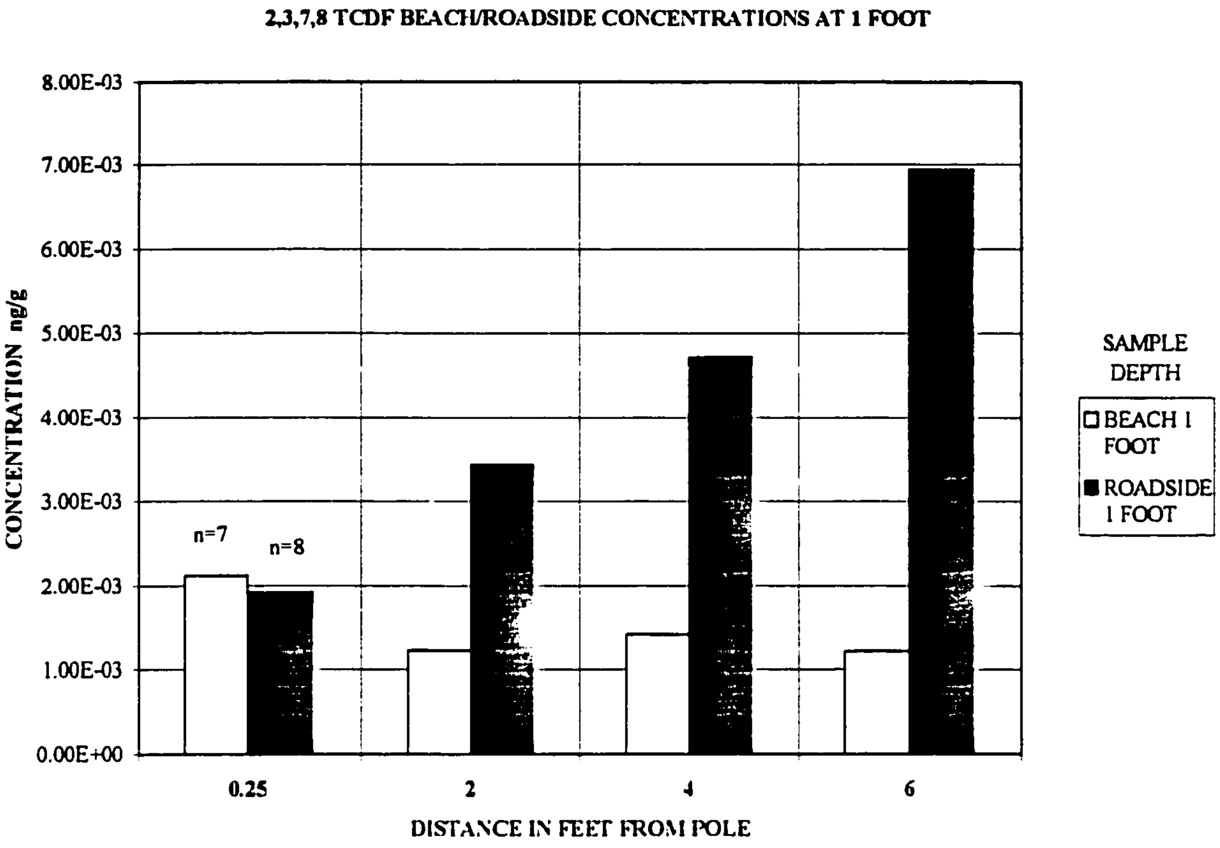


FIGURE A-26. 2,3,7,8 TCDF beach and roadside concentrations at a depth of one foot from the surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately one foot high.

Average 2,3,7,8-TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

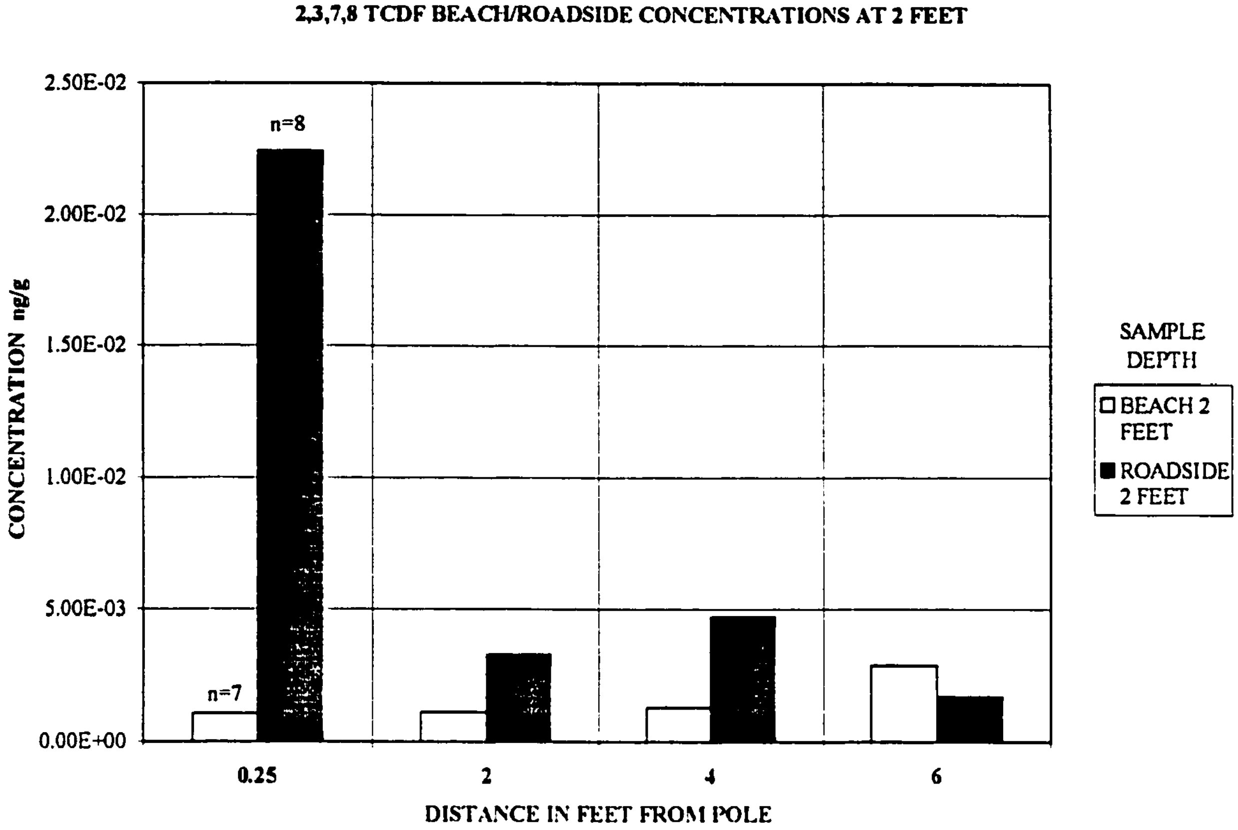


FIGURE A-27. 2,3,7,8 TCDF beach and roadside concentrations at a depth of two feet from the surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average 2,3,7,8-TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

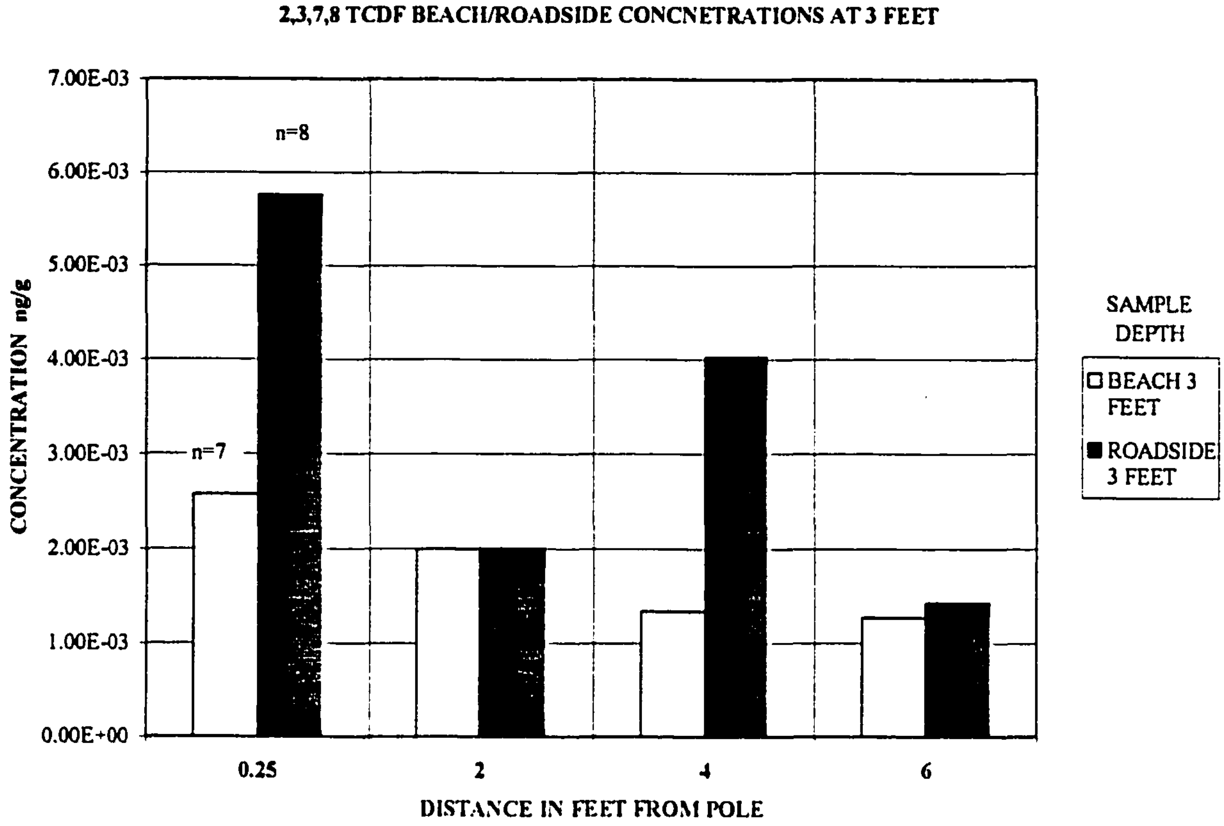


FIGURE A-28. 2,3,7,8 TCDF beach and roadside concentrations at a depth of three feet from the surface varying by distance.

The US EPA Office of Solid Waste and Emergency Response recommended preliminary residential soil remediation goal = 1.0E+00 ng/g (1 part per billion (ppb)) TEQ. US EPA 2,3,7,8 TCDF Toxic Equivalency Factor (TEF) = 0.1. Individual TEQ congeners are calculated by multiplying the soil concentration of individual congeners by their respective Toxic Equivalency Factor (TEF). The overall Toxic Equivalency (TEQ) of the soil mixture is the sum of the individual TEQ congener concentrations. If this recommended soil remediation goal were plotted on this scale, the graph illustrating this recommended goal would be approximately two feet high.

