UNIVERSITY OF NORTH TEXAS
HEALTH SCIENCE CENTER AT FORT WORTH
1970

Hull, Kimberly M., The Relationship Between Atrazine Exposure and Breast and Ovarian Cancer Incidence Rates in Texas Agricultural Statistical Districts. Masters of Public Health (Environmental Health), May 2006, 95pp., 16 tables, 7 illustrations, reference, 74 titles.

The herbicide, atrazine, is suspected to cause cancer primarily through drinking water. This ecological study analyzed relationships between potential atrazine exposures and female breast and ovarian cancer incidence rates in Texas Agricultural Statistical Districts. Atrazine exposures are: atrazine usage, rural population, and public water systems. Study results indicate an inverse relationship between four atrazine exposures and breast and ovarian cancer incidence rates (county level). There is a positive relationship between surface water systems and ovarian cancer incidences rates (county level). There also is an inverse relationship between one atrazine usage index and ovarian cancer incidence rates (district level). Study results are similar to other atrazine and cancer studies; correlations prevent statements of causal inference.

THE RELATIONSHIP BETWEEN ATRAZINE EXPOSURE AND BREAST AND OVARIAN CANCER INCIDENCE RATES IN TEXAS AGRICULTURAL STATISTICAL DISTRICTS

Kimberly McGee Hull, B.S.

APPROVED:

Major Professor

Committee Member

Committee Member

Department Chair

Dean, School of Public Health

THE RELATIONSHIP BETWEEN ATRAZINE EXPOSURE AND BREAST AND OVARIAN CANCER INCIDENCE RATES IN TEXAS AGRICULTURAL STATISTICAL DISTRICTS

THESIS

Presented to the School of Public Health

University of North Texas
Health Science Center at Fort Worth

in Partial Fulfillment of the Requirements

for the Degree of

Masters of Public Health

By

Kimberly McGee Hull

Fort Worth, Texas

May 2006

ACKNOWLEDGEMENTS

I want to thank the University of North Texas Health Science Center, School of Public Health, Department of Environmental & Occupational Health, faculty for passionately teaching me the essential principles of the responsibility I now have to protect the public's health through identifying and mitigating environmental and occupational hazards. I would like to personally thank my advisor and major professor, Terrance Gratton, Dr.P.H., M.S., for being a wonderful mentor during my Masters program and championing me by nominating me for various awards and scholarships. I want to thank my thesis committee Terrance Gratton, Dr.P.H., M.S., Eric Johnson, M.D., Ph.D., M.P.H., D.T.P.H., and Sejong Bae, Ph.D., M.S. for their guidance and support. I wish to thank Debbie Scott for always going the extra mile whenever I would ask for a favor. I need to thank my parents, Richard and Deborah McGee, relatives, and friends for their love and support through my masters program. I especially want to thank my husband, Brian, for his love, patience, encouragement, and computer expertise during my journey on the road to completing my Masters in Public Health.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

Rationale- Research Problem

Atrazine is heavily used on agricultural crops in various counties and agricultural statistical districts in Texas. Several research studies assert that the herbicide, atrazine, is an endocrine disrupter that may increase cancer risk in humans, causing tumor formations in hormonally sensitive tissues, such as the breasts and ovaries (Donna et al., 1989; Kettles et al., 1997). Therefore, since atrazine is one of Texas' most common tap water contaminants in finished drinking water, it is a major public health concern that has the potential to adversely affect large populations in Texas (Information Ventures, 1995; Texas Center for Policy Studies, 1999).

Statement of Purpose

The purpose of this study is to determine, if there are any relationships between Texas agricultural statistical districts and/or Texas counties that have high atrazine exposure and Texas agricultural statistical districts and/or Texas counties that have high breast and/or ovarian cancer incidence rates.

Research Hypotheses

1. There is a relationship between atrazine exposure and breast and ovarian cancer rates in Texas counties.
2. There is a relationship between atrazine exposure and breast and ovarian cancer rates in Texas agricultural statistical districts.

Delimitations

The sample population selected for this study is limited to women first diagnosed with breast and/or ovarian cancer from 1998-2002 that have an identified Texas county as the location of permanent residence at the time of diagnosis. All counties in the United States with 2000 U.S. age-adjusted breast and ovarian cancer incidence rates for women 0-54 years old and younger and 55 years old and older would be able to be compared to breast and ovarian cancer incidence rates in this study.

Limitations

Since this is an ecological study, relationships seen on the county or agricultural statistical district level hold an ecological bias at the individual level (Oskasha, 2005). Also, misclassifications could arise in breast and ovarian cancer incidence data due to population movement (Kettles et al., 1997). Actual atrazine usage for each county was not available, so estimated atrazine usage by square mile from Battaglin and Goolsby had to be used. In addition, 27 counties are considered to have no data or zero atrazine data (1995). Another limitation, a public water system's finished drinking water could potentially be a mix of threatened and non-threatened surface water sources (A. Cherepon, personal communication, May 23, 2005). A key factor that limits the interpretation of data is that all the data is secondary data.

Assumptions

1. The women diagnosed with breast and/or ovarian cancers in the study are assumed to have received exposure to atrazine from the same county where they were first diagnosed with breast and/or ovarian cancer.
2. Since this is an ecological correlation study, every person in a county or agricultural statistical district is assumed to have received equal amounts of atrazine exposure.
3. Every person in a county or agricultural statistical district is assumed to have received the same level of continued atrazine exposure every day since birth.
4. Atrazine usage is the only cancer exposure being evaluated in this study. Exposure to other kinds of herbicides and pesticides reportedly used in Texas, considered to be endocrine disrupters that potentially cause cancer, are not accounted for in this study.
5. The main route of exposure to atrazine to the general population was assumed to be through surface drinking water (EPA, 2005c; Texas Center for Policy Studies, 1999).

Definition of the Terms

Agriculture Statistical District - Group of counties in a district that share common features; characterized by their geography, crop production, or economic development (USDA-NASS, 2005b).

Atrazine - 2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine is an organic herbicide that provides residual broad-spectrum and some grassy weed control by inhibiting photosynthesis (PMEP, 2005b; Regional Pest Management Centers, 2003; EPA, 2005a).

Spearman Rank Correlation - A non-parametric test that makes no assumptions about the distribution of the values. Spearman rank correlation coefficient analysis converts data into rank order and measures the strength of the relationship between two variables (Lowry, 2006).

Importance of the Study

Positive correlations between atrazine exposure and breast and ovarian cancer incidence rates could provide more information to support the need for more rigorous studies to confirm the findings, and confirmation may lead to more rigid atrazine monitoring programs in Texas to reduce breast and ovarian cancers in areas that have high atrazine exposure levels.

CHAPTER II

LITERATURE REVIEW

The purpose of this study is to identify if any relationships exist between atrazine exposure and breast and ovarian cancer incidence rates in Texas counties and agricultural statistical districts. Previously published and unpublished studies were reviewed. This chapter, the Review of Literature, concentrates on six major areas of research: (1) Breast and ovarian cancer statistics and risk factors; (2) Atrazine, its uses, restrictions, and the environment; (3) Atrazine and drinking water; (4) Atrazine as a public health concern; (5) Atrazine research studies on humans and animals; and (6) Background on data collection.

According to the Texas Cancer Data Center in 2000, breast cancer ranked second behind lung and bronchus cancer as the leading cause of cancer death in Texas women. Ovarian cancer was the fifth leading cancer death in Texas women in 2000 (TCDC, 2005). In 2006, the American Cancer Society's cancer estimates put breast cancer as the second-highest cause of cancer death in American women and ovarian cancer as the fifth cause of cancer death in American women (ACS, 2006). Fifteen percent of the total cancer deaths in women (40,970) are breast cancer and 15,310 may die due to ovarian cancer (6% of the total American women cancer death estimates for 2006) (ACS, 2006).

Approximately, 212,920 breast cancer incidence cases are expected in the United States for 2006 (31% of all the new cancer cases in American women) making the breast the leading site for cancer incidence cases for 2006. Lung and bronchus cancer are the second highest with an estimated 81,770 incidence cases expected to be diagnosed (12% of overall estimated new cancer cases in American women). Ovarian cancer ranks eighth with an estimated 20,180 cases for 2006 making it 3% of total new cases in American women (ACS, 2006). The Texas Cancer Registry estimates female breast cancer, with 15,277 new cases for 2006, is the leading new cancer site in Texas. Ovarian cancer new cases are estimated to be 1,574 for 2006 (Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services, 2006b).

Factors known to increase a woman's chance of developing breast cancer include: increasing age, having a sister, mother, or daughter with breast cancer, first menstrual period before 12 years old, onset of menopause after 55, and using menopausal hormone replacement drugs (NCI, 2003; Kirsh & Solomon, 2005). Also, postmenopausal women who are obese have an increased risk for breast cancer (NCI, 2003). Ovarian cancer risks increase if a woman has survived breast cancer, has never become pregnant, has abnormally functioning ovaries, has had multiple miscarriages or abortions, or has taken ovulation-inducing fertility drugs such as clomiphene (HealthGate Data Corp., 2003).

Endogenous estrogens are principally responsible for the development and maintenance of the female reproductive system and secondary sexual characteristics. The ovarian follicle is the primary source of estrogen in normally cycling adult women (RxList Inc., 2005). Women's estrogen levels change throughout their lives for a variety of reasons. Fluctuations in estrogen levels create changes in the breasts and ovaries, which increases or reduces a woman's risk of developing cancer (NCI, 2003). During pregnancy hormonal changes occur that potentially reduce a woman's chances of developing breast and ovarian cancer later in life (NCI, 2003; Health Gate Data Corp, 2003). Breast cancer risk is reduced the younger a woman is when she has her first child, when a woman has subsequent births, and when she breastfeeds. Also, some studies have shown an association between breast cancer and marital status. Married women are less likely to develop breast cancer and more likely to be diagnosed with breast cancer earlier than unmarried women (Osborne et al., 2005). The risk of ovarian cancer tends to be slightly lower in women who have taken birth control pills or have had a tubal ligation or hysterectomy (Health Gate Data Corp, 2003).

