Health Consultation

Public Comment Release

Analysis of Human Exposure Pathways for Pesticide Use
in Churchill County

FALLON LEUKEMIA PROJECT

FALLON, CHURCHILL COUNTY, NEVADA

JULY 18, 2003

Comment Period End Date: **August 25, 2003**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material. In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members.

The Public Comment Period is an opportunity for the general public to comment on Agency findings or proposed activities for this written consultation. The purposes of the comment period are to
1) provide the public, particularly the community associated with a site, the opportunity to comment on the public health findings, 2) evaluate whether the community health concerns have been adequately addressed, and 3) provide ATSDR with additional information. There will be a time period for written comments, which will run until August 25, 2003. Please address correspondence
to the Chief, Program Evaluation, Records, and Information Services Branch, Division of Health Assessment and Consultation, Agency for Toxic Substances and Disease Registry, Fallon Leukemia Project, 1600 Clifton Road, NE (E60), Atlanta, Georgia 30333.

The conclusions and recommendations presented in this health consultation are the result of site specific analyses and are not to be cited or quoted for other evaluations or health consultations.

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HEALTH CONSULTATION

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in Churchill County

FALLON LEUKEMIA PROJECT

FALLON, CHURCHILL COUNTY, NEVADA

Prepared by:

Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

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1.0 Background and statement of issues

In July 2000, the Nevada Department of Human Resources, Nevada State Health Division (NSHD), identified an increase in the incidence rate of acute lymphocytic leukemia (ALL) in children from Churchill County, Nevada. Most leukemia cases were in or near the city of Fallon, the largest population center in the county. Approximately 7,540 persons live in Fallon and about 24,000 persons live in the surrounding unincorporated parts of Churchill County that comprises a 5,000 square mile area (Bureau of the Census 2000).

In March 2001, NSHD requested that the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Center for Environmental Health (NCEH) evaluate environmental risk factors that might be linked to the childhood leukemia cluster in the Fallon, Churchill County, Nevada, area. NCEH designed and conducted a cross-sectional exposure assessment of selective contaminants using environmental (household) and biologic specimens for case-families and a reference population (Nevada Department of Human Resources 2001).

ATSDR and NCEH developed a Public Health Action Plan (PHAP) to evaluate environmental pathways for available sampling data, data gaps, and potential human exposures. These pathways include groundwater, air, soil, surface water, sediment, and biota (Agency for Toxic Substances and Disease Registry and Centers for Disease Control and Prevention 2001).

Among the community concerns was the potential association of agricultural pesticide usage with leukemia. This health consultation evaluates potential exposure to pesticides in Churchill County and any associations between pesticide exposures and childhood leukemia (primarily ALL). Exposures to other chemicals are evaluated in separate reports.

The term *pesticide* encompasses a broad group of chemicals used to prevent, control, or eliminate insects, weeds, fungus, and bacteria. Pesticides are categorized by the type of pest they are intended to control. Specific types of pesticides include insecticides, herbicides, and fungicides. Pesticide use is common throughout the United States and occurs both inside and outside the home. Exposure to pesticides is a complex process that may occur from multiple sources through several different pathways and routes (Figure 1). Sources refer to the location and purpose of pesticide use and include:

- Pesticides used to control insects inside buildings or to control insects and weeds in lawns and gardens. The buildings can be homes, stores, offices, or industrial facilities as well as public buildings. Lawns and gardens can be at these locations; parks, golf courses, and athletic fields can be included.
- Pesticides used in farming to control weeds and insects.
- Pesticides used to control mosquitoes.
- Pesticides used to control weeds in other public places such as roads or public lands.

All of these sources are common in Churchill County. Pesticides are used for agriculture, to control weeds along roadways and irrigation canals, and to control mosquitoes. In general, pesticides are also used in the home to control insects and in lawn and garden applications.

The U.S. Environmental Protection Agency (EPA) estimates that one billion pounds of pesticides (based on active ingredients and excluding disinfectants, sulfur, and oils) were used in the United States in 1997. About 77% of these pesticides were used for agriculture; 12% for industrial, commercial, and government purposes; and 11% for home and garden applications (U.S.EPA 2002b).

Pathways of exposure refer to the movement of the pesticides from the location of use to points where human exposure can occur. Pesticides can move through the environment during or after application indoors and outdoors, and can move through the air, water, or with the soil.

Pesticides can enter human bodies by three different routes of exposure: inhalation, skin contact, or ingestion. Inhalation exposure can occur during pesticide applications or when pesticides vaporize after application. Persons can come into direct skin contact with the pesticides during application or when a residual is left on surfaces that people contact. An example is kitchen surfaces where pesticides may settle after intentional spraying of areas like the baseboards or cracks and crevices. Persons also come into contact with pesticide residues on or in food items.

In a pesticide exposure study of children in Yuma, Arizona, researchers found that floor dust (presumably through ingestion) was the major medium (68.8%) by which young children were exposed to organophosphates, followed by solid food (18.8%), and beverages (10.4%) (O'Rourke and others 2003). In 2000, the Food and Drug Administration (FDA) sampled 1,035 food items from across the country and found that DDT was the most detected residue (21% of samples) with concentrations ranging from 0.0001 to 0.062 parts per million (ppm). Malathion and methyl-chlorpyrifos were respectively the second and third most commonly found residues (detected in approximately 18% of the food items analyzed) with residue concentrations ranging from 0.0003 to 0.078 ppm malathion and 0.0002 to 0.086 ppm methyl-chlorpyrifos (FDA 2002).

1.1 Quality Assurance and Quality Control

In preparing this report, ATSDR relied on laboratory results in the referenced documents. The agency assumes quality assurance and control measures for the data were followed with regard to chain of custody, laboratory procedures, and data reporting. The validity of analyses and conclusions drawn in this document is determined by the reliability of the information referenced in this report. A quality assurance project plan (QAPP) and quality assurance evaluation of the project was not available to ATSDR for the sampling data used. Hence, some uncertainty is introduced into our evaluation.

2.0 Discussion

ATSDR evaluated pesticide exposures in Churchill County using the following data:

- **Blood and urine samples** were analyzed for pesticides as part of the NCEH Cross-sectional Exposure Investigation (Centers for Disease Control and Prevention 2003). Study participants consisted of children with ALL and their families, as well as matched controls. A total of 14 case families and 51 matched comparison families (205 participants) were included in this study. Questionnaire data collected as part of this investigation were also used.

- **Indoor dust and residential yard soil samples** were analyzed for pesticides as part of the NCEH Cross-sectional Exposure Investigation. The samples, collected by the Nevada Department of Environmental Protection (NDEP), were collected at 80 current and former residences of the case and comparison families (Centers for Disease Control and Prevention, National Center for Environmental Health Division of Environmental Hazards and Health Effects Health Studies Branch 2003).

- **Pesticide use in Churchill County by governmental agencies and the agricultural industry** was identified through interviews with the Churchill County Mosquito and Weed Abatement District (Abatement District), Nevada Department of Agriculture, Truckee-Carson Irrigation District (TCID), and Frey-Spray, Inc. These interviews provided information on:
    - Agricultural pest and weed control
    - Irrigation canal weed control
    - Mosquito control
    - Noxious weed control
    - Roadside weed control

  Information on agricultural pest and weed control was also obtained from the state pesticide-use database of the Nevada Department of Agriculture containing information about commercially applied pesticides for agriculture. This database contained the date of use, county of use, land owner/applicator, product applied, application rate, number of acres, crop applied, and target pest.