Average 2,3,7,8-TCDF laboratory limit of detection = 1.2E-03 ng/g or 1.2 parts per trillion (ppt). All graphed values are either at or above this limit.

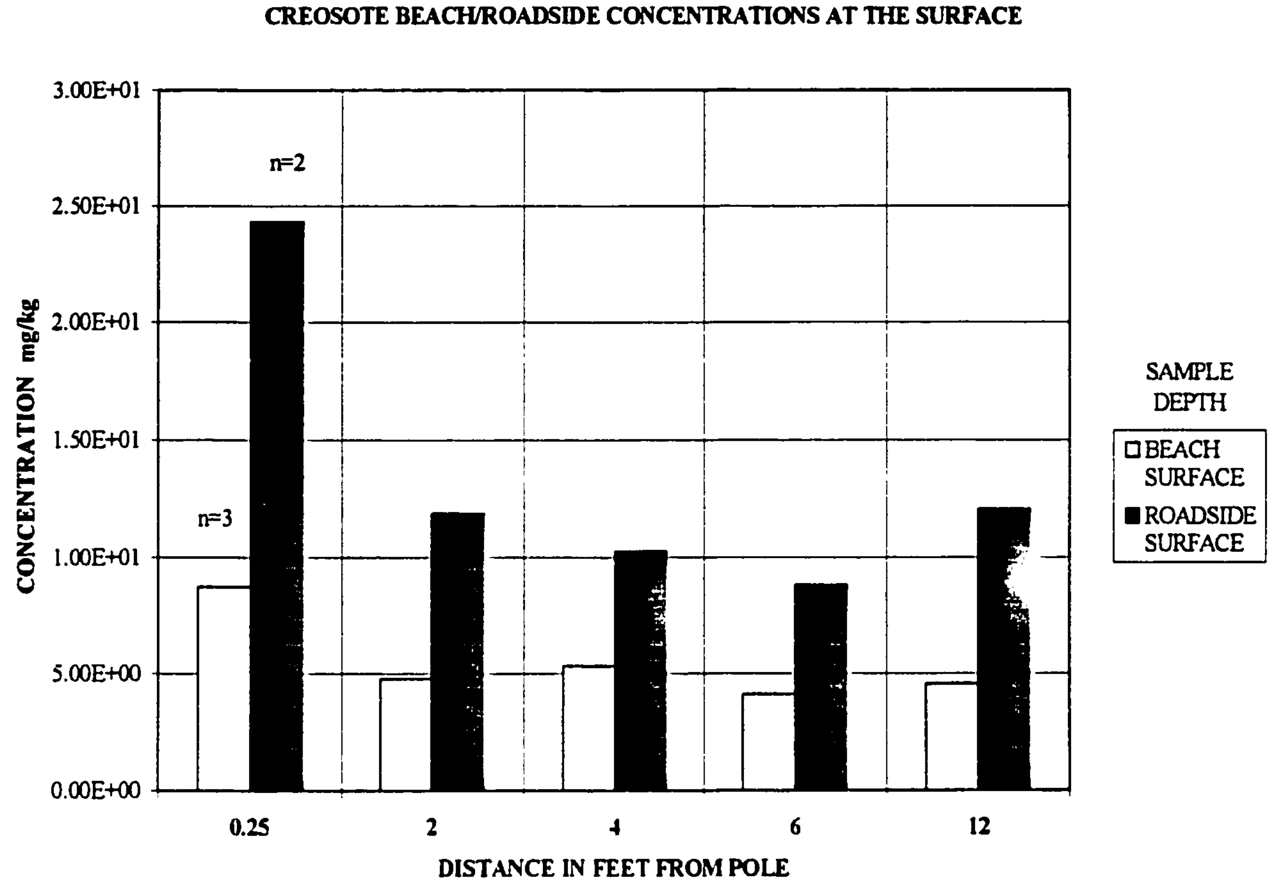


FIGURE A-29. Creosote surface concentrations comparing samples of silty/loam soil (roadside area) concentrations to sandy soil (beach area) varying by distance.

US EPA Soil Remediation Action Level for creosote = 200 milligrams per kilogram (mg/kg) or 200 parts per million (ppm). If the action level were plotted on this scale, the graph illustrating the action level would be approximately two feet high.

Average creosote laboratory limit of detection = 0.8E-01 mg/kg or 0.08 ppm. All graphed values are either at or above this limit.

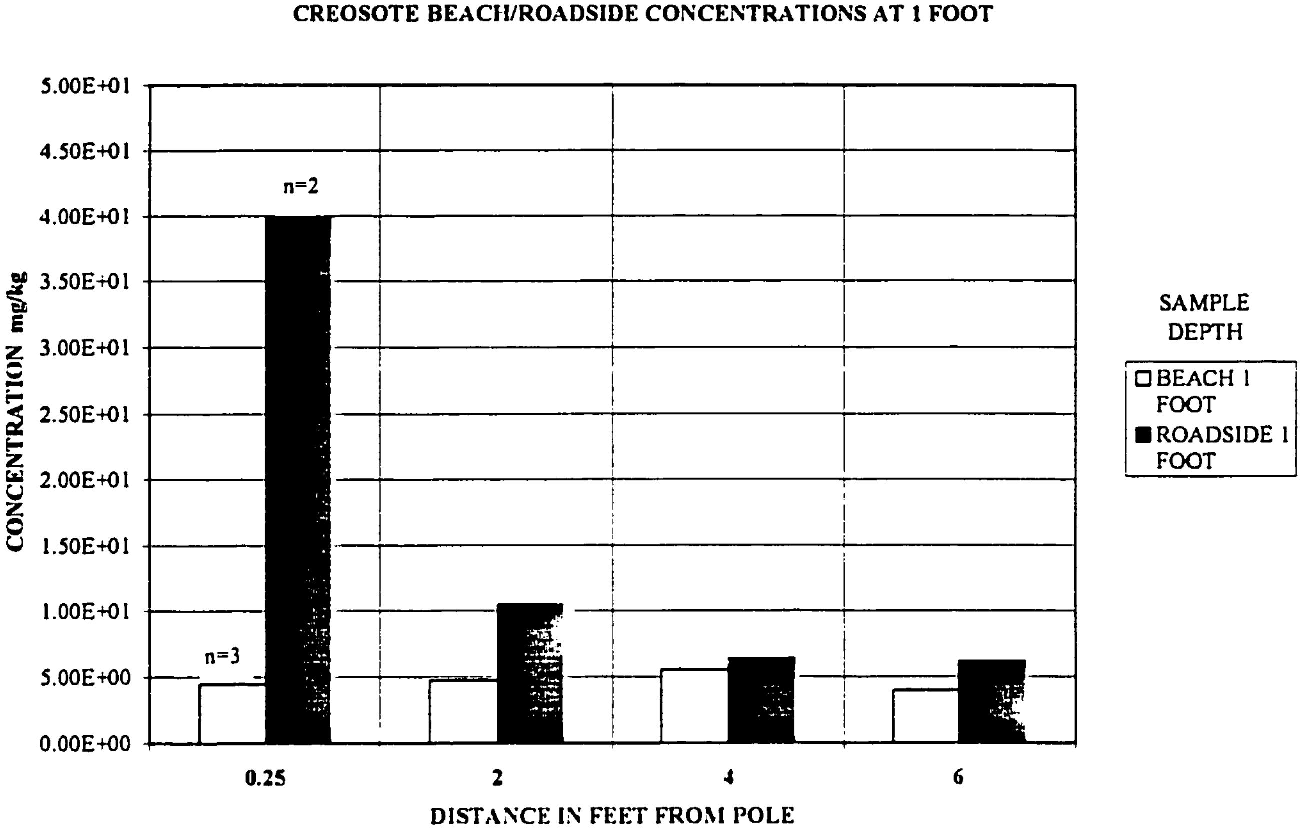


FIGURE A-30. Creosote beach and roadside concentrations at a depth of one foot from the surface varying by distance.

US EPA Soil Remediation Action Level for creosote = 200 milligrams per kilogram (mg/kg) or 200 parts per million (ppm). If the action level were plotted on this scale, the graph illustrating the action level would be approximately one foot high.

Average creosote laboratory limit of detection = 0.8E-01 mg/kg or 0.08 ppm. All graphed values are either at or above this limit.

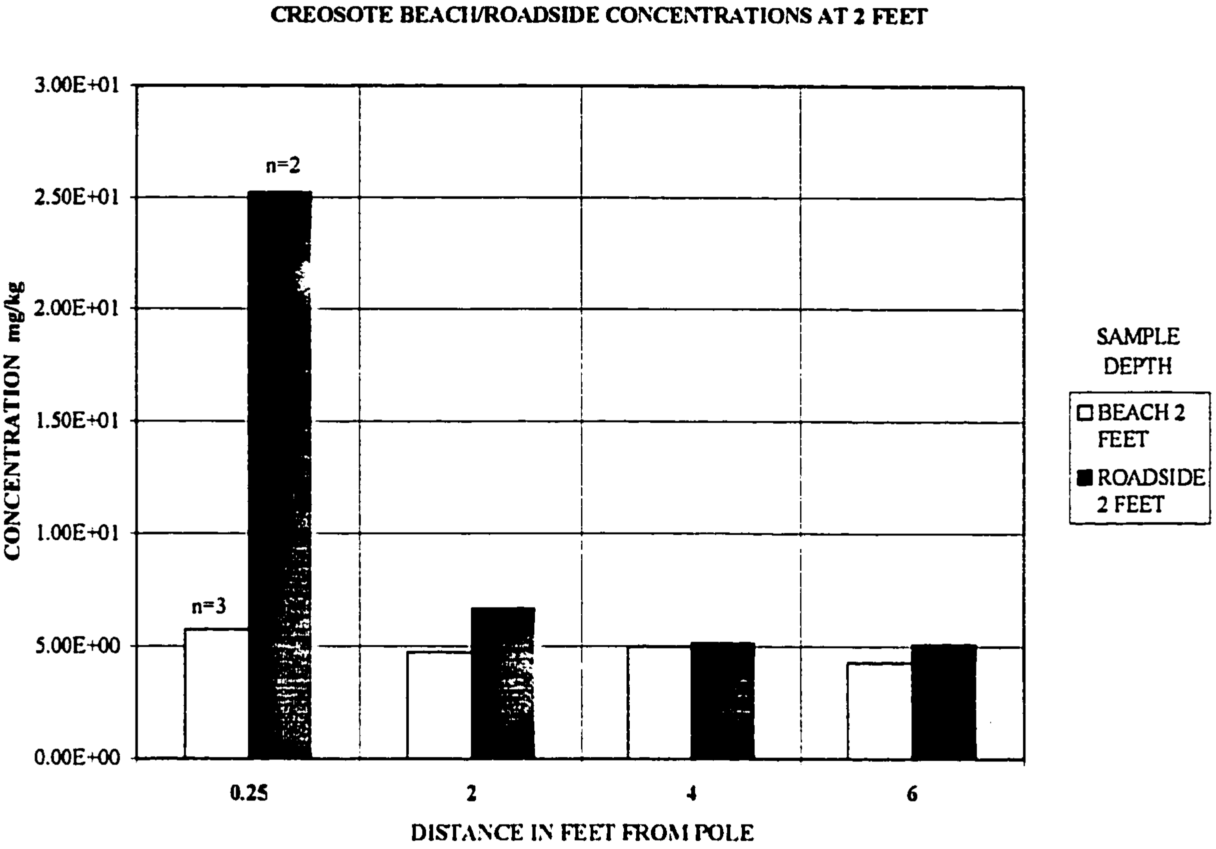


FIGURE A-31. Creosote beach and roadside concentrations at a depth of two feet from the surface varying by distance.