Natural and synthetic endogenous estrogen associated with reproductive tissues trigger hormonal changes in the body (Kirsh & Solomon, 2005). Phytoestrogens are natural chemicals in foods rich in soy that have estrogen-like effects in the body (Takeshi, 2006). Triazine herbicides such as atrazine, simazine, and cyanazine and organochlorines, such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCB), chlordane, heptacholor, endosulfan, dieldrin, and toxaphene are synthetic chemicals that are considered to have estrogenic properties that cause uterine weight gain and enhance proliferation of estrogen-sensitive cells in the body (Mills & Yang, 2006; Kettles et al., 1997). Endocrine disruption can prompt unregulated cell division among hormonally sensitive cells, increasing the chance of mutations and supporting the proliferation of abnormal cells (Kirsh & Solomon, 2005). In animal studies atrazine produced abnormal endocrine activity, while human studies indicated that atrazine mimicked normal endocrine activity (Kirsh & Solomon, 2005).

Atrazine, 2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine is an organic herbicide that provides residual broad-spectrum and some grassy weed control (PMEP, 2005b; Regional Pest Management Centers, 2003; EPA, 2005a). Atrazine controls weeds by inhibiting photosynthesis (EPA, 2005a). Atrazine in its purest form is an odorless white crystalline solid powder that dissolves in water. It does not occur naturally, and is not very volatile, reactive, or flammable (EPA, 2005c; ASTDR, 2004). The Ciba-Geigy Corporation first registered atrazine in the United States in 1958 (ATSDR, 2003a; EPA, 2005a). There are many trade names and synonyms associated with atrazine (see Table 2-1). Currently, there are many products containing atrazine available in many different formulations, including suspension concentrates, wettable powders, flowable liquids, and water-dispersible granules (ATSDR, 2003b).

In search results on atrazine usage in the National Center for Food and Agricultural Policy National Pesticide Use Database, atrazine is primarily used on agricultural crops such as corn, sorghum, and sugarcane (2005; National Ag Safety Database, 2005). Atrazine was estimated to be the most heavily used herbicide in the United States in 1987 and 1989, with its most extensive use on corn and sorghum in the mid-western states of Illinois, Indiana, Iowa, Kansas, Missouri, Nebraska, Ohio, Texas, and Wisconsin (EPA, 2005c). An estimated 76.4 million pounds of atrazine are applied annually to corn crops, which accounts for approximately 86% of total U.S. domestic poundage, followed by sorghum (10%), sugarcane (3%), and all other uses (1%) (EPA, 2005a). On average, approximately 75% of the field corn acreage grown in the U.S. is treated with atrazine (EPA, 2005a).

In 1988, atrazine producers proposed an atrazine management program to the Environmental Protection Agency (EPA). In 1990, the EPA approved the program. The program classified atrazine as a restricted-use-pesticide (RUP) because of concern of its release into surface water and groundwater (PMEP, 2005a). At present, atrazine can only be applied by certified applicators or under the supervision of a certified applicator. General consumer weed control products used on lawns cannot contain more than 4% active atrazine (ATSDR, 2003a).

Currently, twenty-four facilities manufacture atrazine. Anywhere from 1,000 to 10,000 pounds of atrazine are manufactured or processed in Georgia. In Alabama, Mississippi, and Missouri very large formulation activities ranging from 1,000,000–10,000,000 pounds of atrazine are manufactured or processed. Facilities in Arkansas and Iowa also process atrazine in large amounts up to 100,000,000 pounds. The greatest amounts of atrazine up to 50,000,000 pounds are housed in facilities in Louisiana that produce, process, manufacture, react, sell, and distribute atrazine (ATSDR, 2003a). Herbicides such as atrazine are released to the environment through normal use, so it should be expected that most of the quantities produced would eventually be released into the environment (Breast Cancer Fund, 2004). Potential point sources for atrazine that could contaminate the environment include manufacturing facilities, distributors, farm, and commercial and non-commercial operations (Breast Cancer Fund, 2004; ATSDR, 2003a).

Triazine herbicides are not considered to be bioaccumulative, but continue to be discovered at high levels in water because of its persistence and ongoing large-scale production and use (Breast Cancer Fund, 2004). Agricultural operations usually apply atrazine to corn as a pre-plant herbicide and follow up with post-plant whole field applications and/or periodic spot treatments (Regional Pest Management Centers, 2003).

As previously mentioned, atrazine is primarily used on corn, sorghum, and sugarcane, but it is also used on winter wheat, guava and macadamia nuts, hay for animal fodder, fallow land, and Christmas trees (National Ag Safety Database, 2005). There are also non-agricultural uses of atrazine such as on highway and railroad right-of-way intersections, golf courses, and lawn turf (ASTDR, 2004; National Ag Safety Database, 2005).

Atrazine is active in the soil anywhere from 60 days (PMEP, 2006) to 7 months (Information Ventures, 1995). Even after years of continuous use, atrazine is not normally found below the first foot of soil (PMEP, 2006). Atrazine is taken up by plants growing in soil or is broken down by soil bacteria capable of catabolizing atrazine to carbon dioxide over a period of days or months (Seffernick et al., 2000). The main breakdown product of atrazine in soil is hydroxyatrazine, which does not move easily in soil. Deisopropylated atrazine and deethylated atrazine are also breakdown products of atrazine that have been found in soil. Downward movement, or leaching, is limited by its absorption to certain soil constituents. Atrazine is more readily absorbed in muck or clay soils than in soils low in clay and organic matter content (PMEP, 2005b).

Atrazine remains in surface or groundwater for an extended period of time, due to the slow breakdown of the chemical in water (ASTDR, 2004). Atrazine is considered moderately soluble in water (33 ug/ml)(PMEP, 2006). It gets into surface water and groundwater via agriculture runoff after rain events (Information Ventures, 1995; Breast Cancer Fund, 2004).

Atrazine can potentially be released into the environment via wastewater from manufacturing facilities and as an applicant on crops (EPA, 2005c). Atrazine can also get into the environment if it is improperly stored or mixed before application (IL Dept. PH, 2005). It mainly enters the environment through application to farm fields (IL Dept. PH, 2005). In Texas, atrazine is principally used to protect crops such as corn, sorghum, and sugarcane from weeds (EPA, 2005c). Groundwater contamination may occur when atrazine moves from an application or spill on soil into a shallow aquifer (IL Dept. PH, 2005). Atrazine is the second most frequently detected pesticide in EPA's National Survey of Pesticides in Drinking Water Wells (EPA, 2005c). For this study, the main route of exposure to atrazine to the general population was assumed to be through surface drinking water.

Regulated contaminants present in public water system's source water such as lakes, rivers, or aquifers could possibly end up in public water systems' finished drinking water. The Safe Drinking Water Act of 1974 requires the EPA to determine safe levels of chemicals in drinking water that do or may cause health problems and requires that all drinking water sources should be protected (EPA, 2004). Amendments in the 1996 Safe Drinking Water Act now require all public water systems to report atrazine levels in their annual water quality report known as a Consumer Confidence Report (CCR) (EPA, 1998).

The EPA has set 3.0 ppb for both the Maximum Contaminant Level Goal (MCLG) and Maximum Contaminant Level (MCL) as the enforceable standard for atrazine in water (EPA, 2005d). The EPA believes that the 3.0 ppb MCLG and MCL for atrazine is a level of protection that should not cause any adverse health effects in human populations. MCLs are set as close to the MCLGs as possible, considering the ability of public water systems to detect and remove contaminants using the best available technology (EPA, 2005c). The MCL has been set at 3.0 ppb because EPA believes, given present technology and resources, this is the lowest level of atrazine water systems can reasonably be required to remove from drinking water (EPA, 2005c). The European standard for atrazine is 0.1 ppb, which is about 30 times lower than America's MCL (Texas Center for Policy Studies, 1999).

Atrazine in finished drinking water is a public health concern since it is one of Texas' most common tap water contaminants (Texas Center for Policy Studies, 1999). In 1998 and 2000, several Texas water bodies did not meet federal standards because atrazine exceeded MCLs in finished drinking water (Texas Center for Policy Studies, 2005). The water bodies in Table 2-2 were put on the 303(d) List for atrazine in finished drinking water in 1998 and 2000 (TCEQ, 2005b). The Texas Commission on Environmental Quality (TCEQ) is required, under Section 303(d) of the federal Clean Water Act, to identify water bodies for which effluent limitations are not stringent enough to implement water quality standards (TCEQ, 2005c).

Atrazine levels in finished drinking water are under-reported. Current drinking water standards calculate the annual level of atrazine by averaging four quarterly samples; seasonal spring peak levels in treated drinking water are almost never detected (Texas Center for Policy Studies, 2005; Environmental Working Group, 2000). Even though current atrazine EPA monitoring guidelines are weak, by only requiring quarterly samples, atrazine is the most frequent pollutant in treated drinking water (Environmental Working Group, 2000).

Ninety percent of Americans use public drinking water systems that are regulated by the EPA (EPA, 2005e). These public drinking water systems, which may be publicly- or privately-owned, serve at least 25 people or 15 service connections for at least 60 days per year (EPA, 2005e). Through the Public Water System Supervision (PWSS) program, EPA implements and enforces drinking water standards to protect public health. The EPA delegates to the states and tribes the responsibility to provide safe drinking water, so they implement many activities to regulate public water supplies (EPA, 2005e). TCEQ is responsible for regulating Texas water supplies (TCEQ, 2005a).

Atrazine routes of exposure for humans are through ingestion of atrazine in water, food, or soil, inhalation of atrazine-containing dust, or dermal when skin comes in contact with atrazine-contaminated soil or water (ATSDR, 2003b). The primary route of exposure to atrazine is ingestion through drinking water contaminated by atrazine. The probability of ingesting food contaminated by atrazine is considered minimal (The Center for Regulatory Effectiveness, 2003).