2.1 Blood and urine data

NCEH reported blood and urine data as part of the NCEH Cross-sectional Exposure Investigation. This investigation analyzed blood and urine samples for 31 non-persistent* and 11 persistent pesticides or pesticide metabolites in 205 participants from 14 case families (families whose children had childhood leukemia) and 55 comparison families. NCEH compared the results to the *Second National Report on Human Exposure to Environmental Chemicals* (National Exposure Report) (Department of Health and Human Services 2003). Samples were collected from August through October 2001. This investigation also included use of questionnaires to collect data on the families' use of pesticides in the home, lawn, and garden.

Results show that five nonpersistent pesticides were found at levels significantly above National Exposure Report data (defined by detections above their respective 95th percentile National

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* Pesticides can be categorized on the basis of their half-life as non-persistent, degrading to half the original concentration in less than 30 days; moderately persistent, degrading to half the original concentration in 30 to 100 days; or persistent, taking longer than 100 days to degrade to half the original concentration. A "typical soil half-life" value is an approximation and may vary greatly because persistence is sensitive to variations in site, soil, and climate ((National Pesticide Information Center (NPIC) 1999).

Exposure Report reference value) in more than 10% of the Churchill County urine samples (Table 1). These pesticides included one organophosphate pesticide (chlorpyrifos), one organophosphate metabolite (diethylthiophosphate), two chlorinated phenol pesticides (2,4,5-trichlorophenol and 2,4,6-trichlorophenol), and a fungicide (o-phenylphenol). NCEH also identified one aromatic hydrocarbon pesticide at slightly higher than the reference value (2-naphthol).

Among 11 persistent pesticides analyzed, NCEH found only 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene (DDE) to be significantly above the National Exposure Report reference value. DDE is a breakdown product of 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane (DDT) and 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane (DDD), which were detected but were not elevated above the National Exposure Report mean value.

NCEH also found the geometric mean level of hexachlorobenzene in the Churchill County study population lower than national level of less than the detection limit. However, the National Exposure Report used an instrument detection limit (60.5 nanograms/gram [ng/g] of lipid) that was substantially higher than the mean level measured in Churchill County (10.5 ng/g of lipid). This means an accurate comparison between Churchill County and the National Report is not possible.

NCEH also used conditional logistic regression analyses to compare exposures between case and comparison families. For most pesticides, the number of participants with detectable levels of pesticides was insufficient to calculate odds ratios and p-values. However, for persistent and non-persistent pesticides and metabolites with sufficient numbers of participants to be analyzed, no statistically significant association could be found between pesticide exposure and the occurrence of leukemia.

These results provide information only about current exposures. If exposure to a chemical caused a child's cancer, that exposure would have to have occurred several years before the diagnosis. Past exposures are evaluated in Sections 2.3.1 and 2.4.

2.2 Indoor dust and residential yard soil samples

Indoor dust and residential yard soil samples were analyzed for pesticides as part of the NCEH Cross-Sectional Exposure Investigation. NDEP collected the samples from September through February 2001 at 80 current and former residences of the case and comparison families. Samples were analyzed for heavy metals, persistent and nonpersistent pesticides, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), and radionuclides. Only the pesticide results are discussed here. Residential surface soil was analyzed for 49 pesticides (Table 2) and indoor dust samples were analyzed for 45 pesticides. Four fewer pesticides were analyzed in the indoor dust samples (guthion, isophorone, Sevin, and methamidophos) because of analytic difficulties.

Overall, 26 pesticides were detected for residential surface soils. The most prevalent pesticides were cis- and trans-chlordane, DDE, diazinon, and heptachlor epoxide. With the exception of diazinon, all these are persistent pesticides and have been banned from use in the United States since 1988 or earlier (DDE is a breakdown product of DDT which was banned in 1972). The Nevada Department of Agricultural database indicates that these pesticides were not used commercially for agricultural purposes (Nevada Department of Agriculture 2002).

The most prevalent indoor dust pesticide found was N,N-diethyl-3-methylbenzamide (66 of 72 homes). Also know as DEET, this compound is the active ingredient in many insect-repellent products including those that are applied directly to human skin. The second most prevalent indoor dust pesticide found was diazinon (65 of 72 homes). Diazinon is used on home gardens and farms to control a wide variety of sucking and leaf eating insects. It is also used on rice, fruit trees, sugarcane, corn, tobacco, potatoes, and on horticultural plants. It is an ingredient in pest strips and is used to control fleas and ticks on pets (Pesticide Information Project 1996b). Additional information on indoor dust and yard soils is included in the ATSDR Pathway Assessment for Churchill County Surface Soils and Residential Indoor Dust (Agency for Toxic Substances and Disease Registry 2003b).

As with the blood and urine data, these results provide information about current exposures.

2.3 Pesticide use

Interviews with the Churchill County Mosquito and Weed Abatement District (Abatement District), Nevada Department of Agriculture, the Truckee-Carson Irrigation District (TCID) and Frey-Spray, Inc. provided information on pesticide use in the county with regards to

- Agricultural pest and weed control
- Irrigation canal weed-control measures
- Mosquito abatement
- Noxious weed control
- Roadside weed control

2.3.1 Agricultural pest and weed control

Agricultural commodities produced in Churchill County include forage, grains, vegetables, melons, alfalfa, dairy, livestock, and bedding plants. The most prevalent crop is alfalfa with approximately 31,000 acres in 1994. (Owens and others 1996). Alfalfa is a perennial plant and can be harvested up to three times per year in Churchill County. Herbicides are generally used early in the growing season before alfalfa begins growing. Afterwards, herbicide may be used throughout the growing season around the periphery of the fields. Insecticides will generally be used from end of May through August (Agency for Toxic Substances and Disease Registry 2001a; Agency for Toxic Substances and Disease Registry 2003c).The growing season ends in October. The pesticides used are described below.

In Nevada, 31.7% of all herbicides are applied through aerial application for the control of weeds on alfalfa, and about 66% of all pesticides for control of insects on alfalfa crops and for mosquito control are applied through aerial application (Nevada Cooperative Extension Service 1991). In Churchill County, insecticides were used on alfalfa and other crops on 83,117 acres in 1992 and 79,049 acres in 1997. Herbicides were used on crops and pasture on 60,958 acres in 1992 and 109,474 acres in 1997 (U.S.Department of Agriculture 1999).

The Nevada Department of Agriculture (NDOA) requires notification of commercially applied pesticides (both restricted- and general-use pesticides) in Churchill County and Nevada for agricultural and structural uses. NDOA maintains a database of commercially applied pesticides for agricultural use. The database begins in 1970 and includes dates of use, county of use, land owner/applicator, product applied, and the purpose of treatment or crop treated. Since 1994, the application rate and the number of acres treated have been added to the database. The most used chemicals (by number of acres applied) in Churchill County back to 1994 are shown in Tables 3 (herbicides), 4 (pesticides), and 5 (mosquito abatement). The fact that data on the number of acres applied were available beginning in 1994 in relation to the age of most children with leukemia in Churchill County make 1994 a reasonable date to begin evaluating historic exposures.

Herbicides were used on a variety of crops, including alfalfa, oats, corn, and barley (Table 3). Pursuit® was the most used herbicide followed by Oust and Velpar (Nevada Department of Agriculture 2002).