US EPA Soil Remediation Action Level for creosote = 200 milligrams per kilogram (mg/kg) or 200 parts per million (ppm). If the action level were plotted on this scale, the graph illustrating the action level would be approximately two feet high.

Average creosote laboratory limit of detection = 0.8E-01 mg/kg or 0.08 ppm. All graphed values are either at or above this limit.

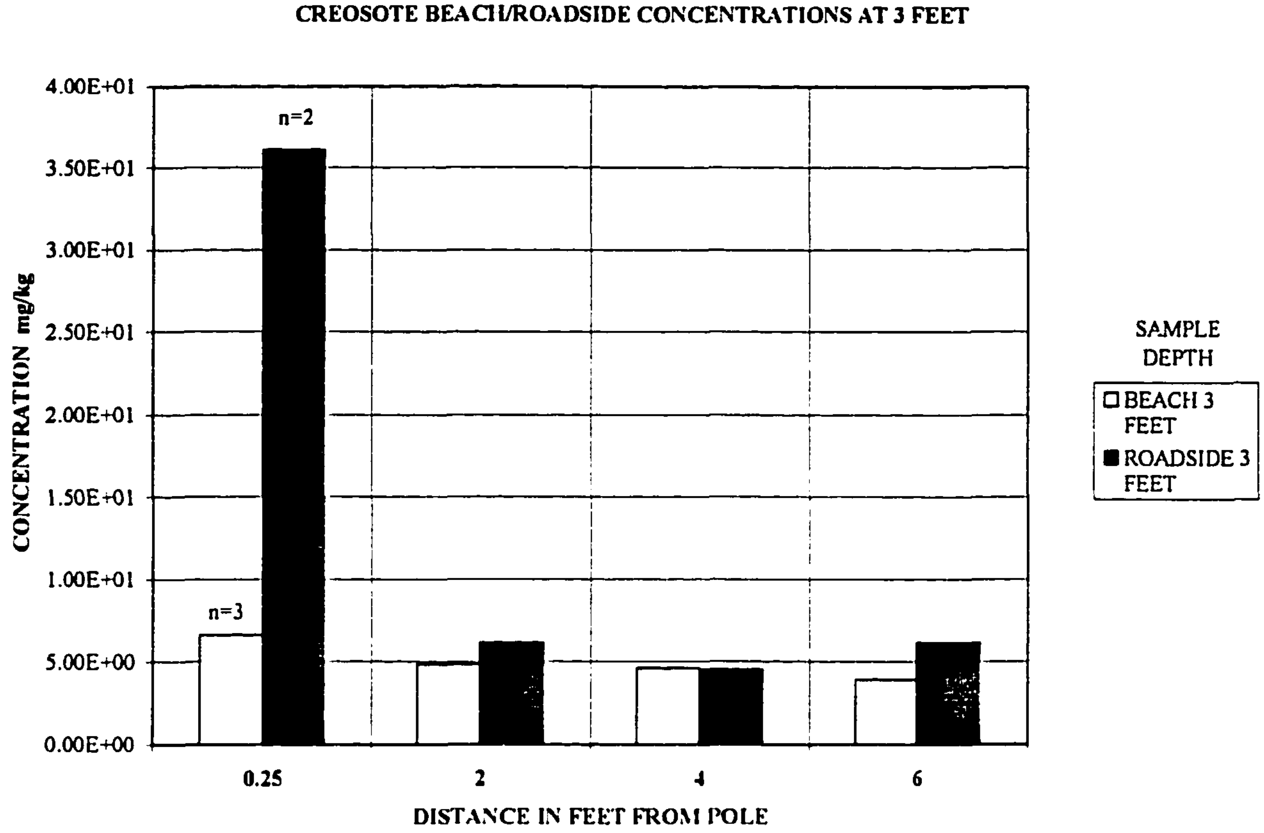


FIGURE A-32. Creosote beach and roadside concentrations at a depth of three feet from the surface varying by distance.

US EPA Soil Remediation Action Level for creosote = 200 milligrams per kilogram (mg/kg) or 200 parts per million (ppm). If the action level were plotted on this scale, the graph illustrating the action level would be approximately two feet high.

Average creosote laboratory limit of detection = 0.8E-01 mg/kg or 0.08 ppm. All graphed values are either at or above this limit.

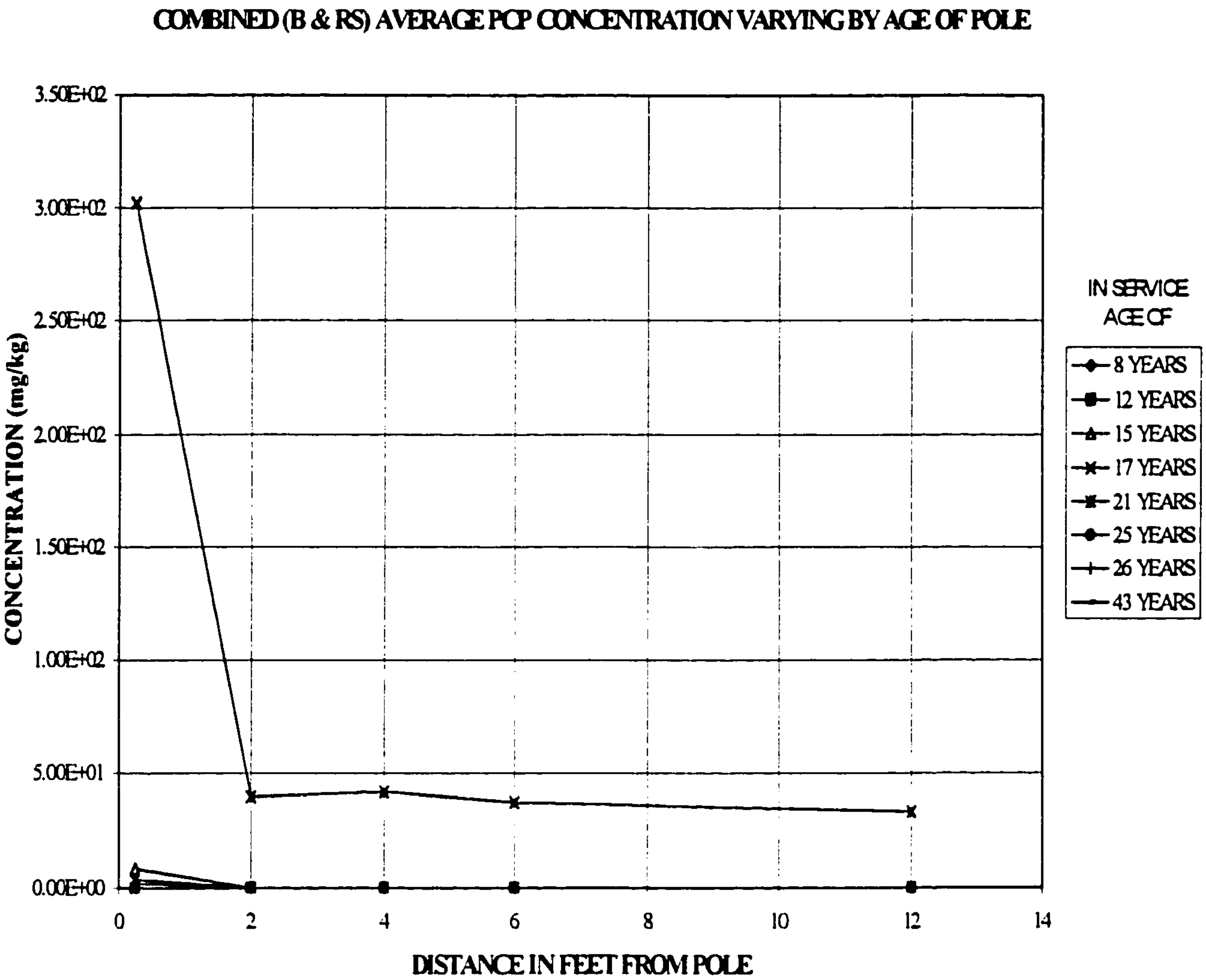
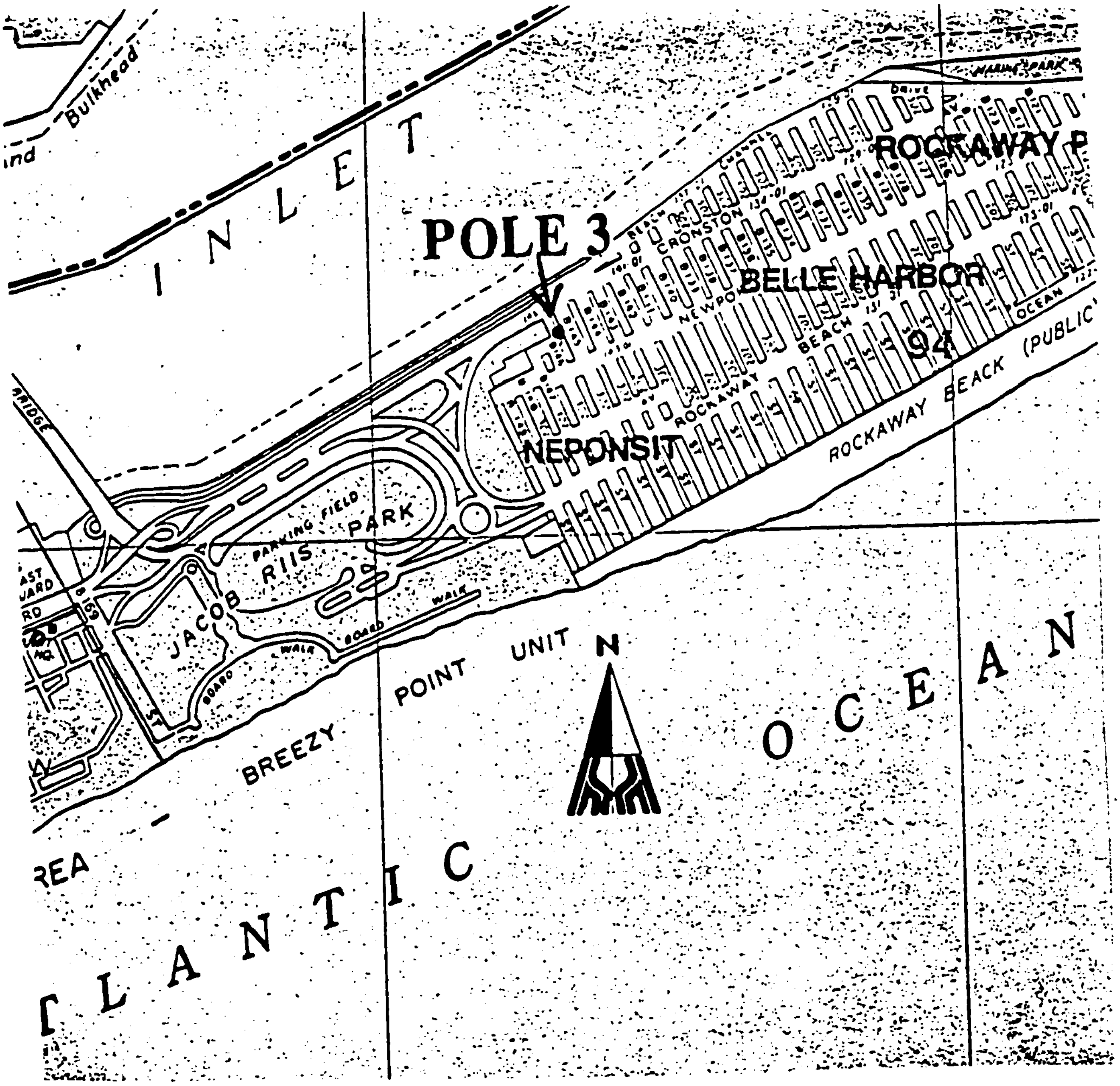