The most likely route of atrazine exposure that would affect large populations of people would be via ingestion of atrazine-contaminated groundwater and surface drinking water (Information Ventures, 1995). Persons coming both into contact with plants, which have just been treated with atrazine, and eating treated berries or vegetables could experience some ill effects (Information Ventures, 1995). Also, an individual may be exposed to small amounts of atrazine through his or her skin while bathing or showering in water contaminated with atrazine (IL Dept PH, 2005). Once atrazine enters the bloodstream it is distributed to many parts of the body (ATSDR, 2003b). Animal studies indicate that atrazine is metabolized in the body. Some atrazine and its metabolites may enter some organs or fat, but it is suspected that atrazine does not build up or remain in the body. Most of the metabolites leave the body within 24-48 hours, primarily in urine, with a lesser amount leaving in feces (ATSDR, 2003b).

Various research studies assert atrazine is an endocrine disrupter that may increase cancer risk in humans, causing tumor formations in hormonally-sensitive tissues such as the breast, the uterus and its lining (Environmental Working Group, 2000) and the prostate (EPA, 2005c; Environmental Working Group, 2000; Agency for Toxic Substances and Disease Registry, 2004; Kirsh & Solomon, 2000). Atrazine exposures may also cause many other serious health problems such as heart, lung, and kidney congestion, low blood pressure, muscle spasm, weight loss (EPA, 2005c; Agency for Toxic Substances and Disease Registry, 2004) and may cause delayed sexual maturation, miscarriages, and altered estrus cycles (Environmental Working Group, 2000).

According to ASTDR's "ToxFAQs for Atrazine", most people are not exposed to atrazine on a regular basis. People who would more than likely be exposed to atrazine are farm workers, chemical sprayers, and factory workers who handle atrazine (ATSDR, 2003b). OSHA has set an exposure limit of 5 mg atrazine/m^3 of workroom air for an 8-

hour workday (ATSDR, 2003b). NIOSH recommends a standard for occupational exposure of 5 mg atrazine/m^3 of workroom air during a 10-hour shift to protect workers from a concern that atrazine may cause cancer (ATSDR, 2003b).

Two atrazine exposure studies on factory workers resulted in two different conclusions. One study found an association between factory workers exposed to atrazine and non-Hodgkin's lymphoma (NHL) (Hoar, 1985; De Roos, 2003). The other study, lead by Snedeker and Clark, studied the effects of triazine exposure among factory workers with an 18-year follow-up (2005). None of the workers had cancer. It is believed that the 18-year period may have not been enough time to develop cancer and that another study needed to be conducted at a later date (Snedeker and Clark, 2005). Also, it was determined that the duration of exposure to the triazines was relatively short; 85% of the definite/probable group had been exposed to the triazines for less than four years (Snedeker and Clark, 2005).

It is difficult to evaluate whether atrazine causes breast cancer in women, because there are no published studies that have specifically looked at the rate of breast cancer in women with and without exposure to atrazine (National Ag Safety Database, 2005). Breast cancer is a very complex disease; there is no one single factor associated with the disease. In 1995, Cornell University founded a Breast Cancer and Environmental Risk Factors Program to address environmental factors and breast cancer risk concerns (National Ag Safety Database, 2005). Breast cancer develops over a long period of time, usually 10 to 30 years (National Ag Safety Database, 2005). A survey of women farmers in the United States did not find a higher rate of death from breast cancer in these women.

However, this study was based on information from death certificates and no information was included on the women's exposure to specific pesticides (Snedeker, 2001).

A few studies have been published on the risk of developing breast or ovarian cancer, but none have measured actual exposure. A study in Italy used questionnaires to compare atrazine exposure in women with ovarian cancer to women with other types of cancer. The study found women diagnosed with ovarian cancer were 2.2-times more likely to be classified as "probably exposed to herbicides" and women diagnosed with ovarian cancer and reported personal use of an herbicide, were 4.4-times more likely to be classified as "definitely exposed" (Donna et al., 1984). In 1989, members of the same research group did a second case-control study. Sixty-nine women with ovarian cancer were compared to women from the same municipal regions. The study found women with ovarian cancer were 1.9 times more likely to have been "possibly exposed" to triazine herbicides and were 2.7-fold more likely to be classified as "definitely exposed" (Donna et al., 1989). Most atrazine and cancer risk studies done on agricultural workers have mainly been conducted on men.

Some ecologic studies have shown an association between increased amounts of triazine herbicides applied to crops and/or increased levels of atrazine measured in drinking water with stomach cancer, leukemia, prostate, brain, testicular, and breast cancers (Van Leeuween et al., 1999; Mills, 1998; Kettles et al., 1997). Two ecological studies conducted in Kentucky compared atrazine exposure to breast and ovarian cancer incidence rates (National Ag Safety Database, 2005). The first study Kettles et al. (1997) found a modest association between high triazine herbicide exposure and counties with increased incidence of female breast cancer rates. The second study performed by Hopenhayn-Rich, Stump, & Browning (2002) found no association between high atrazine exposure and counties and agricultural districts with increased incidence of female breast cancer incidence rates.

Of several pesticide use ecological studies conducted in California, one study performed regression analysis to determine if there was an association between pesticide use and breast cancer in Latina women. The study found positive associations between organochlorines methoxychlor and toxaphene and breast cancer incidence rates. No associations were found between atrazine and simazine and breast cancer incidence rates (Mills & Yang, 2006). The EPA suggests that even though possible associations between atrazine exposure and cancers such as NHL and ovarian cancer, have been reported in a few epidemiology studies, there is still no supporting evidence that cancers, such as these, resulted from exposure to atrazine (EPAe, 2005).

Many researchers who study atrazine believe since many animals exposed to atrazine, have been adversely affected, like demasculinized frogs (Hayes, et al., 2002), mammary tumors in Sprague-Dawley rats (EPAe, 2005; Wetzel et al., 1994), and lymphomas and testicular cancer in some rats and mice (Donna et al., 1981; Donna et al., 1986; Pinter et al., 1990), that humans exposed to atrazine, could be adversely affected, with similar or unknown conditions (Hayes et al., 2002). Atrazine has been found to demasculinize frogs even at exposure levels far below ecologically relevant doses (Hayes et al., 2002). Atrazine's impact on frogs appears to be caused by this herbicide's ability to promote the conversion of testosterone to estrogen via activity of the enzyme aromatase (Hayes et al., 2002).

This mechanism is found not just in frogs, but other vertebrates as well as mammals. Cold-blooded animals, such as frogs, metabolize differently, but studying them raises important questions about the potential for atrazine to affect human health via the same enzymatic pathway (Hayes et al., 2002). In another study female pigs were treated with relatively low doses of atrazine. The pigs developed multiple ovarian follicular cysts and cystic degeneration of secondary follicles. The abnormal stimulation in ovarian tissues in the pigs indicates the possibility that atrazine exposure could evoke precancerous changes in mammalian ovaries (Gojermac et al., 1996).

The EPA believes mutagenic and estrogenic activities do not appear to play a significant role in atrazine-associated carcinogenicity (EPAe, 2005). Atrazine is associated with mammary and pituitary tumors in female Sprague-Dawley rats (EPAe, 2005). The mammary gland in laboratory animals is similar to the human breast (Snedeker, 2001). Atrazine exposure causes constant estrus and accelerates the normal aging process in female Sprague-Dawley rats; this combination leads to the formation of mammary tumors (EPAe, 2005). Constant estrus results from the modulation of the gonadotrophin-releasing hormone (GnRH), reduction of the luteinizing hormone (LH), and elevation of estrogen and prolactin (EPAe, 2005). It is believed that atrazine might cause adverse effects on hypothalamic pituitary function in humans, but the hormonal environment conducive to tumor development that is found in Sprague-Dawley rats, is not expected to occur in humans (EPA, 2005b).

There are so many conflicting studies on the effects of herbicide exposure in animals and humans. Similar hormonal mechanisms in many animals and humans may be involved in the development of breast, endometrial, and ovarian cancer, which should support an argument not only for limiting human exposure to herbicides, but also for continued research into these connections (Snedeker, 2001). Some researchers have suggested that the breakdown product of estrogen, 16-alpha hydroxyestrone, may increase the risk of breast cancer. One group of researchers found that human breast cancer cells grown in the laboratory that were exposed to atrazine made more of this estrogen breakdown product, while another group of researchers did not see this effect (Snedeker, 2001). More research needs to be conducted to see if atrazine causes cancer directly by causing mammary tumors, if atrazine causes cancer by disrupting the endocrine system, or if atrazine poses no health risk at all to humans (Snedeker, 2001).

This study determines if any correlations between atrazine exposure variables and breast and ovarian cancer incidence rates exist. The exposure variables are: atrazine usage, percent surface water public water systems, and percent rural population. Two sample populations are being used: Texas counties and Texas agricultural statistical districts. As shown in Figure 2-1, Texas has 254 counties. The USDA's National Agricultural Statistics Service, Texas Field Office, as shown in Figure 2-2, grouped all 254 Texas counties into 15 Texas agricultural statistical districts. None of the 15 districts overlap or share the same county. The counties in each district share common features; characterized by their geography, crop production, or economic development (USDA-NASS, 2005b).

A negligible amount of information was accessible through the U.S. Department of Agriculture regarding atrazine usage in Texas at the county and agricultural statistical district level. Texas applicators are not required to submit use data to the regulatory agencies, they only have to record it, but very little substantial information actually exists. The EPA does require manufacturers to submit annual sales data, but not by crop, state or acreage covered (D. Renchie, personal communication, May 31, 2005).