Insecticides (excluding mosquito control) were used mostly on alfalfa (Table 4). Paraspray (ethyl parathion) was the most used insecticide followed by dimethoate and Furadan (carbofuran) (Nevada Department of Agriculture 2002).

Information on mosquito abatement as performed by the Churchill County Mosquito & Weed Abatement District is described in Section 2.3.3. The NDOA database also shows that the Naval Air Station Fallon controlled for mosquitos using predominately malathion, pyrethrin, and methoprene (Table 5) (Nevada Department of Agriculture 2002).

2.3.2 Irrigation canal weed-control measures

The Truckee-Carson Irrigation District (TCID) uses prescribed burns and herbicides to control weeds in the irrigation supply system consisting of 200-to-400 miles of canals and laterals. The main canals and laterals are supplied with water every year from approximately March 15th to November 15th. However, the actual dates for the water season depend on the weather. The canals are empty of irrigation water during the rest of the year (Agency for Toxic Substances and Disease Registry 2001b).

TCID conducts prescribed burns to clean main canals and laterals of accumulated dead vegetation. Burning activities begin in early January or February, depending on the weather, and can continue until the beginning of the water season in mid-March. Of the nearly 350 miles of canals managed by TCID, fewer than 150 miles (or 175 acres) are typically subjected to burning each year (Agency for Toxic Substances and Disease Registry 2002b). Health implications of the burning activity are described in the ATSDR report Air Exposure Pathway Assessment for the Fallon Leukemia Cluster Investigation (Agency for Toxic Substances and Disease Registry 2003a).

Beginning in late May and continuing throughout the water season, herbicides are applied as spot treatments for noxious weeds along the banks and edges of canals and laterals. Spot spraying typically occurs once or twice during the growing season at any single location. A herbicide-and-water mixture is used for spot spraying. Herbicides in the mixture are Rodeo©, a non-selective herbicide, and Weedone® for broadleaf control. Rodeo© (active ingredient n-phosphono-methylglycine glyphosate isopropylamine salt) is also used in September, October, and November to clear vegetation (principally willows) in main canals and laterals (Agency for Toxic Substances and Disease Registry 2002a). The active ingredients in Weedone® are 2,4-dichlorophenoxyacetic acid (2,4-D) and butoxyethyl ester.

During the irrigation season from 1995 through 2001, TCID used Magnacide® H (EPA Reg. No. 10707-9; active ingredient acrolein; 92% by weight minimum) to control submerged aquatic weeds, specifically Sego pondweed. TCID typically treated a 10-mile section of canal by adding an approximate one-gallon mixture of Magnacide for each cubic foot per second of canal water to achieve an approximate concentration of 9 ppm in the water. This treated water was then delivered to a farmer's field but not used in any wetlands area because acrolein is toxic to wildlife. In 2001, TCID conducted four treatments on a total of 40 miles of ditch (Overvold 2001; Agency for Toxic Substances and Disease Registry 2002a)

Acrolein was not included in any available water-quality analyses for samples collected in Fallon. One historic sample was collected in 1993 in the Carson River upstream of Fallon and acrolein was not detected (detection limit of 20 micrograms per liter [µg/L]).

Acrolein is rather unstable in the environment with a relatively short half-life. The half-lif e in air is 15-20 hours, and the half-life in surface water is 1-6 days. A substantial amount of acrolein is removed from surface water and soil through volatilization.

Acrolein is rather unstable in the environment with a relatively short half-life. The half-life in air is 15-20 hours, and the half-life in surface water is 1-6 days. A substantial amount of acrolein is removed from surface water and soil through volatization. Exposure to air levels greater than 0.17 ppm can cause eye irritation. ATSDR found no definitive studies on the carcinogenic effects of acrolein in humans or animals. Exposure during swimming in the canals is most likely rare since it is very unlikely that people would be swimming during the very infrequent use of acrolein. In addition, the amount ingested would also be too small to cause health effects. Exposure via groundwater may exist but degradation rates are likely to be too rapid for this to occur.

2.3.3 Mosquito abatement

Since 1986, the Churchill County Mosquito and Weed Abatement District (the Abatement District) has conducted mosquito abatement efforts. From 1960 to 1986, other county departments treated sporadically for mosquitos. The Abatement District addresses mosquito control for all parts of the county except for property associated with the Fallon Naval Air Station (Agency for Toxic Substances and Disease Registry 2001b).

The mosquito season runs from February or March until October. During the spring season (from April or May until July 4th), mosquitoes are of particular concern in the area northwest of Fallon. They also begin emerging in other areas as well. Because of lower costs and greater ease of application, the preferred control agent involves ground treatment with liquid, pucks, or granules containing larvicide (Vectobac or methoprene). However, once flying mosquitoes emerge (April, May, and June), trucks and airplanes are used to apply dibrom, and trucks are used to apply Pyrenone™ (active ingredients are pyrethrins) (Figure 2). Scourge™ (active ingredient resmethrin) was used instead of Pyrenone™ before 1994 (Churchill County Mosquito and Weed Abatement District 2001a; Churchill County Mosquito and Weed Abatement District 2003).

Use of the Nevada Department of Agriculture (NDOA) database of pesticides in Churchill County includes entries for mosquito abatement activities. These pesticides are listed in Table 5 and described in Section 2.3.1.

2.3.4 Noxious weed control

The Nevada Department of Agriculture, through the Nevada Weed Action Committee, coordinates and facilitates local, county, state, and federal agency programs and projects for the control and management of noxious and invasive weeds in Nevada. Under Nevada law, owners or occupiers of land in Nevada have the obligation and responsibility to control all weeds designated as noxious by the Nevada Department of Agriculture (Nevada Department of Agriculture 2001).

Noxious weeds can be controlled by various techniques including pesticides, which can be implemented by government agencies and individuals. ATSDR learned through interviews about the Tall Whitetop Weed Control Project, which was implemented in Churchill County by the Abatement District. From 1999 through 2001, the Abatement District applied the herbicide Weedar 64 (active ingredient is 2,4-D) along the Carson River to control tall whitetop. Spraying was done from the water's edge to the adjacent roadway or up the bank if no road was present -- a distance of 20 to 40 feet. (Agency for Toxic Substances and Disease Registry 2001b).

2.3.5 Roadside weed control

State and local agencies provide roadside weed control in Churchill County to prevent pavement destruction, maintain visibility, and control noxious weeds. The Nevada Department of Transportation (NDOT) conducts routine pre-emergent herbicide application along state roads (Agency for Toxic Substances and Disease Registry 2001b). The Churchill County Mosquito and Weed Abatement District (Abatement District) applies herbicide treatments along county roadways and some state roads. As a supplemental treatment method, the Abatement District also conducts a limited amount of prescribed burning to remove roadside weeds (Churchill County Mosquito and Weed Abatement District 2001b).

Since 1998, the Abatement District has applied herbicides along certain county roads (Figure 2). These treatment applications occur in two parallel zones. In the first zone, located from the edge of the roadway out a distance of 3-4 feet, the Abatement District uses a full-spectrum herbicide (Arsenal, active ingredient imazapyr-isopropylammonium) to kill all plants, including grass. In the second zone, located from the edge of the first zone to private property lines, the Abatement District uses broad leaf control agents (Weedone LV6 with a dilute mixture of Glyphos; active ingredients 2,4-D and glyphosate, respectively). The Abatement District also conducts spot spraying along state roads for noxious weeds such as puncture vine using the Weedone/Glyphos mixture (Agency for Toxic Substances and Disease Registry 2001b). In the spring, the Abatement District uses Pendulum (active ingredient pendimethalin) as a pre-emergent herbicide.