FIGURE A-33. PCP concentration plotted by the in-Service Age of the Utility Pole.

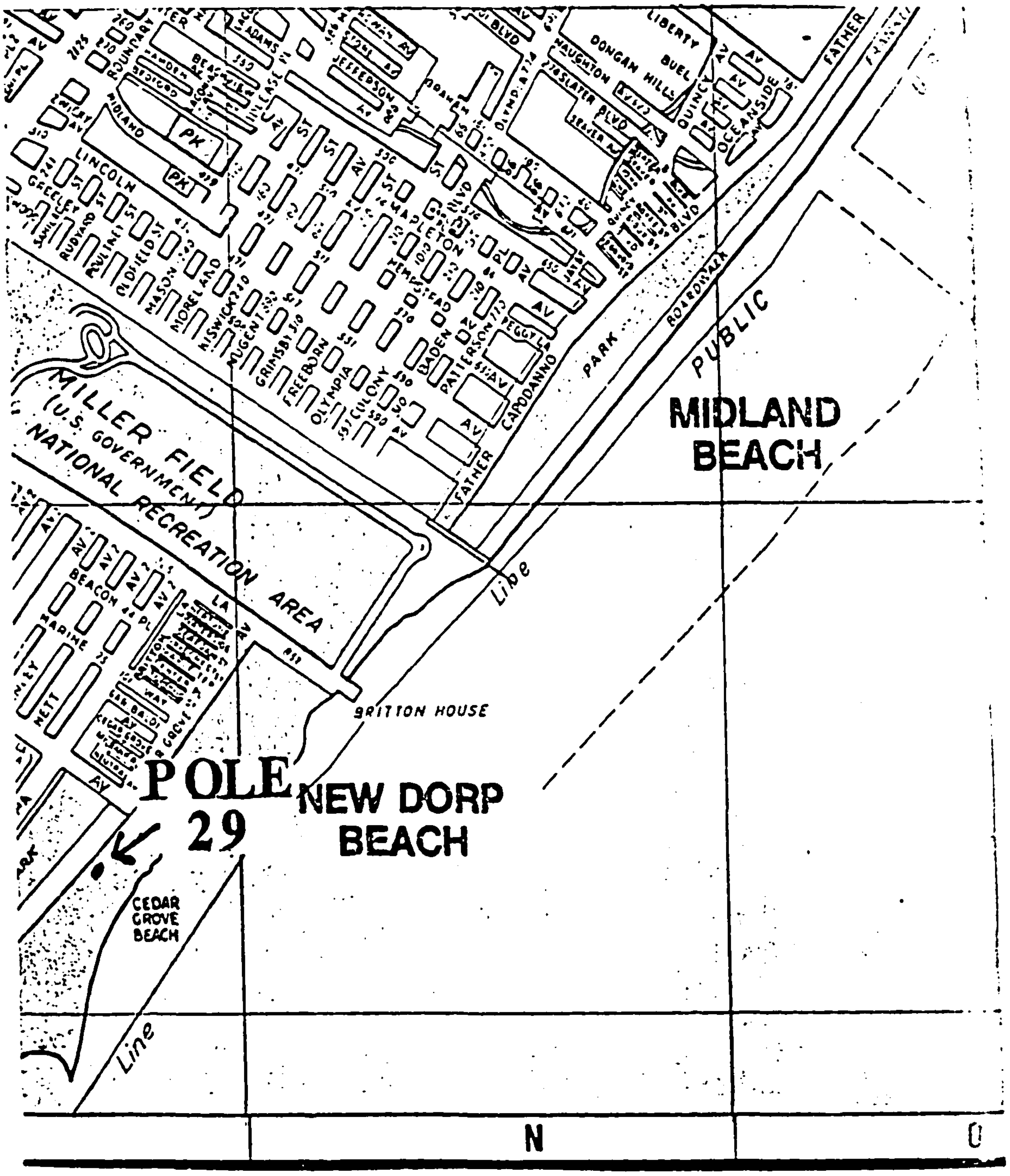
APPENDIX 2

MAPS

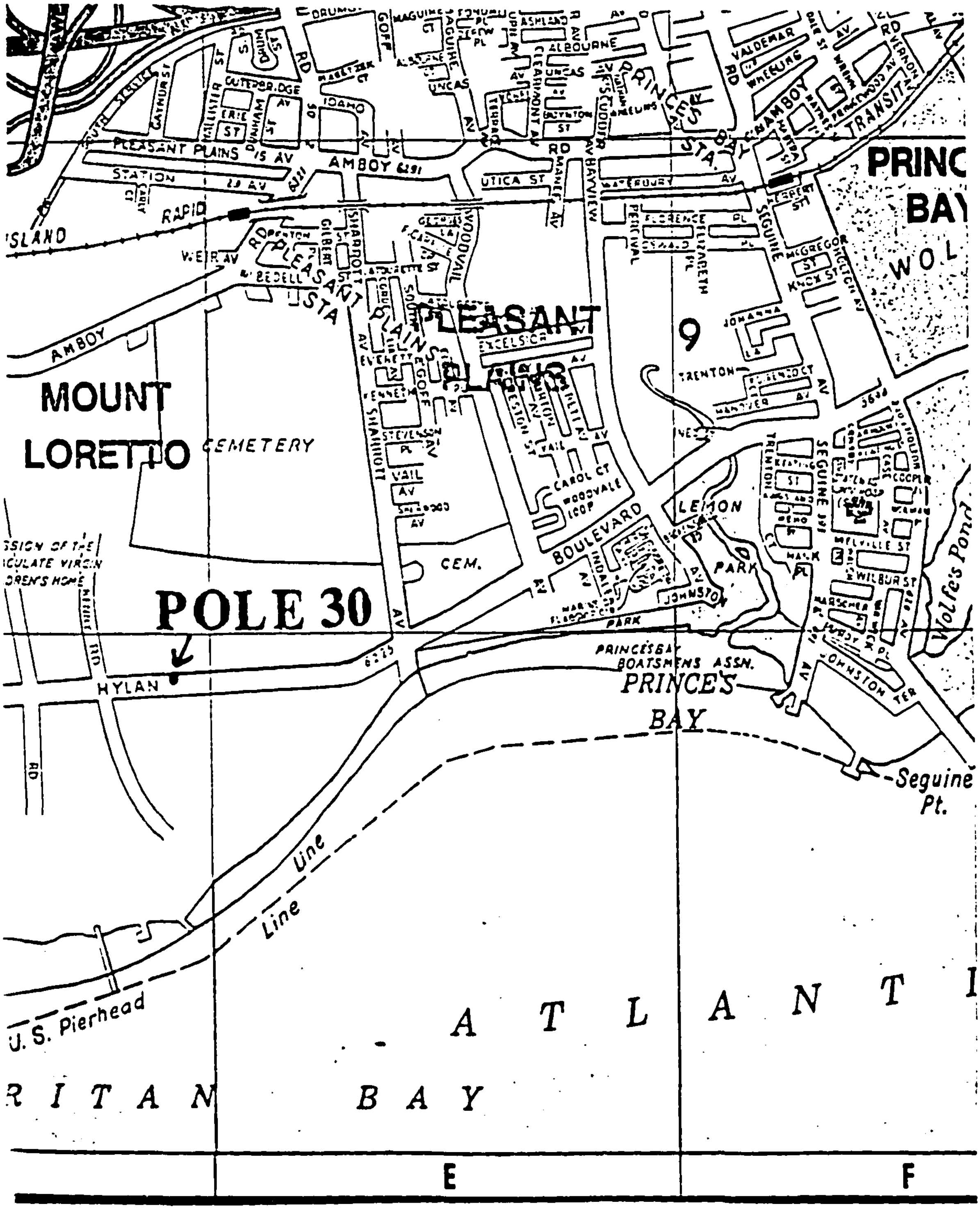


MAP 1. Utility Pole Soil Sampling location near 465 – B145th Street, Neponsit, Queens; Pole #3