Atrazine usage data, an exposure variable for this study, was extracted from Battaglin and Goolsby (1995). Battaglin and Goolsby constructed GIS coverages for all the counties in the contiguous United States from herbicide data collected in Gianessi and Puffer (1991). Gianessi and Puffer tabulated estimates of county-level herbicide use for 96 herbicides. Many counties have usage data for several different types of herbicides. Many of these herbicides are associated with increased breast and ovarian cancer risk. This study does not account for other herbicides that potentially cause cancer that are present in each county; only atrazine is being studied.

They use crop acreage data from the 1987 U.S. Census of Agriculture. Herbicide use estimates are 1989 usage amounts. The amounts were constructed by compiling statistics from surveys sent to USDA Cooperative Extension weed scientists and surveys sent to farmers. Survey data was augmented with published surveys and reports from individual states (Gianessi and Puffer, 1991). Pounds of atrazine by square mile is divided into six categories they are: (1) No data or zero, (2) 0.01-2.32, (3) 2.33-13.46, (4) 13.47-52.35, (5) 52.36-163.73, and (6) more than 163.73 (Battaglin and Goolsby, 1995). In order to simplify calculations, the midpoint of each pound of atrazine by square mile is used for each category. None of the counties exceeded more than 163.73 pounds of atrazine per square mile (Battaglin and Goolsby, 1995).

Exposure variable surface water public water system is used because atrazine agricultural runoff potentially contaminates surface drinking water after substantial rains (Information Ventures, 1995; Breast Cancer Fund, 2004). For simplification, further references to surface water public water systems in the paper are surface water systems. The Water Utility Database was used to record the number of public water systems each county has and if the public water system uses surface or ground water.

The database is a collection of data from Texas Water Districts, Public Drinking Water Systems and Water and Sewer Utilities who submit information to the TCEQ (TCEQ, 2005b). The Water Utility Database does not yet contain water analysis results for public water systems (TCEQ, 2005b). Community and non-community public water systems are included in this study. Only one private public water system exists in Texas. This system was excluded from the study since the focus is on community and non-community public water systems (TCEQ, 2005b). There are a total of 6,666 public water systems in the Water Utility Database of those 1,216 are surface water systems. None of the public water systems had both surface water and ground water (TCEQ, 2005b). Percent surface water systems for this study were calculated by dividing the number of surface water systems by the total number public water systems in the county.

The percent of a county's population that is considered rural is used in this study as an atrazine exposure variable because atrazine is used on several agricultural crops and agricultural crops are predominately grown in rural areas. According to the 2000 U.S.

Census, rural population is calculated by subtracting the urban population, which is the population inside urbanized areas and inside urban clusters, from the total county's population (2005). An urban cluster is a densely settled area that has between 2,500 and 50,000 people. An urbanized area (UA) is an area consisting a central location(s) and surrounding area with a general population density of at least 1,000 people per square mile of land area that together have a population of at least 50,000 people. Qualifications and boundaries are determined by published U.S. Census criteria (U.S. Census, 2005). Percent rural population for this study is the rural population divided by the total county population.

Breast and ovarian cancer incidence rates are from the Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services, Texas Cancer Registry. The Texas Cancer Registry has maintained a statewide incidence database since 1995, collecting all new cancer cases diagnosed throughout the state. The Texas Cancer Registry has incidence rates that have been calculated for every county in Texas. However, the Cancer Registry did not have cancer rates for agricultural statistical districts. David Risser, Ph.D., M.P.H., an epidemiologist at the Texas Cancer Registry, created a new variable in his cancer file to generate 2000 U.S. age-adjusted breast and ovarian cancer incidence rates for each agricultural statistical district to use for this study (Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services, Texas Cancer Registry, 2006a).

Overall, there were many challenges in collecting data for this study since not much research has been done on atrazine exposure in Texas. Spearman rank correlations are conducted to determine if any relationships between atrazine exposure variables and breast and ovarian cancer rates exist at the Texas county and/or agricultural statistical district level. The null hypothesis is: there are no relationships between atrazine exposure variables and breast and ovarian cancer rates at the Texas county and agricultural statistical district level.

CHAPTER III

METHODOLOGY

Population and Sample

The 2000 U.S. Census was used to calculate total population for each county and to calculate population weights for each agricultural statistical district. The population of Texas in 2000 was approximately 20.8 million persons in living 254 counties divided into 15 agricultural statistical districts (U.S. Census Bureau, 2005). Two databases were created. Both databases contained the 2000 U.S. population, 1987 U.S. atrazine usage GIS coverages, and (1998-2002) 2000 U.S. age-adjusted breast and ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older for each county and agricultural statistical district.

Protection of Human Participants

IRB approved this study because only secondary data was utilized. No human beings were involved in this research study in any way. Health Insurance Portability & Accountability (HIPPA) Training was completed in June 2005.

Data Collection Procedures

Breast and ovarian cancer incidence rates for each Texas county and agricultural statistical district were average annual rates (1998-2002) per 100,000 and age-adjusted to the 2000 U.S standardized population. To be included in the study, all female cases of breast and ovarian cancer had to be newly diagnosed during the study period and have an identified Texas county as the location of permanent residence at the time of diagnosis. Correlations were performed for two age groups. One group is breast and ovarian cancer incidence rates using cases 54 years old and younger at time of diagnoses, and the other group is breast and ovarian cancer incidence rates using cases 55 years old and older at the time of diagnoses.

The two age groups were created to see if ages at cancer diagnose affects correlations with atrazine exposure, since breast and ovarian cancer risk appears to increase in women 55 years old and older (Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services, Texas Cancer Registry, 2006a). Table 3-1 and Table 3-2, show 1998-2002 breast and ovarian cancer incidence rates for women 54 years old and younger and women 55 years old and older for each Texas county and agricultural statistical district, respectively. Cancer incidence rates for each agricultural statistical district were calculated using age-specific case and population data in order to age-adjust the rates (D. Risser, personal communication).

Exposure variables for each county were the atrazine concentrations (lbs./sq.mi.) from Gianessi and Puffer (1991). Total area exposure for each county is atrazine concentration (lbs./sq.mi.) multiplied by the total square miles in the county. 2000 U.S.

Census data was used for population calculations. Total population exposure is total area exposure divided by the total population in the county. Since atrazine is not bioaccumulative, total population exposure assumes that persons received continuous exposure to atrazine every day (see Table 3-3).

Exposure variables for each agricultural statistical district are population-weighted or area-weighted. Population-weighted atrazine exposure was calculated using 2000 U.S. Census county populations. Atrazine concentrations (lbs./sq.mi.) in each county are multiplied by the total population in the county. County exposures were then summed and divided by the total population in the agricultural statistical district (Ventura County Air Pollution Control District, 2004). Population-weighted exposures represent average potential exposures in the agricultural statistical district, and not health impacts on individuals in counties. "Potential" is used, since daily activity affects an individual's exposure (Ventura County Air Pollution Control District, 2004).

Area-weighted atrazine exposure characterizes the potential average atrazine exposure per unit area. It represents a composite of exposure for each county-weighted to emphasize equally the exposure throughout agricultural statistical district. Area-weighted atrazine exposure was calculated in a similar fashion to population-weighted atrazine exposure. The variation was county atrazine concentrations (lbs./sq.mi.) were multiplied by the total square miles in the county. Exposures are then summed and divided by the total square miles in the agricultural statistical district (see Table 3-4; Ventura County Air Pollution Control District, 2004).

Population, water area, and land area data was obtained from the 2000 U.S. Census and aggregated at the county and agricultural district level. Population data was used to define demographic characteristics for the total Texas population by county, agricultural statistical district, sex, and age. Percent rural population, percent surface water system, and population were tabulated for each agricultural statistical district using county-population-weighted averages. Water area and land were tabulated for each agricultural statistical district using county-area-weighted averages (see Table 3-3; see Table 3-4).

Instrumentation

This study relied on quantitative data from the databases below:

- U.S. Census Bureau- 2000 Census Fast Facts for Congress has an assortment of databases that contain various statistics on demographics and economics at the national, state, county, city, census tract level (2005).
- Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services- Texas Cancer Registry is a database of cancer mortality and incidence cases and rates in Texas (2006a).
- Texas Commission for Environmental Quality (TCEQ)- Water Division Databases is a database of water and sewer systems in Texas (2005).

- United States Department of Agriculture- National Agricultural Statistics Service (USDA-NASS)- Agriculture Statistics Database is a database of crops planted and harvested in the United States (2005).
- National Center for Food and Agricultural Policy (NCFAP)- National Pesticide Use Database is a database of pesticide use on agricultural crops in the United States (2005).

Data Analysis

Spearman rank correlation coefficient analyses were done using Statistical Package for the Social Sciences (SPSS) 11.5. Spearman rank correlation is a nonparametric test that makes no assumptions about the distribution of the values. Spearman rank correlation coefficient analysis measures the strength of the relationship between atrazine exposure variables and breast and ovarian cancer incidence rates (Lowry, 2006). The Spearman rank correlation coefficient formula is (Lowry, 2006):

$$1-\frac{6\sum D^2}{N(N^2-1)}$$

Spearman rank correlation was used as a statistical analysis tool for this study because, there was no indication if any of the exposure/cancer incidence rate correlations are normally distributed. The Spearman rank correlation converts data into rank order, x and y, which were atrazine exposure variables and cancer incidences rates, respectively (Lowry, 2006). Significant correlations can be positive or negative and weak ($r < 0.33$), moderate ($0.33 < r < 0.66$), or strong ($r > 0.66$)(Lowry, 2006). Correlation results were organized into tables and significant correlations were graphed.

Summary

An ecological study was performed using secondary data to understand the relationship between atrazine exposure variables and breast and ovarian cancer incidence rates. Spearman rank correlation coefficient analyses were conducted using atrazine exposure variables for each county and agricultural statistical district and breast and ovarian cancer rates for women 54 years old and younger and 55 years old and older for each Texas county and agricultural statistical district. Atrazine exposure variables were weighted by county-population and county-area for each agricultural statistical district. Atrazine exposure variables were: atrazine usage, percent surface water systems, and percent rural population. The atrazine usage variable was used to create various units of atrazine exposure such as: pounds of atrazine per person, average pounds of atrazine by square mile, and total pounds of atrazine.