2.3.6 Inert ingredients

Although inert ingredients can be toxic, ATSDR did not evaluate them in this report because most data on pesticide use in Churchill County did not include manufacturer names or formulations. Pesticide products contain both "active" and "inert" ingredients. Since 1947, the terms "active ingredient" and "inert ingredient" (also called “other ingredients”) have been defined by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). An active ingredient prevents, destroys, repels, or mitigates a pest, or is a plant regulator, defoliant, desiccant or nitrogen stabilizer. By law, the active ingredient must be identified by name on the label together with its percentage by weight. For this health consultation, ATSDR reviewed only “active” ingredients.

An inert ingredient is simply any ingredient in the product that is not intended to affect a target pest. For example, in some products isopropyl alcohol may be an active ingredient and antimicrobial pesticide; however, in other products, it is used as a solvent and may be considered an inert ingredient. Unless an inert ingredient is determined to be highly toxic, identification by name or percentage on the label is not required, but the total percentage of such ingredients must be declared. Neither FIFRA nor the regulations define the term "inert ingredient" on the basis of toxicity, hazard or risk to humans, non-target species, or the environment. Since 1987, EPA has had policies to reduce the potential for adverse effects from the use of pesticide products containing toxic inert ingredients (52 FR 13305) and has a program to evaluate their toxicity.

2.4 Exposure reconstruction

The use of biologic and environmental sampling data is one method of evaluating pesticide exposures. However, the available sampling data may not allow for an adequate assessment of exposure during the etiologic period for disease (Brody JG and others 2002). Of particular concern are the exposures of pregnant women and their fetuses because little is known about the potential developmental hazards of such exposures (Berkowitz and others 2003) (Perera and others 1999).

Because children in the Churchill County leukemia cluster are now three years of age or older, environmental exposures before 1999 or 2000 may be important. To identify past exposures, ATSDR conducted interviews and reviewed the agricultural database. These sources provide information about the types of products used and in some cases the locations and amounts. ATSDR then investigated whether past exposures could be deduced by using this information together with a mathematical model that predicts the movement of pesticides in the environment. The possible outcome from this effort would be to predict possible historic air and soil pesticide concentrations.

Because many different pesticides and herbicides as well as different methods of applications were used, ATSDR initially approached this work by focusing on a reasonable worst-case range of exposures. ATSDR selected a range of model inputs that were expected to encompass the different operating and meteorologic conditions and to produce a range of results including maximum concentrations.

ATSDR selected aerial rather than ground application as the source of pesticide exposure. Drift of airborne pesticides from the target site at the time of aerial spray application (spray drift) is a source of concern because this technique represents the highest potential for off-target loss (Bird and others 1996) and exposure of residential populations bordering or within the application area. Willis and McDowell (1987) in (Bird and others 1996) report that 20% or more of the sprayed pesticide may move off the field site through the air during the initial pesticide application. In Nevada, 31.7% of herbicides are applied through aerial application for the control of weeds on alfalafa and about 66% of pesticides for control of insects on alfalfa crops and for mosquito control (Nevada Cooperative Extension Service 1991).

Once spray drift occurs, direct and indirect exposure can occur. Direct exposures can occur through inhalation. The spray drift will also land on downwind surfaces (deposition). From deposition, indirect exposures may occur from ingestion via food, drinking water, or contact with soil or dust (Brody JG and others 2002). For this evaluation, ATSDR reviewed direct inhalation of airborne pesticides and ingestion of soils contaminated from pesticide deposition because they have the potential for the greatest exposures.

This exposure reconstruction consisted of three parts:

- Review of pesticide use.
- Modeling of pesticide aerial spraying from a single spray event of a hypothetical 40-acre field to calculate potential air and soil concentrations.
- Assessment of the modeled concentrations for potential health effects.

2.4.1 Review of pesticide use

From the review of pesticide use, ATSDR selected two pesticides/herbicides to represent the range of products used. Although ATSDR has estimates of the acres on which pesticides were applied, the exact locations are not known. ATSDR estimated the locations three different ways.

The first method used Churchill County property parcel data and land-use information. The parcel data included land-use categories of agricultural, residential, commercial, and industrial (Figure 3). Figure 4 is a close-up of the city of Fallon with these categories. One could assume that pesticides are applied to all agricultural fields. In many cases, agricultural fields (and possible pesticide use) and residential areas are located near each other.

The second method was to link the property owners listed in Churchill County property parcel data with those listed in the Department of Agricultural pesticide-use database. The results are shown in Figure 5. A limitation of this method is that many people listed in the agricultural pesticide-use database were not found in the property parcel map. In addition, a person may own several properties, and it may not be known to which property the pesticide was applied. The figure shows that several agricultural plots are close to residential areas.

The third method was through interviews. Because we were interested predominately in aerial applications of pesticides, we interviewed the main crop-dusting company and the Churchill County Mosquito & Weed Abatement District because they would be involved with most of the pesticides applied for agricultural use or weed and mosquito control (Figure 2). This figure also shows that areas in which pesticides were used are close to residential areas.

Because of the complexity and uncertainty of the locations, ATSDR used a hypothetical 40-acre field for analysis.

2.4.2. Modeling of pesticide aerial spraying from a single spray event of a hypothetical 40-acre field to calculate potential air and soil concentrations.

ATSDR used the AgDRIFT® Aerial Spray Drift Model to predict the downwind air and soil concentrations from the unintended drift of pesticides applied aerially (Bird and others 2002; Esterly 2002). The model scenario was the aerial spraying of a hypothetical 40-acre field by a typical crop dusting using standard boom and nozzle arrangements. Guidance and implementation on the modeling was conducted by David Esterly of Environmental Focus, Inc. and supplemental support was provided by Leonard Young of Eastern Research Group. Details of the modeling are provided in Appendix A.

The AgDRIFT® model inputs are grouped into four categories: meteorologic, equipment setup, application parameters, and product physical properties. The modeling focused on input parameters that have been shown to have the greatest effects on pesticide drift. These key inputs are selected using a “worst-case" scenario concept and are set to reflect upper limits of allowable or reasonable operating conditions. The remaining parameters that have less effect on drift are based on regional best-management practices, or model defaults.

Results of the AgDRIFT model are primarily a function of the distribution of liquid droplet size ejected from the spray nozzles, water content of the spray mixture, ambient temperature and humidity, and wind speed. Results are independent of the chemistry of the pesticide or herbicide, but a function of initial concentration of non-volatile components of the spray tank mixture (U.S.EPA 1997). Pesticides and herbicides are generally non-volatile. To model each pesticide and herbicide used in Churchill County would be a lengthy task that would not provide specific information. Therefore, ATSDR modeled two compounds to represent the range of pesticides and herbicides reported. The herbicide and insecticide products used in the model were represented by Gramoxone® Extra (paraquat dichloride), a relatively dilute application, and Parathion 8 EC (ethyl parathion), a relatively concentrated application. Drift was predicted using the AgDRIFT® 2.0.05 model employing site-specific inputs. The set of regional conditions available in the model was modified to reflect the range of meteorologic conditions one would expect in the Fallon, Nevada, area during the normal application season (Esterly, David M. 2002).