Hagstrom Map #17

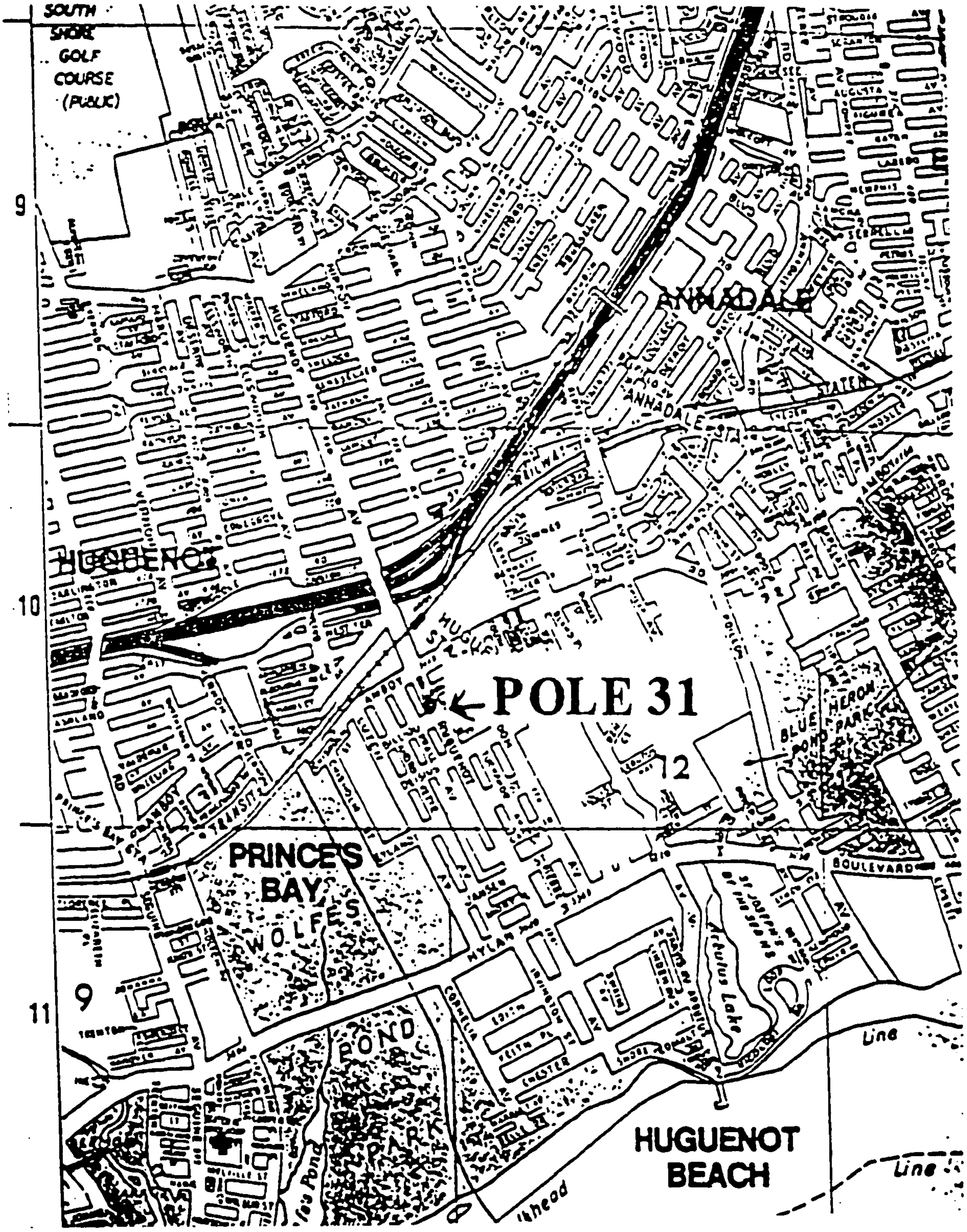


MAP 2. Utility Pole Soil Sampling location Cedar Grove, Staten Island, New York; Pole #33 Hagstrom Map #29



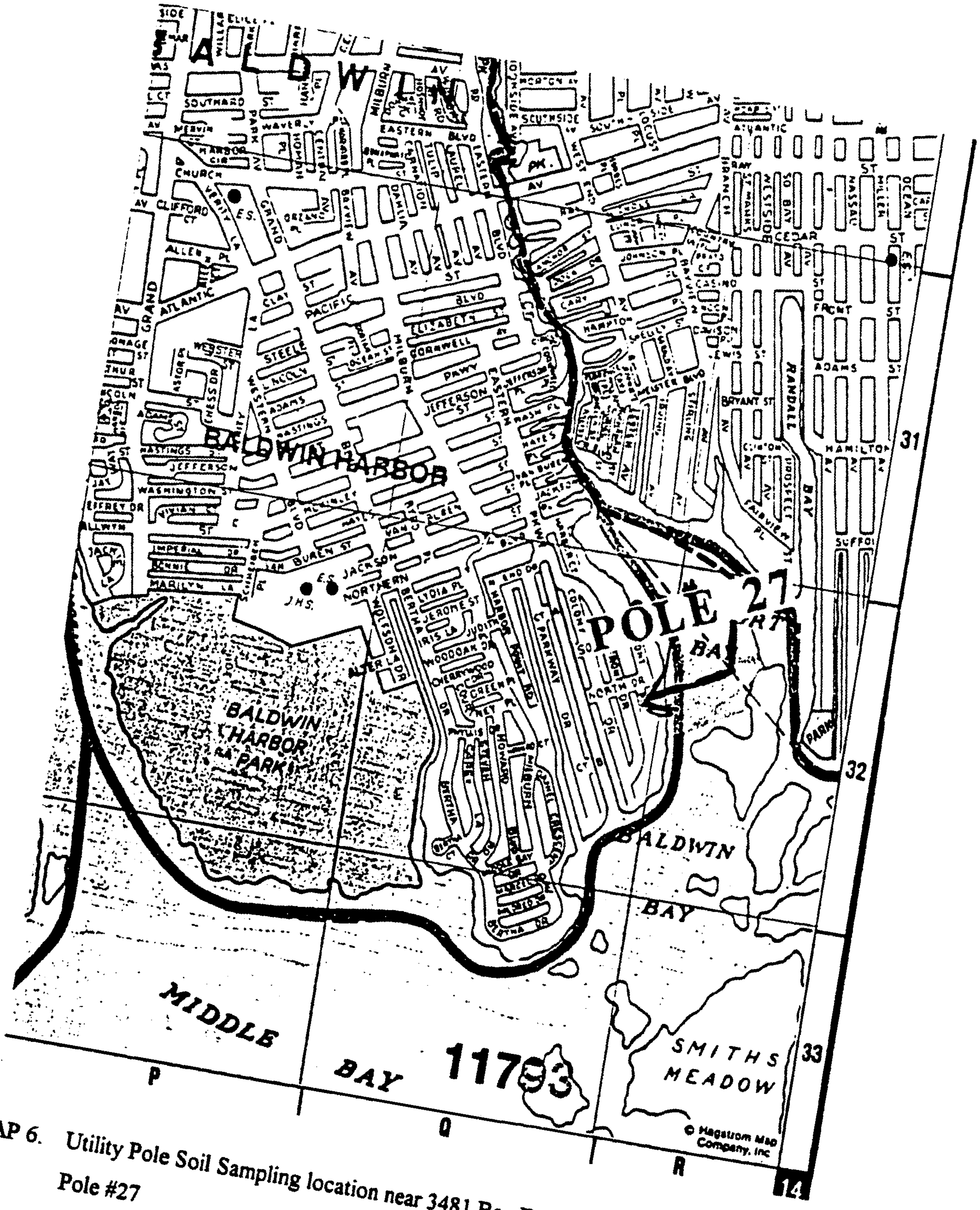
MAP 3. Utility Pole Soil Sampling location near Mount Loretto School, Hylan Blvd., S. I., N.Y.; Pole #25969

Hagstrom Map #30

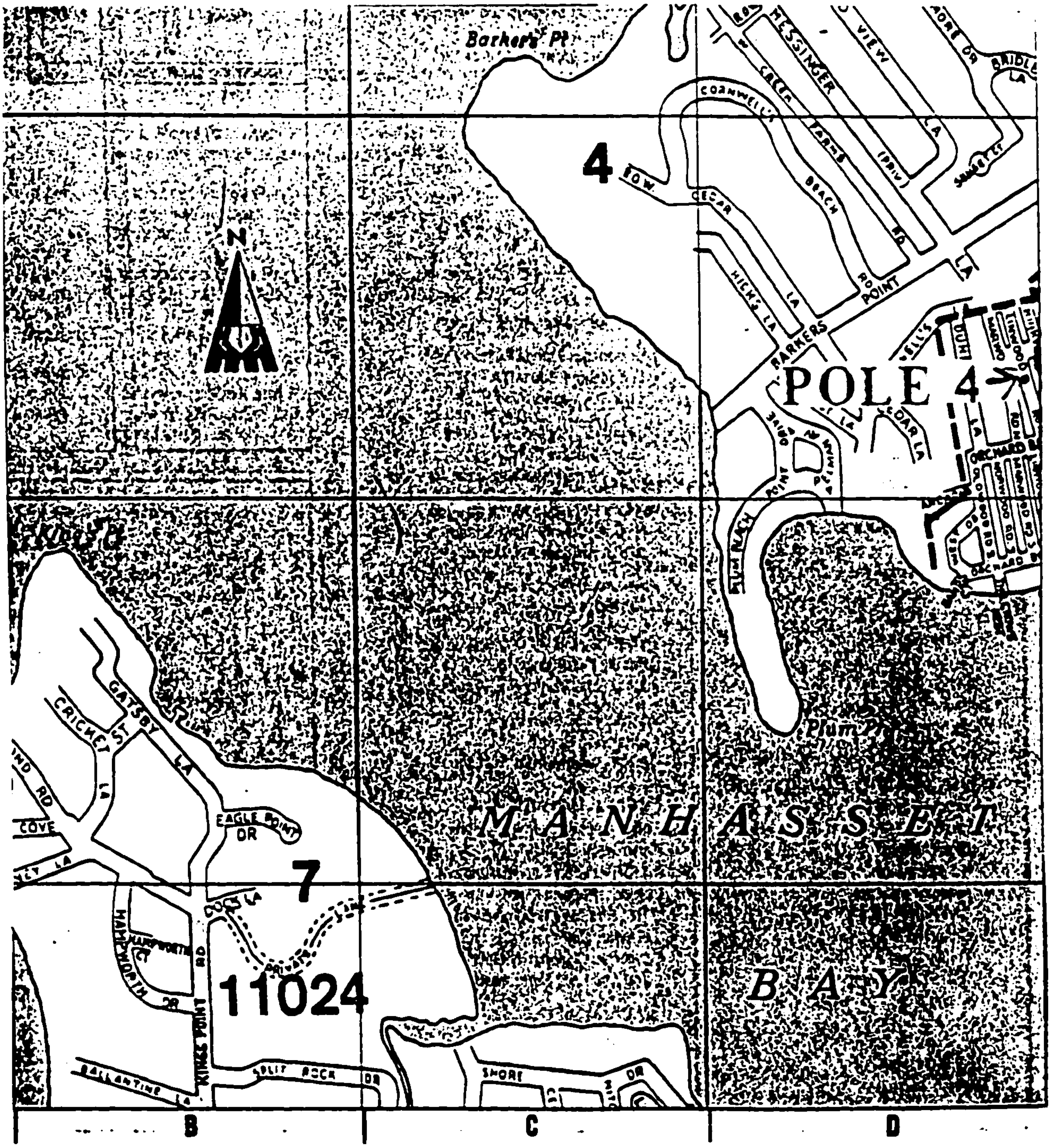


MAP 4. Utility Pole Soil Sampling location near 1099 Hugenot Ave. S.I., NY;
Pole #106
Hagstrom Map #31