CHAPTER IV

RESULTS

Spearman rank coefficient correlations were performed to find relationships between breast and ovarian cancer incidence rates for women 54 years old and younger and women 55 years old and older and atrazine exposure variables: atrazine usage, percent surface water systems, and percent rural population at the county and agricultural statistical district level.

Statistical analysis determined a correlation between one county level atrazine usage variable, pounds of atrazine per person. A weak negative correlation exists between pounds of atrazine per person and breast cancer incidence rates for women 54 years old and younger (see Table 4-1). As shown in Figure 4-1, these results indicate that breast cancer incidence rates decrease as the number of pounds of atrazine per person increase. Pounds of atrazine per person were correlated with two other atrazine exposure variables. Pounds of atrazine per person correlates positively with percent county rural population in county ($r=0.194$; p, 0.002) and pounds of atrazine per person correlates negatively with percent surface water systems in county ($r=-0.137$; p, 0.029). Pounds of atrazine per person were then compared to total acres of corn and sorghum planted in each county in 2000 from the USDA-NASS Agriculture Statistics Database (2005a). The correlation showed a moderate positive relationship, its significant at the 0.01 level (2-

tailed), between atrazine pounds per person and total acres of corn and sorghum planted in each county in 2000(r=0.575). A possible explanation for the negative association between pounds of atrazine per person and breast cancer incidence is that this simply reflects the urban/rural differences in breast cancer incidence, with rural counties tending to have lower rates than urban counties.

No significant relationships exist between breast and ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older and average pounds of atrazine by square mile at the county level (see Table 4-2) and total pounds of atrazine at the county level (see Table 4-3).

County-rates are considered to be less stable than agricultural statistical district rates because county rates consist of fewer cancer cases than an agricultural statistical district rate that consists of many more cancer cases. One relationship exists at the agricultural statistical district level. As shown in Figure 4-2, a moderate negative correlation exists between average pounds of atrazine by square mile weighted by area and ovarian cancer incidence rates for women 54 years old and younger (see Table 4-4). A strong negative correlation exists between average pounds of atrazine by square mile weighted by area and the percent of the population that is considered rural in an agricultural statistical district (r= -0.680; p, 0.005). As average pounds of atrazine per square mile weighted by area increase ovarian cancer incidence rates for women 54 years old and younger decrease.

No significant correlations exist between breast and ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older and average pounds of atrazine by square mile weighted by population (see Table 4-4), total pounds of atrazine in agricultural statistical district weighted by population (see Table 4-5), and pounds of atrazine per person weighted by population (see Table 4-6) which are potential atrazine exposure variables used for agricultural statistical districts (Hopenhayn-Rich, Stump, & Browning, 2002).

Spearman rank correlation analyses determined that weak correlations exist for the two other atrazine exposure variables, percent rural county population and percent of surface water systems in county, and breast and ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older.

Three weak negative correlations exist between percent rural population in county and breast cancer incidence rates for women 54 years old and younger and ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older. Percent rural population in county was negatively associated with breast cancer and ovarian cancer incidence rates for all ages, even though the it was not statistically significant for breast cancer incidence rates for women 55 year old and older it important to note that it negatively correlates with percent rural population in county. As shown in Figure 4-3 and Figure 4-4, the results suggest that as breast cancer incidence rates for women 54 years old and younger and ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older decreases the percentage of the county 's population that is considered rural increases (see Table 4-7). The slight protective effect for breast cancer incidence rates for women 54 years old and younger and ovarian cancer incidence rates for women in both age groups could be due to a variety of positive health benefits associated with living in rural areas.

A weak positive correlation exists between percent surface water systems in the county and ovarian cancer incidence rates for women 54 years old and younger. As shown in Figure 4-5, the result shows that ovarian cancer incidence rates increase as the percentage of the county that has surface water systems increase (see Table 4-9). Also, a moderate positive relationship exists between percentage of surface water systems in county and total water area in county ($r = 0.372$). The correlation is significant at the 0.01 significance level (2-tailed). A positive correlation between percentage of county that has surface water systems and ovarian cancer incidence rates could mean that counties with many or large surface water bodies tend to have more water bodies designated as drinking water sources. These drinking water sources are potentially vulnerable to atrazine runoff (Information Ventures, Inc., 1995).

No agricultural statistical districts have relationships between percent rural population of agricultural statistical district (see Table 4-8) and percent surface water systems in agricultural statistical district (see Table 4-10) and breast and ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older. A reason why significant relationships are not seen at the agricultural statistical district level for these exposure variables are because the agricultural statistical district level is a weighted average of counties; therefore, it is possible for weak relationships at the county level to disappear at the agricultural statistical district level.

Five correlations resulted from county atrazine exposure variables and county breast and ovarian cancer incidence rates. All the county-significant correlations were weak. Four were negative correlations and one was a positive correlation. Pounds of atrazine per person in each county and percent population in county that is rural correlates negatively with breast cancer incidence rates for women 54 years old and younger. Percent county population that is rural correlates negatively with ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older. Percent of the county that has surface water systems correlates positively with ovarian cancer incidence rates for women 54 years old and younger. There is one significant correlation at the agricultural statistical district level. There is a moderate negative correlation between pounds of atrazine by square mile weighted by area and ovarian cancer incidence rates for women 54 years old and younger. There are no other significant correlations between agricultural statistical district atrazine exposure variables and agricultural statistical district breast and ovarian cancer incidence rates.

CHAPTER V

CONCLUSIONS & RECOMMENDATIONS

Summary

Some published studies believe atrazine increases breast and ovarian cancer risk in women (Donna et al., 1989; Kettles et al., 1997). This study using Spearman rank correlation show five significant correlations between county atrazine exposure variables: atrazine usage, percent surface water systems, and percent rural county population and county breast and ovarian cancer incidence rates. Atrazine usage is used because of its heavy usage on certain agricultural crops in various counties and agricultural statistical districts in Texas. Pounds of atrazine per person in each county and percentage of county population that is rural correlates negatively with breast cancer incidence rates for women 54 years old and younger. Percentage of county population that is rural correlates negatively with ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older. Percentage of the county that has surface water systems correlates positively with ovarian cancer incidence rates for women 54 years old and younger. There is one significant correlation at the agricultural statistical district level. There is a moderate negative correlation between average pounds of atrazine by square mile weighted by area and ovarian cancer incidence rates for women 54 years old and younger. Since atrazine is most commonly found in surface drinking water it poses a major public health concern that has the potential to adversely affect large populations in Texas (Information Ventures, 1995; Texas Center for Policy Studies, 1999). There are no other correlations between agricultural statistical district atrazine exposure variables and agricultural statistical district breast and ovarian cancer incidence rates.

Conclusion

Spearman rank correlation coefficient analyses were conducted using atrazine exposure variables for each county and agricultural statistical district and breast and ovarian cancer rates for women 54 years old and younger and 55 years old and older for each Texas county and agricultural statistical district. Since five correlations resulted from county atrazine exposure variables and county breast and ovarian cancer incidence rates, the null hypothesis that there are no associations between atrazine exposure variables and breast and ovarian cancer rates is rejected. All five county correlations are at least significant at the 0.05 significance level (2-tailed). All five are weak; four are negative correlations and one is a positive correlation. When pounds of atrazine per person in each county and percent of county population that is rural increase breast cancer incidence rates for women 54 years old and younger decrease. When the percentage of the county population that is rural increases ovarian cancer incidence rates for women 54 years old and younger and 55 years old and older decreases. When percentage of county that has surface water systems increase ovarian cancer incidence rates for women 54 years old and older also increase.

There is one moderate correlation at the agricultural statistical district level. The null hypothesis there are no associations between atrazine exposure variables and breast and ovarian cancer rates at the agricultural statistical district level; therefore is rejected. When pounds of atrazine by square mile weighted by area increase then ovarian cancer incidence rates for women 54 years old and younger decrease at the agricultural statistical district level. There are no correlations among the remainder of the atrazine exposure variables and breast and ovarian cancer incidence rates. It is possible that variables that were weakly correlated at the county level were not strong enough to be correlated at the agricultural statistical district level. Even though agricultural statistical districts are counties organized into groups that share common geography, economics, and crop production the counties are still very different when it comes to sharing similar atrazine exposures and breast and ovarian cancer incidence rates.

Discussion and Implications

Findings in this study are similar to previous studies that have shown an overall weak relationship between atrazine exposure and cancer. This study does not have any strong relationships that cancer results from atrazine exposure and due to study limitations, inherent in ecological studies; this study precludes any statement of causal inference (EPAe, 2005; Kettles et al., 1997).

Kettles et al. (1997) found a modest association between high triazine herbicide exposure and counties with increased incidence of female breast cancer rates. In this study, a weak negative association was found between increased pounds of atrazine per person exposure and counties with increased incidence of female breast cancer rates for women 54 years old and younger. An explanation for the difference in results is that this study did not control for covariates such as water contamination, corn planted, and demographic data as in the Kettles et al. study (1997).

The second Kentucky study found an inverse association between atrazine exposure indices and ovarian cancer incidence rates at the county and area development district level (Hopenhayn-Rich, Stump, & Browning, 2002). This study found an inverse association between pounds of atrazine by square mile weighted by area and ovarian cancer incidence rates at the agricultural statistical district level. Hopenhayn-Rich, Stump, & Browning study also controlled for water contamination, corn planted, and demographic data (2002). However, the two studies had similar results. Breast cancer incidence rates for women 54 years old and younger in each county reflect the urban/rural differences in breast cancer incidence, with rural counties tending to have lower rates than urban counties. Conversely, ovarian cancer incidence rates had no association with percent rural population at the district level.