The model was run using 12 different scenarios, 2 different chemicals, 3 drop-size distributions (fine, fine-medium, and medium), and 2 different wind speeds (5 and 10 miles per hour) to determine the sensitivity of the model and to ensure a "worst-case" scenario (i.e., greater exposure). The 12 different scenarios were:

Gramoxone-5 mph wind
- Fine drop-size distribution
- Fine-medium drop-size distribution
- Medium drop-size distribution

Gramoxone-10 mph wind
- Fine drop-size distribution
- Fine-medium drop-size distribution
- Medium drop-size distribution

Parathion 8 EC-5 mph wind
- Fine drop-size distribution
- Fine-medium drop-size distribution
- Medium drop-size distribution

Parathion 8 EC-10 mph wind
- Fine drop-size distribution
- Fine-medium drop-size distribution
- Medium drop-size distribution

Modeling Results

Model results are air concentrations or deposition amounts downwind for each of the 12 scenarios. For example, for one scenario, the air concentrations in micrograms per cubic meter (µg/m$^{3)}$ are:

Maximum air concentrations (µg/m^3) of Gramoxone Extra			
Distance downwind (ft)*	Drop-size distribution class		
	Fine	Fine - Medium	Medium
500	22.583	8.308	5.736
1,500	7.840	2.732	1.781
2,500	4.491	1.589	0.990
5,000**	2.297	0.788	0.470
10,000**	1.151	0.387	0.221

µg/m^3 micrograms per cubic meter
* 5 miles per hour wind speed
**Downwind distances of 5,000 and 10,000 feet are extrapolated values.

The particle diameters range from 76 microns to about 518 microns (see Table 2 in appendix A for details.)

ATSDR combined results of the 12 scenarios and selected maximum, average, and minimum concentrations to represent the potential range of air concentrations. The air concentrations are plotted in Figure 6. From this figure, a range of possible air concentrations for any pesticide can be determined as a function of distance from the sprayed field.

A similar process was completed for deposition. An example of the AgDrift deposition results is shown below.

Ground deposition (mg/cm^2) of Gramoxone Extra* -			
Distance downwind (ft)	Drop-size distribution class		
	Fine	Fine - Medium	Medium
500	3.35E-04	1.37E-04	9.85E-05
1500	8.54E-05	3.28E-05	2.18E-05
2500	3.45E-06	1.11E-05	7.96E-06
5000	4.02E-06	1.07E-06	8.21E-07
10000	1.65E-07	6.86E-08	4.96E-08

mg/cm^2 milligrams per square centimeter
*5 miles per hours wind speed

Instead of a concentration in µg/m^3, the model results are an amount of pesticide deposited in milligrams per square centimeter (mg/cm^2). Because the exposure evaluation requires a concentration per unit mass of soils, ATSDR converted the deposited amount per area to a concentration per volume of soil by assuming that the deposited pesticide mixes 1 cm deep with soil, with an average soil density of 1.56 grams/cm^3. The soil density is based on data for Churchill County from the U.S. Natural Resources Conservation Service (2002).

As with air concentrations, ATSDR combined results of the 12 deposition scenarios and selected maximum, average, and minimum concentrations to represent the potential range of soil concentrations. The soil concentrations are plotted in Figure 7. From this figure, a range of possible soil concentrations for any pesticide can be determined as a function of distance from the hypothetically sprayed field. For example, air and soil concentration at two downwind distances -- adjacent to the field (about 5 to 6 feet) and ¼ mile away -- are shown below with a range to represent differences from the different pesticide or herbicide dilutions, wind speeds, and droplet size distributions.

Concentration ranges of pesticides or herbicides in air and soil at two distances from sprayed field, pesticide exposure study, Churchill County, NV, 2001

Distance downwind from field	Concentration range (average)	
	Air (µg/m^3)	Soil (mg/kg)
5.5 (10 meters)	32 to 819 (244)	0.7 to 3.7 (1.8)
¼ mile (about 2,400 meters)	2.8 to 83 (24)	0.079 to 0.69 (0.29)

µg/m^3 micrograms per cubic meter
mg/kg milligrams per kilogram

Air concentrations represent the maximum 1-hour-average air concentrations that would occur at specified distances downwind after a spray event. Model assumptions indicate that air concentrations would return to background levels after one hour. Soil concentrations represent total pesticide deposited from spray drift. Soil concentrations would decrease over time through either natural degradation or movement if the soil is disturbed (e.g., by wind, plowing, or rain).

2.4.3. Assessment of modeled concentrations for potential health effects.

ATSDR's approach to evaluating potential health effects from pesticides has two components. The first involves a screening process that may indicate the need for further analysis. The second involves a weight-of-evidence approach that integrates estimates of likely exposure with information about the toxicology and epidemiology of the substances of interest.

Screening is a process of comparing appropriate environmental concentrations and doses to ATSDR or EPA comparison values. These comparison values include

- ATSDR Environmental Media Evaluation Guides (EMEGs).
- Reference Media Evaluation Guides (RMEGs) which are derived from EPA reference doses.
- Minimum Risk Levels (MRLs) based on dose in units of mg/kg/day.
- Cancer Risk Evaluation Guidelines (CREGs).
- EPA Reference Concentrations (RfCs).
- EPA Reference Doses (RfDs).
- Risk-Based Concentrations (RBCs) developed by EPA.

These health-based comparison values (CVs) are considered "safe" media-specific concentrations, using default conditions of exposure. Default conditions are typically based on estimates of exposure in most (i.e., the 90^{th} percentile or more) of the general population. Comparison values are not thresholds of toxicity. Rather, they are levels at which ATSDR believes even long-term exposure of sensitive populations would not result in an increased likelihood of developing adverse health effects. When a level is above a comparison value, it does not mean that health effects could be expected – it does, however, represent a point at which further evaluation is warranted.

Comparison values are based on a variety of toxicologic and exposure assumptions that might or might not reflect actual exposure conditions and the risk of adverse health outcomes. If warranted, ATSDR evaluates several parameters, depending on the contaminant and site-specific exposure conditions. Such parameters can include biologic plausibility, mechanisms of action, cumulative interactions, health outcome data, strength of epidemiologic and animal studies, and toxicologic and pharmacologic characteristics. These evaluations also consider noncarcinogenic health effects (e.g., heart disease) and carcinogenic health effects (e.g., leukemia). In general, a common non-carcinogenic health effect of most organophosphate pesticides include transient decreases in cholinesterase levels that affect transmission of information between nerves cells. This effect sometimes results in temporary neurologic disorders.

For this evaluation, ATSDR used the air and soil concentration at ¼ mile downwind from the hypothetical agricultural field as a general population estimate of exposure. Using the location adjacent to a field (5 to 6 feet) is not a realistic scenario because, at this distance, a person would practically be standing under the plane during the spraying, which is not realistic. ATSDR focused on the top 24 pesticides that were used (Table 6).

Exposures to pesticides in soil and in air were reviewed differently. Exposure to pesticides in soils was considered chronic exposure (exposures with durations of 1 year or more) because soils are relatively immobile and can be contacted repeatedly. Air concentrations were treated as acute exposure because of the short duration of drifting air-spray plumes.