MAP 5. Utility Pole Soil Sampling location near 3253 Parkway Drive, Baldwin, L.I.;
Pole #1
Hagstrom Map #14

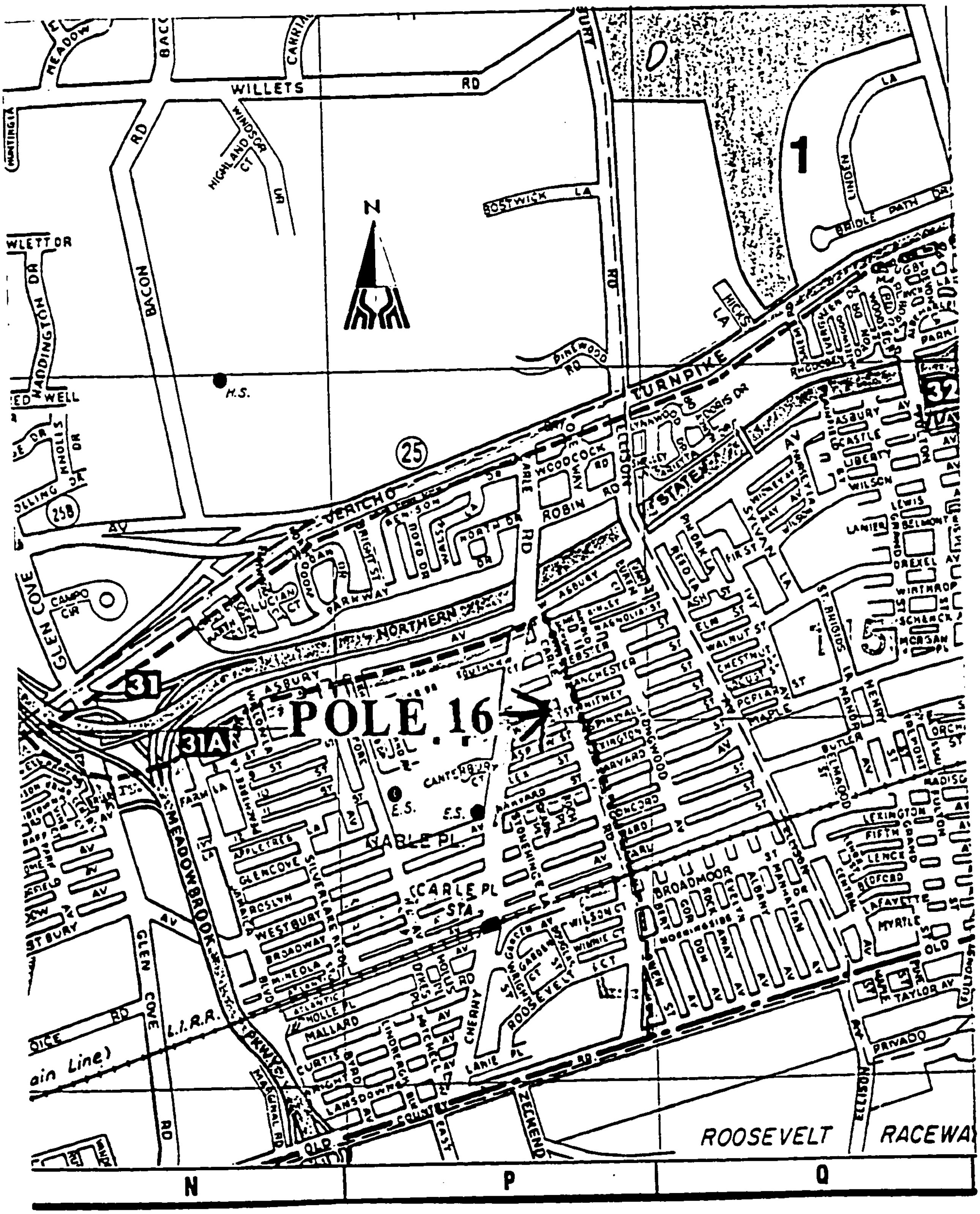


MAP 6. Utility Pole Soil Sampling location near 3481 Bay Front Drive, Baldwin, L I.;
Pole #27
Hagstrom Map #14



MAP 7. Utility Pole Soil Sampling location near 19 Linwood South Road, Port Washington, L.I.; Pole #4

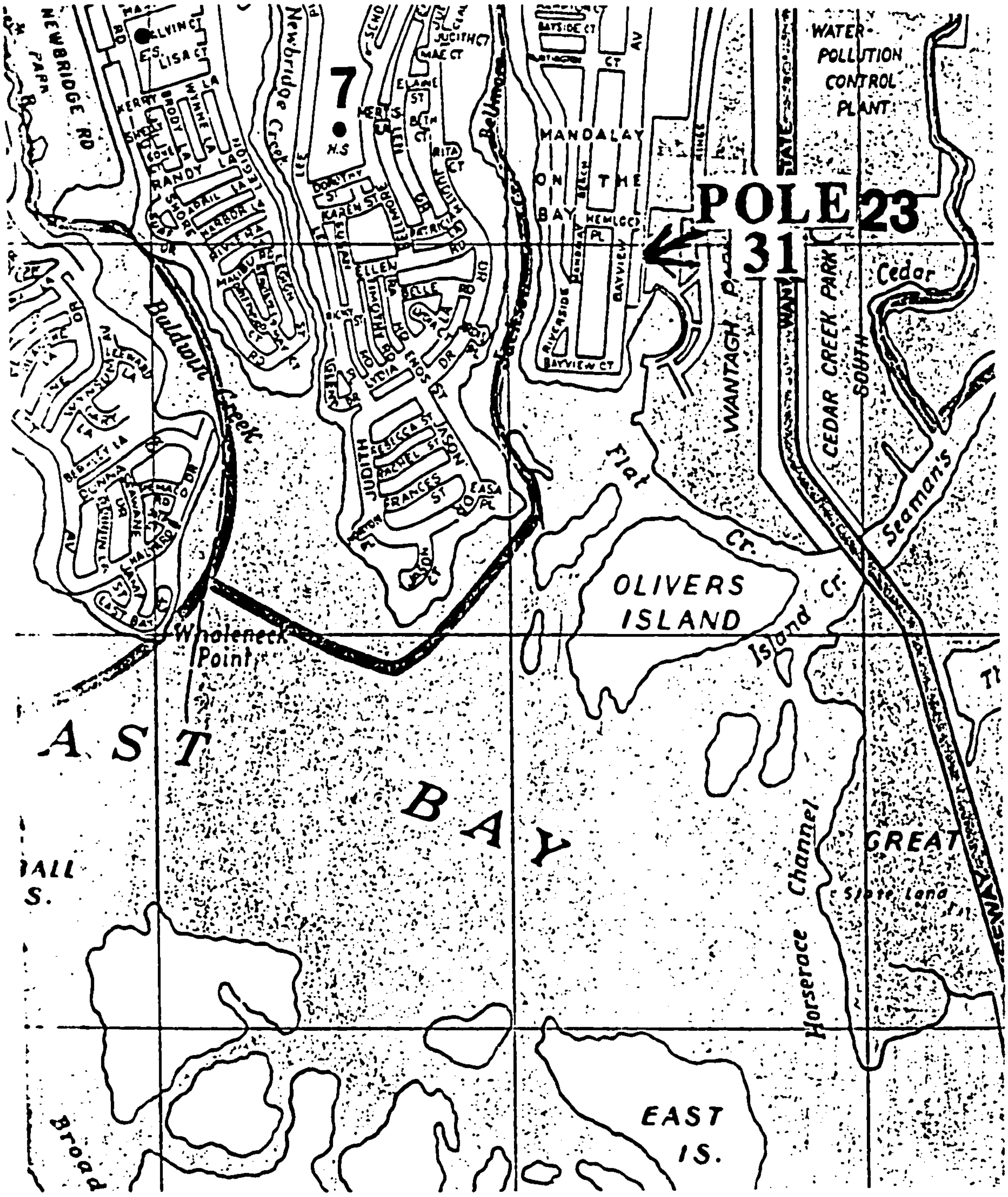
Hagstrom Map #1



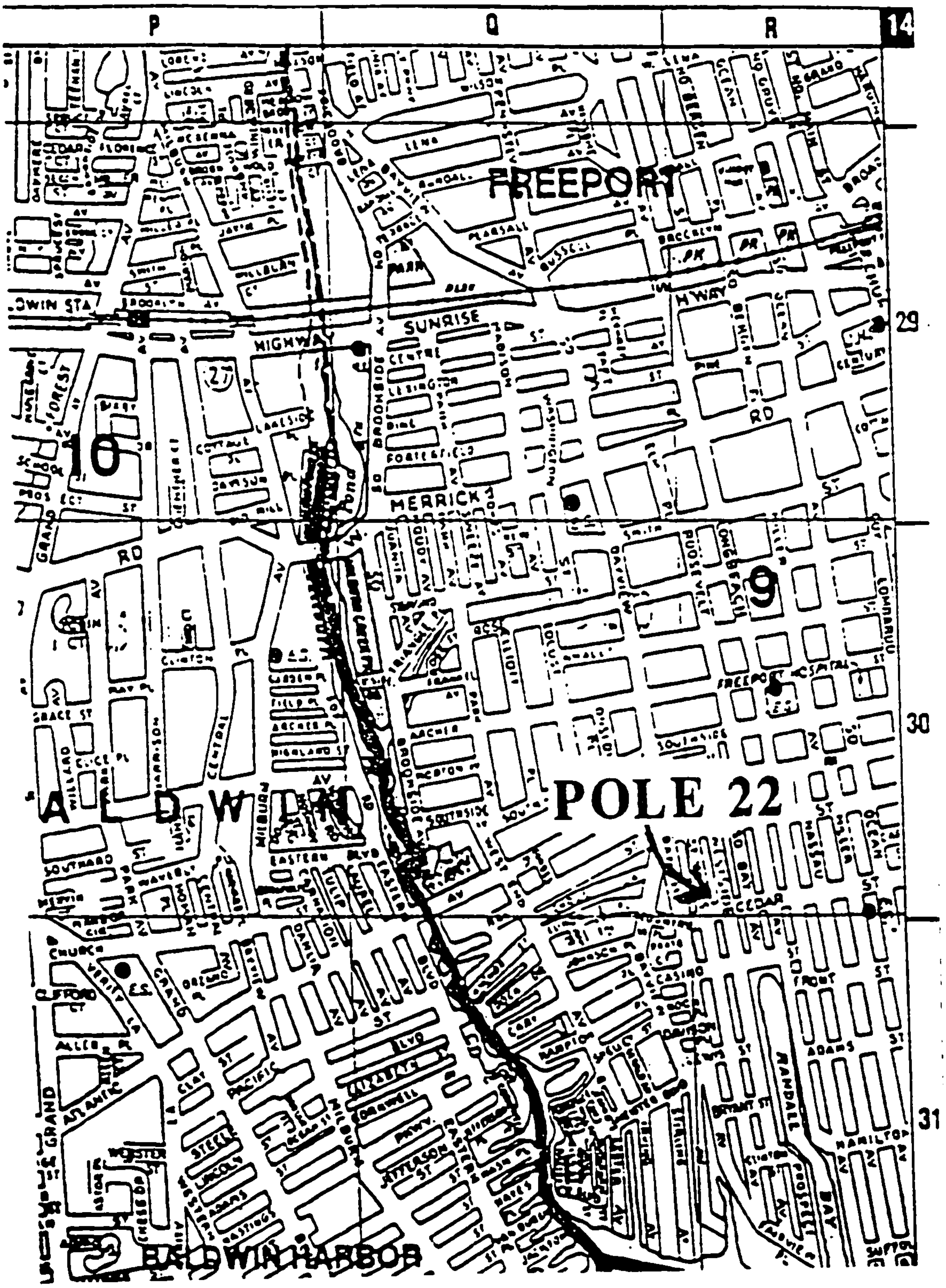
MAP 8. Utility Pole Soil Sampling location near 202 Carle Place, Carle Place, L.I.;