In addition, a California study found positive associations between organochlorines methoxychlor and toxaphene and breast cancer incidence rates and no associations between atrazine and simazine and breast cancer incidence rates (Mills & Yang, 2006). Therefore, the results of this study are similar to other published works that studied the association between atrazine exposure and cancer incidence rates.

In this study, there was no association between breast and ovarian cancer incidence rates and five atrazine usage variables: average pounds of atrazine by square mile at the county level; total pounds of atrazine at the county level; average pounds of atrazine by square mile weighted by population at the agricultural statistical district level; total pounds of atrazine in agricultural statistical districts weighted by population; and pounds of atrazine per person weighted by population at the agricultural statistical district level. A reason as to why no associations were found with these atrazine usage variables could be because of the ecological nature of this study it did not control for other potential breast and ovarian cancer risk factors and other socioeconomic factors that increase or decrease breast and ovarian cancer risk. Study findings support many other studies that found no association between atrazine exposure and cancer (MacLennan et al., 2002; MacLennan et al., 2003; Rusiecki et al., 2004; Brown et al., 1993; Mills & Yang, 2006). Researchers found no increase in leukemia, colon cancer, or myeloma in white non-Hispanic men exposed to atrazine (Snedeker, 2001). One study found an association between pesticide exposure and cancer only after adjusting for potential exposures to other commonly used pesticides (Burmeister, 1990). Even though these studies did not find convincing evidence of a causal relationship between triazine exposure and any type of cancer, further studies are needed (Snedeker and Clark, 2005). This study did have many restrictions with procuring secondary data, but Spearman rank correlation analysis did provide the groundwork for additional atrazine exposure and breast and ovarian cancer research and monitoring to be conducted focusing on Texas counties and Texas agricultural statistical districts.

Breast cancer and ovarian cancer incidence rates for all ages are negatively associated with percent rural population in county. Even though percent rural population in county is not statistically significant for breast cancer incidence rates for women 55 year old and older it is still negatively correlated with percent rural population in county. Percent rural population and pounds of atrazine per person were compared. A weak positive relationship is present between percentage rural population and atrazine pounds per person ($r=0.194$; p, 0.002). As percent rural population increases, pounds of atrazine per person increases, which is understandable because most agriculture is in rural populated areas. Percent rural population in county also could be considered an established risk factor for breast cancer risk. A study in California found that breast cancer incidence rates were higher in suburban and city areas than in small town/rural areas (Reynolds et al., 2005b). The study is similar to the inverse relationship between percentage of county population that is rural and breast cancer incidence rates for women 54 years old and younger found in this study. Pounds of atrazine by square mile in county correlate negatively with percentage of a county population that is considered rural ($r=-0.246$) and significant at the 0.01 significance level (2-tailed). This means that pounds of atrazine by square mile increase as a county's rural population decrease. Which shows atrazine use to be slightly higher in counties with higher urban populations.

Since a weak positive correlation exists between percentage of county that has surface water systems and ovarian cancer incidence rates for women 54 years old and younger and a moderate positive percentage of surface water systems in a county and total water area in county, then percentage of surface water systems and total water area in county were compared to pounds of atrazine per person in county. A negative relationship is present between percentage of surface water systems in county and pounds of atrazine per person in county (r=-0.137; p,0.029). A weak negative relationship is also present between total water area in county and pounds of atrazine per person (r=-0.219) and significant at the 0.01 significance level (2-tailed). A possible explanation why pounds of atrazine per person increase when percentage of surface water systems and total water area in county decrease, may simply be due to the fact that as surface water systems increase there is less land area available for atrazine application.

This study uses cancer incidence rates (1998-2002) for women 54 years old and younger and women 55 years old and older. In this study, five relationships are significant at least at the 0.05 significance level (2-tailed) using breast and ovarian cancer incidence rates for women 54 years old and younger. One relationship was significant using ovarian cancer incidence rates for women 55 years old and older. More atrazine exposure variables were correlated with breast and ovarian cancer rates for women 54 years old and younger.

Strengths of the study are that cancer rates are not usually studied at the Texas agricultural statistical district level. Even though this study took a crude look at the relationship between atrazine exposure variables and county breast and ovarian cancer incidence rates in Texas counties and Texas agricultural statistical districts, breast and ovarian cancer rates have never been studied at an agricultural statistical district level before in Texas. 2000 U.S. age adjusted breast and ovarian cancer incidence rates for each Texas agricultural statistical district had to be created by David Risser, Ph.D., M.P.H. at the Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services (2006a). The Texas Cancer Registry now has a database ready for anyone that wants cancer incidence and mortality cases and rates information for Texas agricultural statistical districts. Secondary atrazine exposure variables percent rural population and surface water systems supported primary atrazine usage variables.

A major weakness in the study is that all the information in the study was secondary information, which makes it difficult to verify if there were any mistakes recorded during primary data collection. Also, the study is compromised because no atrazine data and zero atrazine use data in pounds per square mile for twenty-seven counties are lumped together (Battaglin and Goolsby, 1995). Not every person in a county or agricultural statistical district received equal amounts of atrazine exposure. Since this was an ecological study the assumption was that everyone was equally exposed. Assuming that associations seen on the group level also hold on an individual level leads to ecological bias (Oskasha, 2005). Confounding factors such as a family history of cancer and other environmental exposures that increase breast and ovarian cancer risk, such as pesticides or radiation, could have weakened the study.

Population shifts in counties and agricultural statistical districts can create misclassifications (Kettles et al., 1997). Therefore, it cannot be assumed that a woman has lived in a particular county long enough to be exposed to atrazine in that county or if she was exposed to atrazine in another county. Adjustments were unable to be made to control for migration. Also, using the assumption that every person in the county was equally exposed to atrazine in order to calculate atrazine per person may have weakened the results. Persons that live closer to atrazine exposures could potentially be exposed to more atrazine than persons that do not live near atrazine exposures in the same county.

One study evaluated residential proximity to agricultural pesticide use and incidence of breast cancer; however, the study provided no evidence that women living in areas of recent high agricultural pesticide use have an increase risk for breast cancer than women who live in areas with a history of little to no agricultural pesticide use (Reynolds et al., 2005a).

Farming practices and weed control practices are not known for each farm operation by county. Some farmer operations may have applied large amounts of atrazine to their crops, but very little to no atrazine ran off into nearby water bodies. Conversely, some farm operations may not have applied much atrazine to their crops, but they did not use best management practices in applying herbicides so most of the herbicide ran off into nearby water bodies.

Another weakness of the study is that the primary route of atrazine exposure is through drinking water and MCLs for atrazine and other herbicides in drinking water are not readily available in Texas. EPA National Primary Drinking Water Regulations cover atrazine and ten other herbicides: alachlor, 2,4-D, dalapon, dinosep, diaquat, endothall, glyphosate, picloram, 2,4,5-TP (Silvex), and simazine (EPA, 2006). Another confounding factor is that exposures to some of these herbicides that potentially increase cancer risk were not accounted for in this study. According to the EPA MCL List, alachlor is the only herbicide listed that increases cancer risk. The EPA believes that there is not enough sufficient evidence to conclude that the other herbicides increase cancer risk (EPA, 2006).

Another factor that furthers complicates the water data is that many public water systems distribute water to many different counties and in fact may not even use local water bodies as their source of water. Public water system's finished drinking water could potentially be a mix of threatened and non-threatened surface and ground water sources and possibly filtered through granular activated carbon that reduces atrazine (A. Cherepon, personal communication, May 23, 2005, IL Dept. PH, 2005).

Recommendations

This atrazine exposure and breast and ovarian cancer relationship study should be repeated when more accurate atrazine usage data for each county, data where atrazine is applied, and data on MCL for atrazine in drinking water are attainable. This estimated atrazine usage study should be compared to an actual atrazine usage study to measure any significant differences. Three inverse relationships were seen between rural populations and breast and ovarian cancer rates and a positive relationship is seen between rural population and pounds of atrazine per person. A follow-up to this study could compare pounds of atrazine per person in urbanized areas or urban clusters and pounds of atrazine per person in rural areas in the same county.

In the future, Spearman rank correlations could be used to find relationships between atrazine exposure variables and other health problems associated with atrazine exposure such as prostate cancer, non-Hodgkin's lymphoma, and men with breast cancer in Texas counties and agricultural statistical districts (EPA, 2005c; Environmental Working Group, 2000; Agency for Toxic Substances and Disease Registry, 2004; Kirsh

& Solomon, 2000; Hoar, 1985; De Roos, 2003). The study should identify persons that live or work in close proximity to atrazine. Also, potential studies should determine how many public water systems reduced or eliminated atrazine from contaminating their potable water by using filters containing granular activated carbon and also evaluate if those filter systems are being serviced regularly to ensure that they are working properly (IL Dept. PH, 2005).

Other herbicides should be included in future atrazine and cancer studies. The EPA health standards that regulate toxic chemicals in drinking water do not account for simultaneous exposure to many different contaminants commonly found in drinking water, seasonal peaks are ignored, and potential exposure of vulnerable infants, children, and sensitive adult organ systems, such as the endocrine, immune, and nervous systems, are not taken into consideration (PMEP, 2005b). A future study should evaluate atrazine exposure using consumer confidence reports, if women who are 54 years old and younger who live in counties with water bodies that exceed the 3.0 ppb MCL for atrazine in finished drinking water are at a greater risk of breast and ovarian cancer compared to women 54 years old and younger who live in counties that have no water bodies that exceeded the 3.0 ppb MCL set for atrazine in finished drinking water.

Upcoming studies should take best management practices into consideration that could potentially reduce or prevent atrazine run off contamination of surface and groundwater. Precautions such as properly constructed wells, riparian barriers, increased distance from surface waters, and appropriate herbicide handling practices could substantially decrease atrazine run off into water bodies (IL Dept. PH, 2005). Counties and agricultural statistical districts best management practices should be compared among each other to measure potential adverse health effects that are assumed to be association with atrazine exposure.