Soil concentrations

Soil concentrations predicted by the model range from 0.079 to 0.69 ppm at ¼ mile downwind from a hypothetical 40-acre field. This is similar to the range of pesticide concentrations detected in residential soils (0.0087 to 0.628 ppm). However, a direct comparison is not necessarily appropriate because sample locations are at different distances from agricultural fields, the fields that used pesticides varied, and the model does not consider natural degradation, which is relatively fast for organophosphates (the principal type of pesticides in use). The process of degradation could mean that soil concentrations in the residential soil samples were higher at one time. Precisely how high could not be calculated because the source of pesticides in soil is not known.

ATSDR compared the highest predicted soil concentrations at ¼ mile downwind (0.69 ppm) to soil comparison values for the 24 most used pesticides (Table 6). All predicted concentrations were below screening values except for methyl parathion of 0.6 ppm based on pica behavior (the childhood behavior of eating a large amount of soil). Although the predicted range exceeds the comparison value slightly, it will not likely present a public health threat because pica behavior does not typically occur daily. An alternative screening value of 20 mg/kg [ppm], based on non-pica chronic behavior in children, may be more realistic and is much greater than the predicted soil concentration.

ATSDR evaluated data on indoor dust and residential soil sampling in the previously released report Pathway Assessment for Churchill County Surface Soils and Residential Indoor Dust, Churchill County, Nevada (ATSDR 2003b). The report reviewed data collected on samples analyzed for 49 pesticides and found that all pesticides detected in residential surface soil were found at levels below available screening levels except for one compound (Table 2). At one residence, dieldrin (detected in 4 of 79 homes) was found at 0.19 ppm. Although this level slightly exceeds the ATSDR chronic oral EMEG for pica children (0.1 ppm), it is not expected to present a public health threat because pica behavior does not typically occur daily and the non-pica chronic oral EMEG for children is 3 ppm.

Indoor dust was sampled for 45 pesticides, and overall 10 pesticides were detected. From these results and comparisons to soil screening values, ATSDR does not expect any adverse health effects in children or adults from exposure at the pesticide levels found in indoor dust (ATSDR 2003b).

Air concentrations

Air concentrations were treated as an acute exposure (exposures that have a duration of 14 days or less) because exposures from aerial spraying would be of short duration with the drift of sprayed pesticides assumed to pass within one hour. ATSDR reviewed these exposure in relation to carcinogenic (specifically childhood leukemia) and noncarcinogenic health effects.

Short-term acute exposures may be an important factor in the cause of long term health effects such as childhood leukemia. Despite extensive research, the etiology (cause and development) of childhood cancer is largely unknown. Considering the early onset of many childhood cancers, especially acute lymphocytic leukemia (ALL), which is the most common in children ages 2 to 5, risk factors occurring very early in life, during pregnancy, or even during conception must be considered (Feychting and others 2001). There are studies which suggest that exposure to household pesticides during critical time periods such as preconception, during pregnancy and postnatal periods, as well as parental occupational exposures to pesticide are risk factors for childhood leukemia, but these studies have a number of limitations, such as a small number of cases, low response rates, and uncertainties in existing data (Zahm and Ward 1998). Attempts to measure exposure levels after diagnosis is confirmed, may pose a research bias. The NCEH cross-sectional exposure assessment questionnaire was used to identify past exposures and did not show an increased risk between pesticide use in the home and presence of childhood leukemia. Considering the published work and NCEH results, it is not clear how short-term single or periodic exposures (acute exposures) of pesticides can effect initiation or promotion of childhood leukemia. Because of these uncertainties, there is a compelling need for further evaluation by the scientific community in the relationship between pesticide exposure and childhood leukemia (Ma and others 2002).

In general, ATSDR found limited information about the carcinogenic health effects of pesticides. Table 7 summarizes some of the known information. All of these compounds have been tested on animals and the evidence of carcinogenicity ranges from negative or no evidence to limited evidence. Some studies are inadequate or provide insufficient information to draw conclusions about a compound's carcinogenicity. Data on human carcinogenicity is much more limited than on animal studies. Most of the compounds have no data. Table 7 also shows the cancer classification given to each pesticide by the International Agency for Research on Cancer (IARC), EPA, and the American Conference of Governmental Industrial Hygienists. Most of the compounds are not classified because these agencies have not reviewed them (indicated by "—" in the table) or the data do not provide sufficient information for a determination (IARC = 3, EPA = D, ACGIH = A4). Four compounds have been classified: 2,4-D, paraquat dichloride (Gramoxone), alachlor (Lasso), and methyl parathion. 2,4-D has a IARC cancer classification of 2B indicating that it is a possible human carcinogen but the ACGIH classification of A4 indicates that there is a concern about its carcinogenicity but there is a lack of data to draw a conclusion. Research on the carcinogenicity of 2,4-D has shown conflicting evidence. Paraquat dichloride and methyl parathion have been classified by EPA as possible human carcinogens. Alachlor has been identified a probable human carcinogen by EPA while IARC and ACGIH have not reviewed it. These classifications are not adequate to evaluate the pesticides relationship with childhood leukemias.

ATSDR evaluation of noncarcinogenic health effects focused on acute health effects because of the acute pesticide air exposures that could occur from spray drift. However, ATSDR does not have non-worker, health-based, **acute** ambient air comparison values (i.e., inhalation MRLs or RfCs) for these pesticides. EPA Reference Doses exist for several pesticides but they are not applicable because they are based on chronic exposures (exposure of 1 or more years at a time). Therefore, ATSDR used worker-based permissible exposure limits (PELs) and worker-based threshold limit values (TLVs) and adjusted the evaluation accordingly. PELs and TLVs are intended to protect healthy adult workers from non-carcinogenic effects of chemical exposures that occur 8-hours a day and 5-days a week. PELs and TLVs were divided by 10 to account for the potential increased sensitivity of children and sensitive adults. ATSDR also used acute screening values of the California Department of Pesticide Registration for dimethoate, a manufacturer-suggested PEL/TLV for imazethapyr, and a Temporary Emergency Exposure Limit (Level 0) for ethyl parathion. These values are shown in Table 8.
To compare the predicted pesticide air concentrations to TLVs and PELs, ATSDR converted the 1-hour air concentrations to 8-hour averages by dividing the concentrations by 8. These spray events are assumed limited to a few fields at a time that are spaced far enough apart so that no one individual would be exposed more than once over a long period of time (months or years). The 8-hour-average air concentrations are shown below.

Calculated 8-hour minimum, average, and maximum air concentrations of pesticides and herbicides one-quarter mile downwind

	Air concentration ($\mu g/m^3$)
Minimum	0.35
Average	3.0
Maximum	10.4

$\mu g/m^3$ micrograms per cubic meter

The predicted 8-hour **average** air concentration did not exceed any of the screening values in Table 8. The **maximum** predicted 8-hour concentration of 10.4 $\mu g/m^3$ was below all screening values except for five compounds: disulfton, Furadan 4F, naled, paraquat (dichloride), and parathion (ethyl). The screening value for disulfton, Furadan 4F, naled, and paraquat (dichloride) is 10$\mu g/m^3$, which is slightly below the maximum concentration. Because the two values are close and the concentration is the maximum of a potential range, the concentration is most likely to be lower and will not likely cause adverse health effects.