Pole #16

Hagstrom Map #11



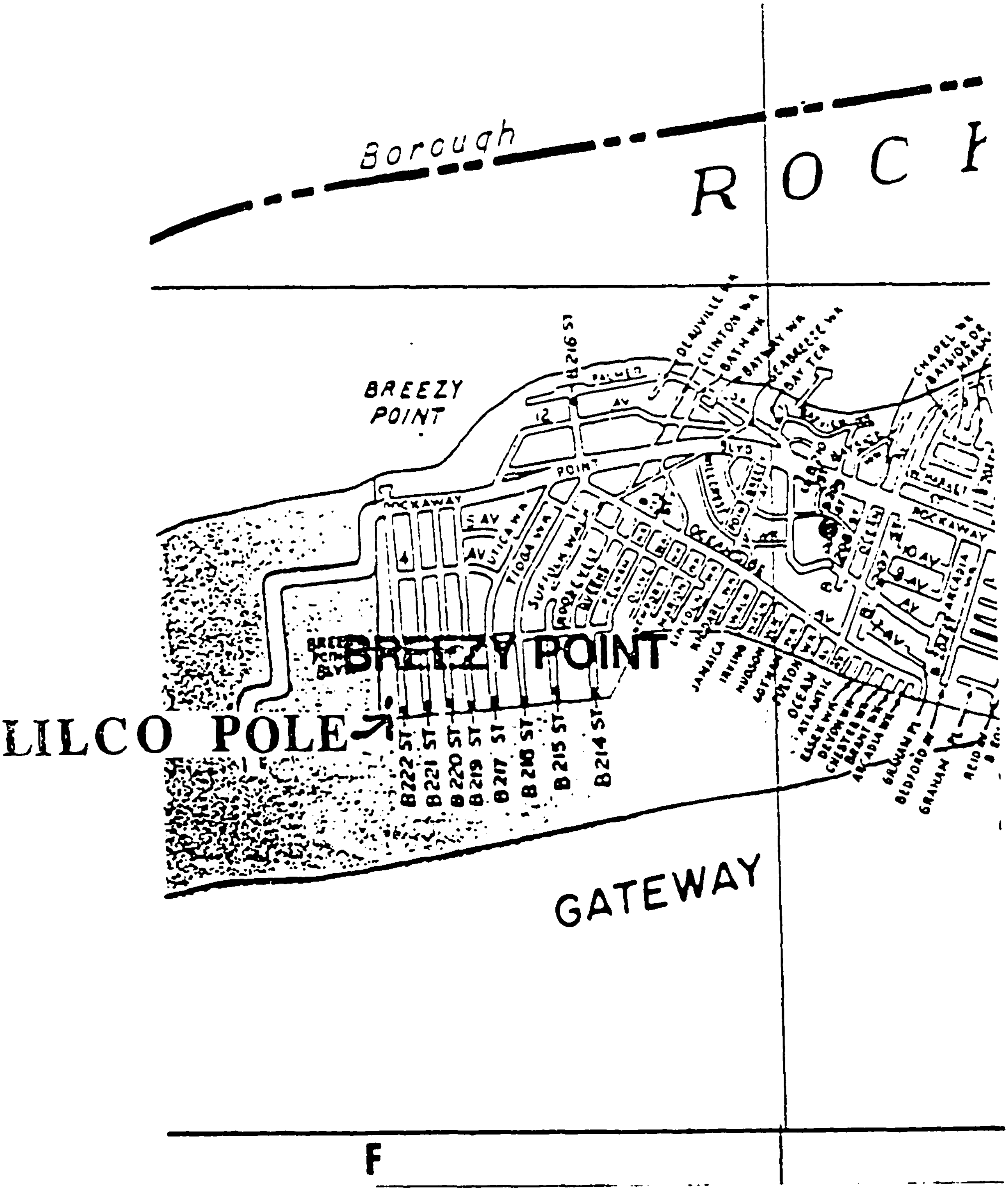
MAP 9. Utility Pole Soil Sampling location near 2630 Bayview Ave., Wantagh, L.I.;
Pole #31
Hagstrom Map #22



MAP 10. Utility Pole Soil Sampling location near 18 Cedar St. Freeport, Long Island.;

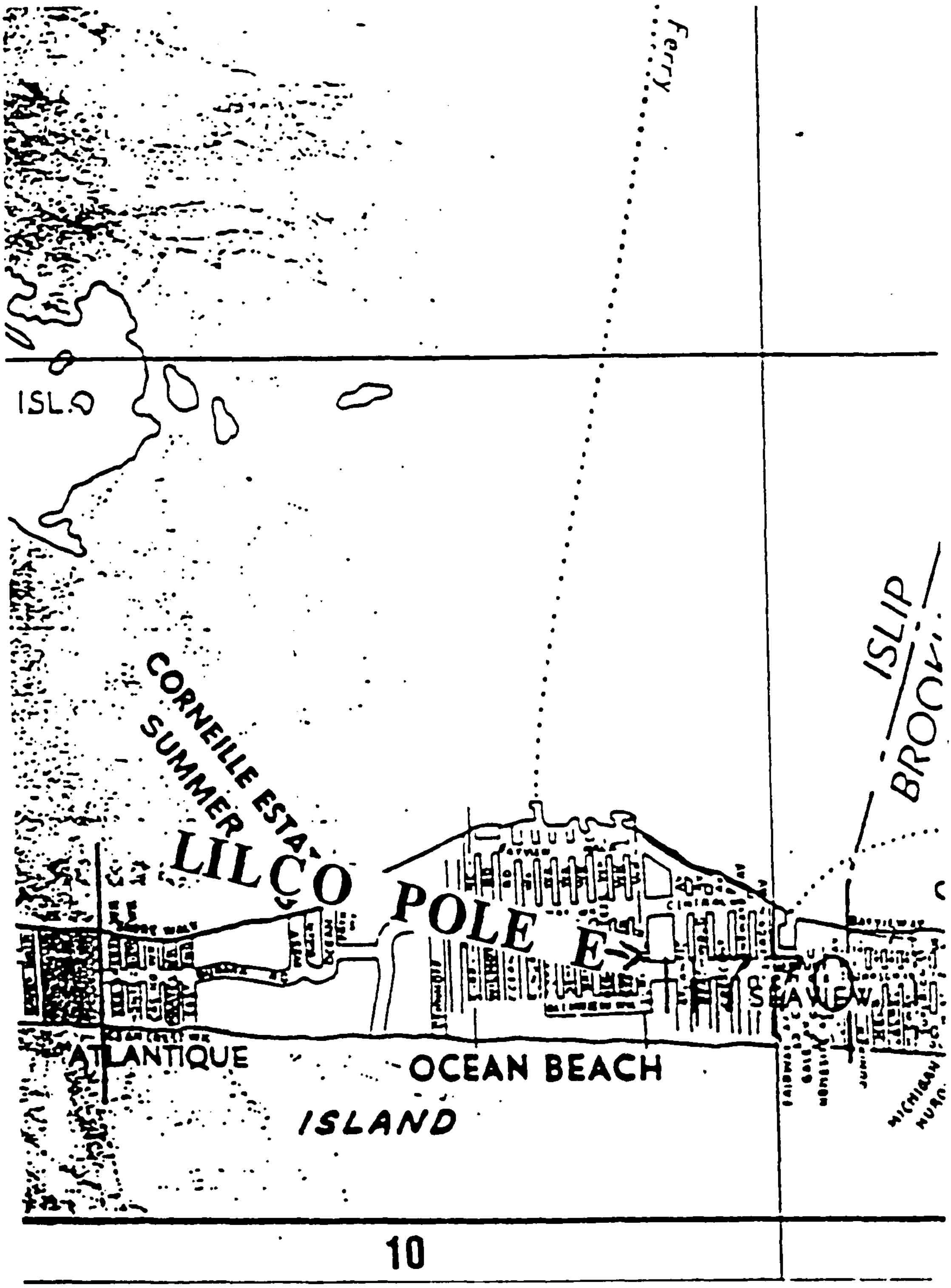
Pole #22

Hagstrom Map #14



MAP 11. Utility Pole Soil Sampling location near Western Most Cabana (SW Corner) Breezy Point, N.Y.; Pole: LILCO NO NUMBER