The Aquilla Public Water System, was on the 303(d) List in 1998 and 2000, has with the cooperation from state and local officials, farmers, and atrazine manufactures implemented best management practices mentioned similar to the ones mentioned above to keep Aquilla Public Water System atrazine levels below the 3.0 ppb MCL and MCLG. It is located in Hill County, in the Blacklands Agricultural Statistical District, and serves as the primary drinking water source for those residents. The Aquilla Public water system has now reported limits below the 3.0 ppb MCL since 2003 (TCEQ, 2003).

Spearman rank correlation coefficient analyses conducted using atrazine exposure variables for each county and agricultural statistical district and breast and ovarian cancer rates for women 54 years old and younger and 55 years old and older for each Texas county and agricultural statistical district proved to be significant for five correlations; four of which are negative and one positive at the county level. One negative correlation exists at the agricultural statistical district level. Study results are similar to weak associations found in other published studies. It should be suggested that further atrazine usage cancer correlation research should be done as more accurate data on atrazine usage becomes accessible.

APPENDIX

TABLES AND FIGURES

Table 2-1

A Few Trade Names and Synonyms for Atrazine [a]

Aatrex	Atred	Fenatrol	Radazin
Actinite PK	Candex	Gesaprim	Strazine
Akticon	Cekuzina-T	Griffex	Vectal
Argezin	Chromozin	Hungazin	Weedex A
Atazinax	Crisatrina	Inakor	Wonuk
Atranex	Cyazin	Pitezin	Zeapos
Atrataf	Fenamin	Primatol	Zeazin

[a] EPA, 2005b.

Table 2-2

Water Bodies on 303(d) List for Atrazine in Finished Drinking Water 1998 and 2000 [a]

County	Water Bodies on 303(d) List for Atrazine in 1998 and 2000
Delta	Big Creek Lake
Van Zandt, Rain, Hurst	Lake Tawakoni
Ellis	Bardwell Reservoir
Ellis	Lake Waxahachie
Collin	Lake Lavon
Navarro	Richland-Chambers Reservoir
Tarrant, Ellis, Dallas	Joe Pool Lake
Hill	Aquilla Reservoir

[a] Texas Commission on Environmental Quality 1998 and 2000 303(d) List, 2005c.

Table 3-1

County Breast and Ovarian Cancer Incidence Rates for Women 54 Years Old and Younger and 55 Years Old and Older (1998-2002) U.S. 2000 Age-Adjusted Grouped by Agricultural Statistical Districts [a]

Code/District	Counties	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
11-Northern High Plains	188-Potter	55.1	370.5	7.4	43.3
11-Northern High Plains	191-Randall	61.6	388.3	4.4	51.0
11-Northern High Plains	117-Hutchinson	50.8	315.2	4.2	33.9
11-Northern High Plains	090-Gray	58.0	378.0	0.0	23.3
11-Northern High Plains	106-Hemphill	36.9	409.9	12.4	0.0
11-Northern High Plains	148-Lipscomb	35.1	566.4	0.0	46.1
11-Northern High Plains	197-Roberts	0.0	605.4	0.0	0.0
11-Northern High Plains	171-Moore	23.7	400.7	8.8	38.3
11-Northern High Plains	059-Deaf Smith	67.3	322.2	6.3	39.4
11-Northern High Plains	095-Hale	53.1	302.1	4.7	43.8
11-Northern High Plains	179-Ochiltree	64.7	235.0	0.0	35.7
11-Northern High Plains	006-Armstrong	0.0	342.7	0.0	0.0
11-Northern High Plains	219-Swisher	48.7	219.8	0.0	55.2
11-Northern High Plains	023-Briscoe	121.9	285.8	0.0	0.0
11-Northern High Plains	077-Floyd	16.4	332.4	8.3	40.3
11-Northern High Plains	033-Carson	50.7	312.9	0.0	90.1
11-Northern High Plains	180-Oldham	29.9	375.1	0.0	145.3
11-Northern High Plains	098-Hansford	52.2	362.7	11.0	34.4
11-Northern High Plains	056-Dallam	116.2	494.3	0.0	123.6

Code/District	Counties	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
11-Northern High Plains	103-Hartley	12.2	127.3	0.0	0.0
11-Northern High Plains	185-Parmer	48.5	366.7	6.1	0.0
11-Northern High Plains	211-Sherman	0.0	382.6	0.0	0.0
11-Northern High Plains	035-Castro	38.3	209.4	0.0	78.9
12-Southern High Plains	156-Martin	58.4	349.9	0.0	34.0
12-Southern High Plains	165-Midland	46.2	328.6	3.5	43.5
12-Southern High Plains	114-Howard	49.0	388.7	8.7	46.1
12-Southern High Plains	152-Lubbock	47.1	368.2	7.0	35.1
12-Southern High Plains	002-Andrews	51.8	362.6	8.0	0.0
12-Southern High Plains	058-Dawson	48.5	294.9	4.7	13.5
12-Southern High Plains	141-Lamb	37.9	339.8	0.0	28.6
12-Southern High Plains	223-Terry	24.5	243.5	5.0	0.0
12-Southern High Plains	083-Gaines	42.8	268.2	9.0	44.0
12-Southern High Plains	251-Yoakum	71.4	507.1	0.0	24.2
12-Southern High Plains	054-Crosby	45.2	292.4	7.6	55.0
12-Southern High Plains	153-Lynn	9.8	292.0	0.0	48.1
12-Southern High Plains	110-Hockley	32.0	339.7	2.4	45.7
12-Southern High Plains	040-Cochran	31.9	385.6	0.0	35.3
12-Southern High Plains	009-Bailey	99.2	588.5	0.0	18.4
12-Southern High Plains	087-Glasscock	79.7	374.7	0.0	0.0
21-Northern Low Plains	078-Foard	81.7	218.8	0.0	0.0
21-Northern Low Plains	243-Wichita	42.7	377.6	7.4	44.1
21-Northern Low Plains	244-Wilbarger	39.6	297.8	7.6	35.8
21-Northern Low Plains	038-Childress	47.2	255.9	0.0	25.1

Code/District	Counties	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
21-Northern Low Plains	099-Hardeman	34.2	413.0	11.2	51.1
21-Northern Low Plains	085-Garza	58.0	235.6	0.0	22.8
21-Northern Low Plains	065-Donley	26.4	384.8	0.0	70.4
21-Northern Low Plains	096-Hall	13.5	489.1	16.5	0.0
21-Northern Low Plains	044-Collingsworth	53.0	325.5	0.0	64.2
21-Northern Low Plains	063-Dickens	19.1	472.8	27.0	0.0
21-Northern Low Plains	051-Cottle	146.6	421.5	29.2	0.0
21-Northern Low Plains	173-Motley	96.6	210.1	0.0	55.2
21-Northern Low Plains	132-Kent	0.0	517.4	0.0	57.2
21-Northern Low Plains	242-Wheeler	58.6	137.8	0.0	30.2
21-Northern Low Plains	017-Borden	0.0	190.6	0.0	0.0
21-Northern Low Plains	135-King	0.0	702.1	0.0	0.0
22-Southern Low Plains	208-Scurry	68.1	342.8	4.2	8.8
22-Southern Low Plains	221-Taylor	63.7	388.5	7.6	52.5
22-Southern Low Plains	177-Nolan	58.2	382.9	7.4	58.0
22-Southern Low Plains	168-Mitchell	7.0	294.7	7.0	17.9
22-Southern Low Plains	076-Fisher	16.3	308.9	16.4	15.1
22-Southern Low Plains	012-Baylor	77.6	280.3	16.3	30.9
22-Southern Low Plains	127-Jones	43.4	265.4	3.2	15.4
22-Southern Low Plains	217-Stonewall	29.6	270.0	0.0	119.6
22-Southern Low Plains	200-Runnels	61.5	322.4	4.6	38.3
22-Southern Low Plains	042-Coleman	17.4	302.4	5.8	0.0
22-Southern Low Plains	104-Haskell	38.9	314.2	11.1	87.6
22-Southern Low Plains	138-Knox	27.4	156.4	0.0	64.2