For parathion (ethyl), the maximum 8-hour air concentration of 10.4 $\mu g/m^3$ exceeded the screening value of 5 $\mu g/m^3$[†]. Because the screening value was exceeded, we evaluated parathion further by analyzing the modeling results. Because parathion was one of the two pesticides we used in the AgDrift air model, we had exact modeled air concentrations instead of ranges of concentrations as used for the other pesticides. Therefore, at ¼ mile from the hypothetical field,

† Based on a TLV of 0.05 mg/m^3 (2003 American Conference of Governmental Industrial Hygienists [ACGIH] update) with a safety factor of 10 and conversion from milligrams (mg) to micrograms (µg).

the model predicts a maximum[‡] air concentration of parathion at 1.4 µg/m^3, which is below the screening value of 5 µg/m^3. Therefore, parathion would not be expected to cause adverse health effects.

Additional information that parathion is not expected to cause adverse health effects is the Temporary Emergency Exposure Limit (TEEL Level 0[§]) of 100 µg/m^3 for parathion, which is a risk-based value for one hour exposures. The maximum predicted air concentration at ¼ mile downwind falls ten times below the TEEL-0 indicating that adverse health effects are not likely.

While pesticide health effect research is ongoing, ATSDR recommends that pesticide exposure (especially children) be reduced or eliminated. In particular, efforts should be directed at decreasing exposure to pesticides used in homes and gardens as well as lawns and recreational areas, which are the major sources of pesticide exposure for the majority of children (Zahm and Ward 1998). It is also prudent public health policy to encourage the use of agricultural practices that minimize off-site migration of pesticides.

2.5 Associations Between Datasets

For most of this consultation, ATSDR reviewed individual datasets. In this section, the associations between datasets are discussed for insight into exposures. The magnitude of the measured values are evaluated in previous sections and not discussed here. The individual datasets include:

- Blood and Urine Samples
- Indoor Dust Samples
- Outdoor Residential Yard Soil Samples

The relationships among these datasets are discussed in the following sections in relation to the Nevada Department of Agriculture database and the NCEH cross-sectional study questionnaire. Table 9 contains a summary of the pesticides discussed in this Section.

2.5.1 Blood and Urine Samples

Actual exposures to pesticides were identified in blood and urine samples collected from case and control families from August to October 2001. Pesticides found significantly above background levels included one organophosphate pesticide (chlorpyrifos), one organophosphate metabolite (diethylthiophosphate), two chlorinated phenol pesticides (2,4,5-trichlorophenol and 2,4,6-trichlorophenol), a fungicide (o-phenylphenol), and DDE. 2-Naphthol was found slightly higher than reference values.

The source of chloropyrifos is most likely from use in homes to control termites and other

‡ Based on different wind speeds and droplet sizes.

§ TEELs are developed by the Department of Energy, Subcommittee on Consequence Assessment and Protective Actions, to assist in emergency preparedness and response. Four TEEL levels are available. TEEL Level 0 values are threshold concentrations below which most persons will experience no appreciable risk of health effects.

insects. Of the 80 homes sampled for pesticides in indoor dust, 21 samples detected chloropyrifos. Only 3 of the homes had chlorpyrifos detected in yard soils. However, NCEH did not find a correlation between urine and blood pesticide levels and the use of pesticides in homes as indicated in the cross-sectional study questionnaire or between urine and blood pesticide levels and indoor and outdoor dust samples (A. Holmes, NCEH/CDC, personal communication, 2003). Exposure to chlorpyrifos in foods is also possible because it was the sixth most detected pesticide residue on foods based on total diet (FDA 2002). Chloropyrifos was not reported in the Nevada Department of Agricultural database.

The compound diethylthiophosphate is a metabolite of at least nine organophosphate pesticides including chlorpyrifos, diazinon, disulfoton (Di-Syston 8), and parathion (ethyl) (Table 10). The agricultural database indicates that disulfoton and parathion have been used to control insects on crops in Churchill County. These two pesticides are restricted-use pesticides indicating that use is limited to specially trained applicators, usually commercial pesticide companies. Parathion was not detected in any of the indoor dust or yard soil samples. Disulfoton was not sampled for. Diazinon was detected in indoor dust samples of 65 homes and in samples of 19 yard soils. Chlorpyrifos was detected in indoor dust samples of 21 homes. Chlorpyrifos was the sixth most frequently found pesticide residue on food (FDA 2002). The increased presence of this metabolite may be from several different sources including use of pesticides in the home, agricultural use, or from foods.

2,4,5-Trichlorophenol and 2,4,6-trichlorophenol are two metabolites of several organochlorine chemicals pesticides including beta- and gamma-hexachlorocyclohexanes. Gamma-hexachlorocyclohexane is also called lindane. Lindane was found in the yard soils of 4 homes, and beta-hexachlorocyclohexane was found in the yard soils of 3 homes. Neither compound was found in indoor dust samples. The hexachlorocyclohexanes were not reported in the agricultural database. Lindane was the eleventh most frequently found pesticide in a 2000 survey of foods representing a total diet (FDA 2002) and is dispensed in prescription shampoos to treat head lice and scabies. It is a persistent organochloride and has long-range atmospheric transport potential. Lindane is no longer manufactured in the United States, and EPA cancelled most agricultural and dairy uses in 1985 because of concerns about the compound's potential to cause cancer (Pesticide Information Project 1996c; U.S.EPA 2002a). If 2,4,5-trichlorophenol and 2,4,6-trichlorophenol are from lindane, the source of this exposure could either be from prescription use, from historical outdoor use, or from long-range transport from international use.

o-Phenylphenol was detected at levels significantly above background levels. o-Phenylphenol is used as a fungicide, germicide, household disinfectant, preservative in water-oil emulsions (including paints), and in a post-harvest treatment of fruits and vegetables to protect against microbial damage (HSDB - Hazardous Substances Data Bank 2002). o-Phenylphenol was not analyzed in indoor dust and yard soils samples and is not in the agricultural database. Exposure is most likely from food or household disinfectants.

DDE is a biologic metabolite and environmental breakdown product of DDT and DDD. DDT is a persistent organochlorine pesticide used to control mosquitoes and insects on agricultural crops. DDD was also used as a pesticide but to a more limited extent. DDD is also a breakdown product of DDT. Use of DDT was banned in the United States in 1972. DDE was found in blood samples and yard soils of 23 homes (Agency for Toxic Substances and Disease Registry 2002c). DDT and DDE have been found in 7 of 195 domestic samples of food (FDA 2002). Exposure to DDE is most likely at background levels perhaps through food or from yard soils.

2-Naphthol was found in urine at slightly higher levels than in reference values. 2-Naphthol has several different uses including dyes, pigments, fats, oils, insecticides, pharmaceuticals, perfumes, antiseptics, synthesis of fungicides, and antioxidants for rubber. 2-Naphthol in urine may also result from exposure to naphthalene in older types of mothballs, fires that produce polyaromatic hydrocarbons (PAHs), and tobacco smoke. 2-Naphthol was not analyzed in indoor dust or yard soil samples and is not listed in the state agriculture database. Exposure could be from any of the intended uses, from tobacco smoke, or from other sources.

2.5.2 Indoor Dust Samples

Four pesticides were detected in indoor dust samples at more than 20 of 80 homes tested: chlorpyrifos (21 homes), diazinon (65), 1-naphthol (26), and N,N-diethyl-3-methylbenzamide (DEET) (66). Detection in dust samples was much less frequent than in outdoor soils.