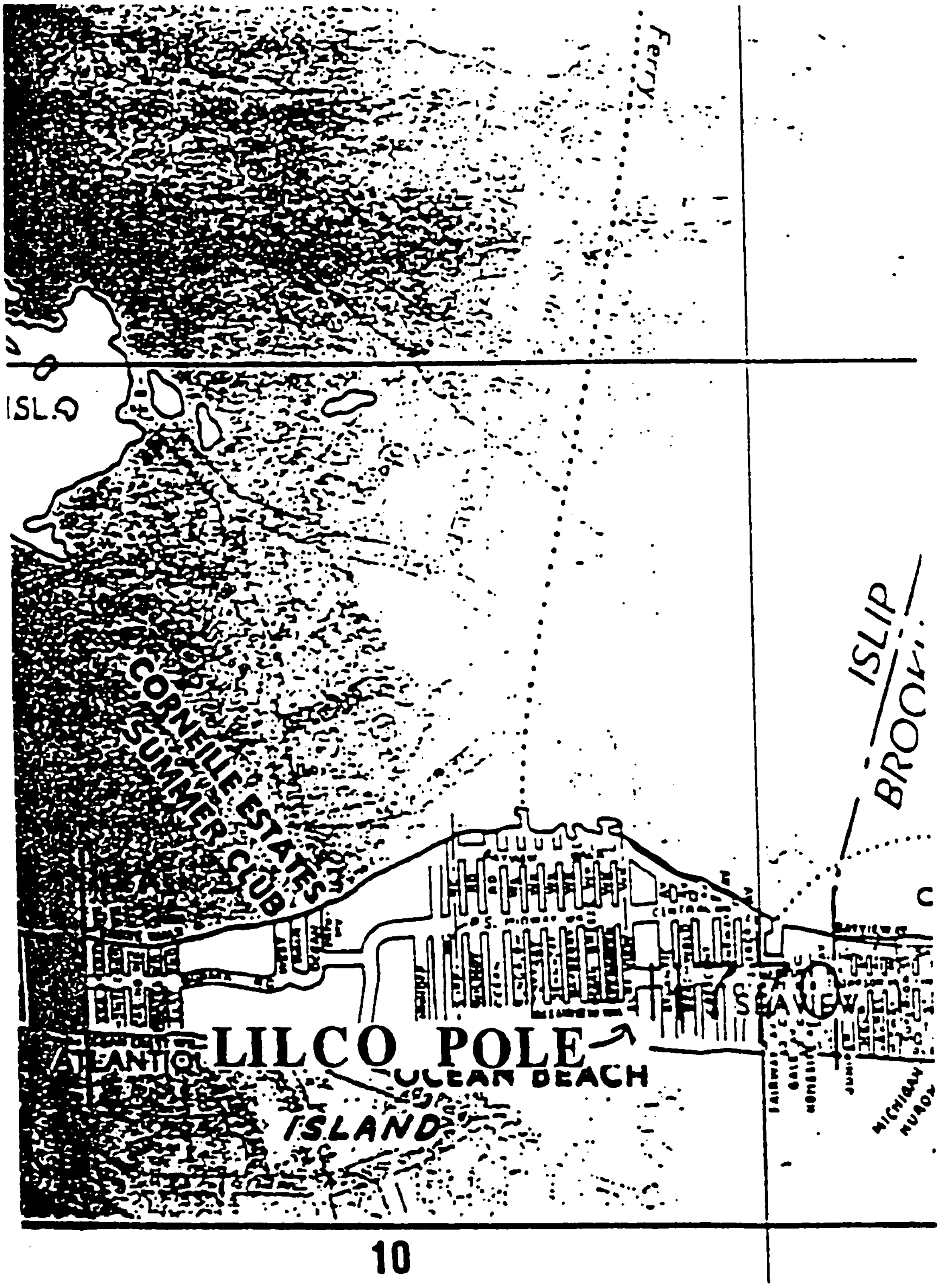
Hagstrom Map #17



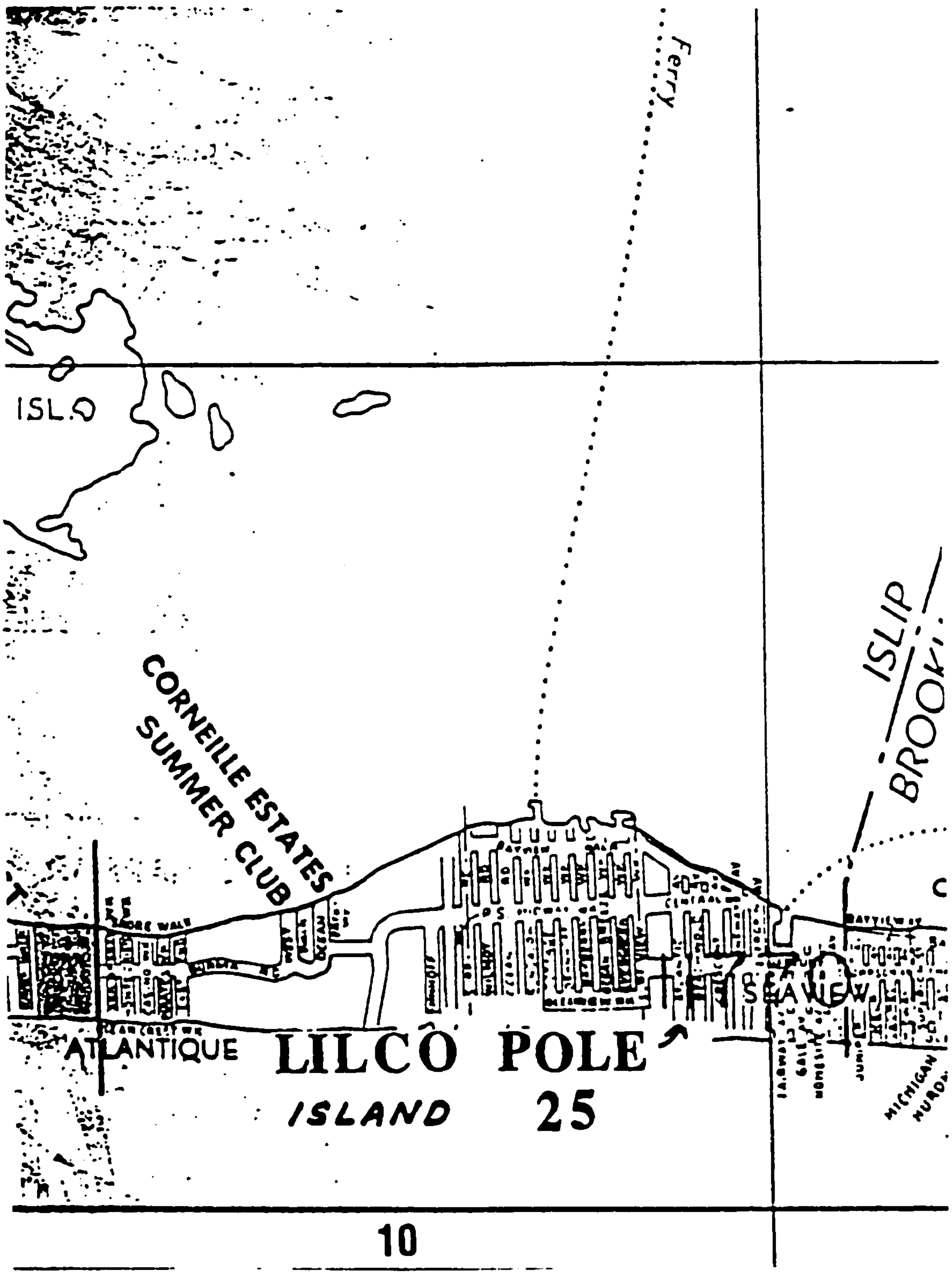
MAP 12. Utility Pole Soil Sampling location near 5 Surfview Walk, Ocean Beach, L.I.;

Pole: LILCO E

Hagstrom Map #10



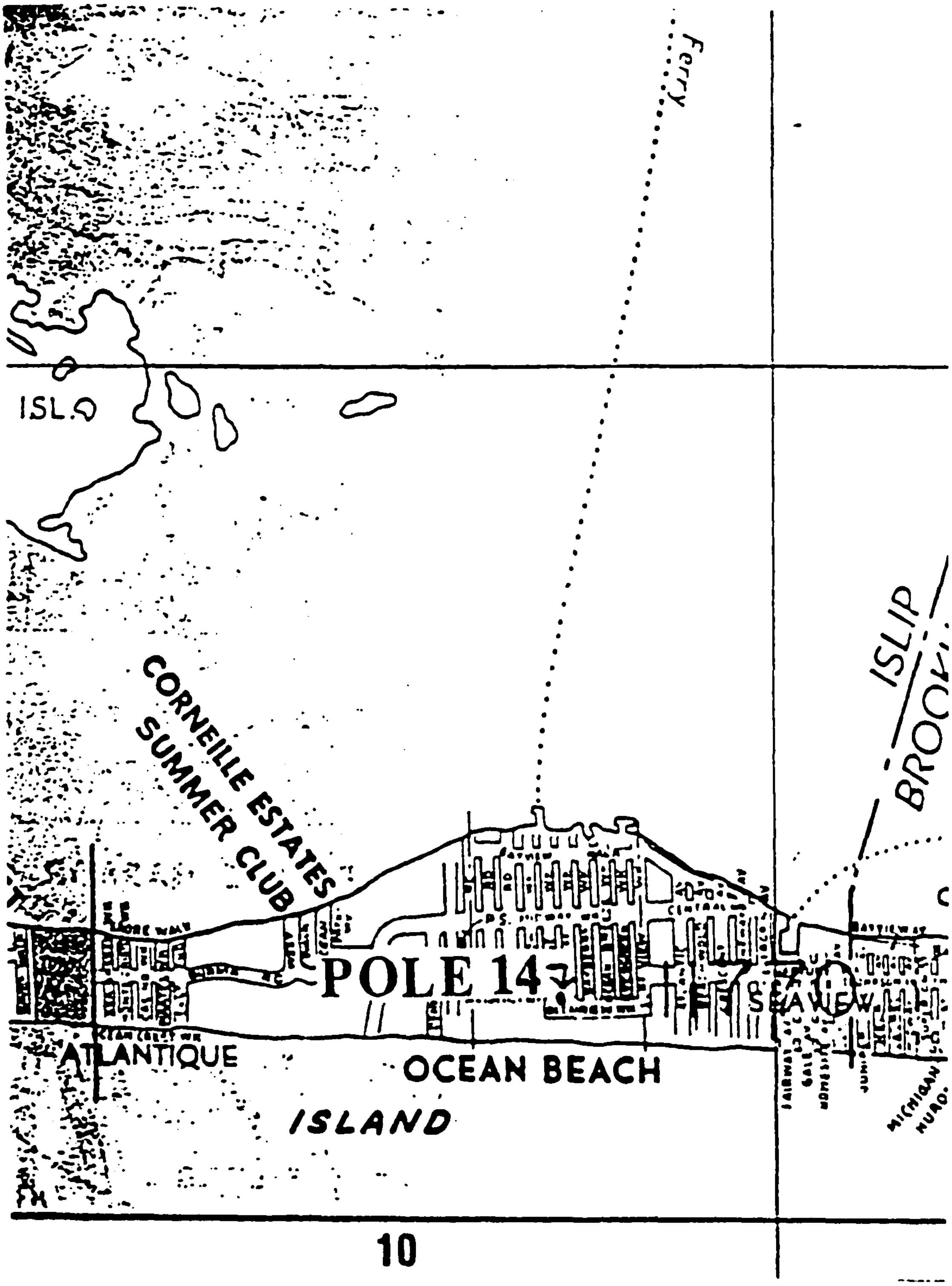
MAP 13. Utility Pole Soil Sampling location near corner of Oceanview & Surfview, Ocean Beach, L.I.; Pole: LILCO
Hagstrom Map #10



MAP 14. Utility Pole Soil Sampling location Atlantic Ave. (last pole), Ocean Beach, L.I.;

Pole: LILCO 25

Hagstrom Map #10



MAP 15. Pole location Oceanview Walk, Ocean Beach, L.I.;

Pole # 14

Hagstrom Map #10

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