Chlorpyrifos is commonly used in the home. Diazinon is classified as a restricted-use pesticide (RUP) and is for use by professional pest-control operators only. Diazinon is a nonsystemic organophosphate insecticide used to control cockroaches, silverfish, ants, and fleas in residential, non-food buildings. It is also used on home gardens and farms to control a wide variety of sucking and leaf-eating insects (Pesticide Information Project 1996b). Urine metabolites of diazinon include diethylphosphate and diethylthiophosphate. Diethylthiophosphate was detected at levels above reference values. Diazinon is listed in the state agriculture database (last reported use was 1983).

1-Naphthol is a urinary metabolite and environmental breakdown product of the carbamate pesticide carbaryl (the active ingredient in Sevin). Other sources of 1-napthol are similar to 2-naphthol discussed above. Carbaryl is listed in the state agriculture database with the latest use in 1984. Carbaryl is a wide-spectrum carbamate insecticide that controls more than 100 species of insects on citrus, fruit, cotton, forests, lawns, nuts, ornamentals, shade trees, and other crops, as well as on poultry, livestock, and pets (Pesticide Information Project 1996a). The carbaryl product Sevin may be purchased in hardware or garden stores. Sevin was detected in yard soils of 3 homes but not in any indoor dust samples. The presence of 1-naphthol in the indoor dust samples may be from many different sources as listed here.

N,N-Diethyl-3-methylbenzamide (DEET) was detected in indoor dust in 66 of 80 homes. DEET is the active ingredient in many insect-repellent products including those including that are applied directly to human skin. The presence of DEET in indoor dust is probably from its intended uses.

2.5.3 Outdoor Residential Yard Soil Samples

Five pesticides were detected in outdoor yard soils at 15 or more of 80 homes. These pesticides include cis-chlordane (21 homes), gamma-chlordane (24), DDE (23), diazinon (19), heptachlor epoxide (17), and N,N-diethyl-3-methylbenzamide (DEET) (66). These compounds were detected much less frequently than in indoor dust samples.

The chlordanes, DDE, and heptachlor epoxide were detected either infrequently or not at all in indoor dust. These compounds were all banned in the United States by 1988 but may still be used in other countries. Their presence is likely from historical use in Churchill County and use throughout the world.

Diazinon and DEET were found frequently in yard soils and indoor dust samples. Diethylthiophosphate, a urinary metabolite of diazinon was found elevated in case and control families. However, no correlations were found between urinary metabolites and pesticide levels found in indoor dust samples or yard soils (A. Holmes, NCEH/CDC, personal communication, 2003).

As discussed here, exposures to different pesticides come from several different sources including agricultural use; home, lawn, and garden use; background and long-range transport of persistent pesticides; and foods. The agricultural database only included commercially applied pesticides to agricultural fields and does not include owner applied pesticides for agricultural purposes or pesticides applied commercially or by owners to homes. Because some of the pesticides found in this data are typically used in the home or found in residues on food, exposure can occur from non-farm sources. The exact exposures cannot be determined with the existing data. To evaluate further, more exact historical information is needed on commercial and owner applications of pesticides in and outside the home, time-activity relationships of the families to determine their locations during pesticide applications, and pesticide residues on the foods consumed. Obtaining accurate data would be very difficult.

3.0 Conclusions

Pesticide use in Churchill County includes typical residential, commercial, and industrial applications but also includes agricultural use, mosquito control, noxious weed control, and control of weeds in and along roads and irrigation canals. Exposure to pesticides also occurs from FDA-allowable residues in the food supply.

The following conclusions are made from these data.

- Levels of pesticides and pesticide metabolites in blood and urine samples indicate that case and control families were exposed to several pesticides at levels greater than were U.S. based reference populations. However, case and control families had similar levels which indicate that there is not a correlation between current pesticide exposures and acute lymphocytic leukemia (ALL).
- Levels of pesticides and pesticide metabolites in blood and urine samples did not correlate with pesticides measured in indoor dust and residential yard soil samples

indicating that current pesticide exposures may be influenced by other sources than those sampled.

- Exposures to pesticides found in residential yard soils and indoor dust samples are not expected to cause adverse health effects based on available health screening values. These levels represent potential current exposures and not historical exposures.
- Acute effects of potential historical exposure of pesticides from the spray drift of aerial applications of pesticides shows that adverse health effects are not likely. However, ATSDR was not able to evaluate long-term health effects such as ALL sufficiently because limited or no data are available on the carcinogenicity of the pesticides.
- Historical evaluation of pesticide exposures in this study was limited to the interviews and the contents of the Nevada Department of Agriculture database. These information sources describe the commercial application of pesticides for agricultural purposes, government weed control, and mosquito control. Use of pesticides by individual farmers or property owners (home owner, land owner, or renter) for any purpose (agricultural, lawn, garden, termites, other insects) is not included. NCEH questionnaires provide information about individual pesticide use but may be subject to recall bias.

ATSDR concludes that **current exposures** are not likely to cause adverse health effects (ATSDR category of *no apparent public health hazard*) because pesticide exposures are occurring but below concentrations associated with adverse health effects.

ATSDR concludes that **past exposures** are an *indeterminate health hazard* because past exposures, especially during the time that childhood leukemia may have been initiated or promoted, is not precisely known. ATSDR tried to recreate historical exposures from agricultural aerial spraying, but other sources of exposure that cannot be accounted for in sampling or modeling are also possible.

4.0 Recommendations

ATSDR recommends that pesticide exposure (especially children) be reduced or eliminated. In particular, efforts should be directed at decreasing exposure to pesticides used in homes and gardens as well as lawns and recreational areas, which are the major sources of pesticide exposure for the majority of children (Zahm and Ward 1998). It is also prudent public health policy to encourage the use of agricultural practices that minimize off-site migration of pesticides. Sources of information about reducing exposure to pesticides are provided in Appendix B.

5.0 Preparers of this report

Brian Kaplan, M.S.
Environmental Health Scientist
Consultations Section
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation

Gail Scogin
Environmental Health Scientist
Exposure Investigation Section
Exposure Investigations and Consultations Branch
Division of Health Assessment and Consultation

Ken Orloff, PhD
Toxicologist
Exposure Investigation Section
Exposure Investigations and Consultations Branch
Division of Health Assessment and Consultation

Michael L. Patterson, MD
Medical Officer
Exposure Investigation Section
Exposure Investigations and Consultations Branch
Division of Health Assessment and Consultation

Technical Assistance

David M. Esterly
Environmental Focus, Inc
Wilmington, Delaware

Steve Martin
Computer Information System Support Contractor/EDS, Inc.
Information Resources Management Branch
Office of Program Operations & Management

Leonard Young
Eastern Research Group
Lexington, Massachusetts

Ira Hubert and Kevin Liske
GIS Specialists
Spatial Analysis and Information Dissemination Section
Office of the Administrator

Jeanne Bucsela
Technical Writer-Editor
Office of Public and External Affairs
Office of the Administrator

Reviewers

John E. Abraham, PhD
Chief, Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation

Susan Moore, MS
Chief, Consultation Section
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation

Susan Metcalf, MD
Chief, Exposure Section
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation

Donald Joe
Chief, Petitions Section
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation

Wendy Kaye, PhD
Chief, Epidemiology and Surveillance Branch
Division of Health Studies

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