Code/District	Counties	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
30-Cross Timbers	111-Hood	60.7	496.0	5.4	71.7
30-Cross Timbers	184-Parker	49.9	342.0	2.9	43.5
30-Cross Timbers	249-Wise	49.9	337.8	6.7	45.0
30-Cross Timbers	025-Brown	47.3	362.2	4.7	30.2
30-Cross Timbers	213-Somervell	67.6	328.1	15.0	27.8
30-Cross Timbers	072-Erath	36.3	315.4	1.9	16.0
30-Cross Timbers	182-Palo Pinto	31.5	336.3	10.4	65.1
30-Cross Timbers	067-Eastland	51.6	351.0	6.4	24.5
30-Cross Timbers	169-Montague	38.6	300.6	6.2	6.4
30-Cross Timbers	252-Young	66.6	360.6	9.0	69.0
30-Cross Timbers	030-Callahan	47.5	360.4	13.7	36.4
30-Cross Timbers	215-Stephens	93.9	358.7	6.1	0.0
30-Cross Timbers	005-Archer	33.9	493.4	0.0	31.5
30-Cross Timbers	039-Clay	36.7	178.0	8.8	12.2
30-Cross Timbers	119-Jack	43.6	338.4	0.0	55.0
30-Cross Timbers	167-Mills	59.1	242.0	0.0	14.5
30-Cross Timbers	209-Shakelford	94.1	363.8	0.0	26.3
30-Cross Timbers	047-Comanche	37.3	253.0	4.7	14.3
30-Cross Timbers	224-Throckmorton	33.1	306.9	0.0	0.0
40-Blacklands	057-Dallas	61.2	407.9	5.6	41.8
40-Blacklands	161-McLennan	59.3	377.6	5.2	30.7
40-Blacklands	220-Tarrant	57.4	393.1	4.8	42.5
40-Blacklands	071-Ellis	43.8	362.4	4.9	45.4
40-Blacklands	129-Kaufman	56.3	436.1	2.8	49.7
40-Blacklands	061-Denton	42.1	332.0	3.3	31.7
40-Blacklands	140-Lamar	51.2	309.2	2.1	14.1
40-Blacklands	199-Rockwall	45.3	313.8	5.3	46.8
40-Blacklands	126-Johnson	54.8	441.5	2.5	34.4
40-Blacklands	043-Collin	55.1	387.8	3.9	40.0
40-Blacklands	091-Grayson	47.4	402.8	3.3	49.7
40-Blacklands	116-Hunt	52.4	337.7	5.7	44.9
40-Blacklands	050-Coryell	38.8	432.1	3.7	21.7
40-Blacklands	014-Bell	59.2	378.9	7.7	35.2
40-Blacklands	246-Williamson	49.9	397.1	2.7	44.4
40-Blacklands	175-Navarro	61.1	334.2	7.5	27.6
40-Blacklands	049-Cooke	53.5	391.2	6.1	16.0
40-Blacklands	147-Limestone	55.8	348.9	10.3	37.2
40-Blacklands	060-Delta	42.6	322.7	0.0	12.4
40-Blacklands	018-Bosque	40.8	351.4	10.0	48.1
40-Blacklands	097-Hamilton	49.4	246.1	0.0	54.4
40-Blacklands	074-Fannin	68.1	440.3	0.0	74.6
40-Blacklands	109-Hill	41.1	385.7	10.6	27.0
40-Blacklands	073-Falls	25.6	250.8	9.3	57.8
40-Blacklands	166-Milam	40.9	320.1	4.6	61.7
51-North East Texas	080-Franklin	40.7	372.6	6.5	82.0
51-North East Texas	092-Gregg	69.1	485.7	7.9	53.8

Code/District	Counties	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
51-North East Texas	019-Bowie	53.9	392.2	5.7	34.1
51-North East Texas	107-Henderson	48.4	373.7	1.5	42.9
51-North East Texas	212-Smith	65.6	442.2	5.4	51.0
51-North East Texas	001-Anderson	68.9	414.4	6.4	63.6
51-North East Texas	032-Camp	70.3	486.8	5.5	75.4
51-North East Texas	102-Harrison	51.8	235.7	2.5	36.5
51-North East Texas	172-Morris	60.9	287.3	0.0	22.5
51-North East Texas	174-Nacogdoches	63.1	374.7	3.1	48.1
51-North East Texas	201-Rusk	50.7	317.8	7.3	29.8
51-North East Texas	225-Titus	65.3	330.0	4.0	22.8
51-North East Texas	230-Upshur	49.1	341.5	6.0	32.9
51-North East Texas	234-Van Zandt	49.7	409.0	8.5	28.3
51-North East Texas	250-Wood	56.3	343.8	9.3	22.2
51-North East Texas	037-Cherokee	42.5	347.0	1.2	59.8
51-North East Texas	112-Hopkins	55.9	346.8	6.7	54.6
51-North East Texas	190-Rains	42.7	326.0	6.1	56.3
51-North East Texas	034-Cass	54.6	327.7	3.4	32.1
51-North East Texas	183-Panola	56.9	289.7	7.1	37.9
51-North East Texas	210-Shelby	50.2	297.7	0.0	41.5
51-North East Texas	113-Houston	93.3	480.8	17.2	22.5
51-North East Texas	194-Red River	74.6	336.2	0.0	30.0
51-North East Texas	155-Marion	44.3	210.0	9.5	58.6
52-South East Texas	170-Montgomery	50.6	367.2	4.0	35.0
52-South East Texas	228-Trinity	55.3	311.6	4.0	30.1
52-South East Texas	003-Angelina	56.2	347.3	3.3	42.8
52-South East Texas	236-Walker	90.6	316.6	6.8	28.3
52-South East Texas	100-Hardin	38.9	373.6	3.3	35.6
52-South East Texas	237-Waller	57.4	250.2	0.0	59.1
52-South East Texas	021-Brazos	58.0	455.2	3.6	40.8
52-South East Texas	121-Jasper	61.6	302.7	4.6	47.3
52-South East Texas	187-Polk	50.3	421.8	8.4	45.2
52-South East Texas	204-San Jacinto	45.3	264.2	0.0	0.0
52-South East Texas	093-Grimes	49.0	363.0	2.8	78.2
52-South East Texas	154-Madison	33.3	269.7	6.5	22.5
52-South East Texas	202-Sabine	47.2	370.4	6.8	46.6
52-South East Texas	229-Tyler	40.0	299.3	10.2	68.5
52-South East Texas	081-Freestone	27.6	387.6	0.0	60.9
52-South East Texas	176-Newton	25.5	289.2	7.2	9.2
52-South East Texas	203-San Augustine	40.6	237.6	0.0	58.8
52-South East Texas	145-Leon	47.1	346.1	7.3	7.3
52-South East Texas	198-Robertson	39.1	380.0	10.8	32.2
60-Trans-Pecos	022-Brewster	82.9	393.7	5.3	16.1
60-Trans-Pecos	052-Crane	36.3	443.6	0.0	0.0
60-Trans-Pecos	055-Culberson	54.8	175.2	0.0	0.0
60-Trans-Pecos	122-Jeff Davis	20.2	224.6	0.0	60.3
60-Trans-Pecos	151-Loving	613.5	0.0	0.0	0.0

Code/District	Counties	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
60-Trans-Pecos	189-Presidio	0.0	328.9	0.0	70.7
60-Trans-Pecos	195-Reeves	31.3	232.7	0.0	37.9
60-Trans-Pecos	222-Terrell	0.0	107.0	0.0	0.0
60-Trans-Pecos	238-Ward	42.3	305.9	0.0	44.8
60-Trans-Pecos	248-Winkler	52.6	577.4	15.2	0.0
60-Trans-Pecos	068-Ector	48.4	410.7	6.2	43.8
60-Trans-Pecos	070-El Paso	55.2	319.8	5.7	46.6
60-Trans-Pecos	186-Pecos	40.0	219.7	12.1	39.3
60-Trans-Pecos	115-Hudspeth	56.2	400.1	0.0	61.9
70-Edwards Plateau	016-Blanco	85.0	446.1	6.1	22.8
70-Edwards Plateau	053-Crockett	36.5	428.9	0.0	41.9
70-Edwards Plateau	069-Edwards	71.9	247.2	22.8	0.0
70-Edwards Plateau	118-Irion	29.7	228.3	28.1	0.0
70-Edwards Plateau	160-McCulloch	41.1	313.9	0.0	51.8
70-Edwards Plateau	193-Real	102.2	408.1	0.0	33.0
70-Edwards Plateau	216-Sterling	0.0	368.3	0.0	0.0
70-Edwards Plateau	218-Sutton	34.9	216.2	14.9	0.0
70-Edwards Plateau	233-Val Verde	52.0	243.0	6.1	38.7
70-Edwards Plateau	130-Kendall	101.5	559.0	6.2	58.2
70-Edwards Plateau	133-Kerr	59.5	363.3	7.1	40.3
70-Edwards Plateau	010-Bandera	53.0	312.3	2.6	48.3
70-Edwards Plateau	086-Gillespie	50.8	425.2	4.9	39.9
70-Edwards Plateau	150-Llano	41.6	407.2	7.2	43.2
70-Edwards Plateau	226-Tom Green	38.8	378.3	6.4	35.5
70-Edwards Plateau	206-San Saba	33.8	320.8	0.0	35.3
70-Edwards Plateau	041-Coke	30.5	201.0	0.0	52.3
70-Edwards Plateau	157-Mason	62.7	265.1	0.0	0.0
70-Edwards Plateau	134-Kimble	49.0	353.2	0.0	26.9
70-Edwards Plateau	192-Reagan	42.7	538.1	0.0	51.7
70-Edwards Plateau	231-Upton	50.3	573.1	0.0	0.0
70-Edwards Plateau	164-Menard	120.1	335.1	0.0	0.0
70-Edwards Plateau	136-Kinney	18.7	323.5	0.0	76.9
70-Edwards Plateau	207-Schleicher	15.6	575.2	0.0	0.0
70-Edwards Plateau	142-Lampasas	58.8	366.3	2.9	27.0
70-Edwards Plateau	048-Concho	36.5	291.8	23.2	0.0
70-Edwards Plateau	232-Uvalde	56.4	267.4	2.4	21.1
70-Edwards Plateau	027-Burnet	90.6	569.2	1.7	25.9
81-South Central	227-Travis	66.5	426.2	4.8	42.9
81-South Central	011-Bastrop	62.9	354.8	6.3	14.1
81-South Central	239-Washington	54.0	382.7	5.4	21.3
81-South Central	008-Austin	57.2	428.9	2.2	40.3
81-South Central	015-Bexar	58.6	369.9	5.7	38.4
81-South Central	105-Hays	58.3	432.8	4.6	35.3
81-South Central	046-Comal	54.5	348.3	5.9	34.0
81-South Central	028-Caldwell	68.3	309.8	11.6	45.7
81-South Central	094-Guadalupe	45.2	355.6	4.2	27.8
81-South Central	026-Burleson	40.6	333.9	3.3	53.1

Code/District	Counties	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
81-South Central	144-Lee	32.8	353.3	4.0	8.5
81-South Central	062-De Witt	56.0	305.8	0.0	36.2
81-South Central	143-Lavaca	46.9	386.3	8.8	54.8
81-South Central	089-Gonzales	62.6	429.8	3.4	54.6
81-South Central	247-Wilson	44.7	307.1	8.0	11.9
81-South Central	013-Bee	32.7	251.2	2.1	7.5
81-South Central	088-Goliad	37.1	166.0	0.0	75.2
81-South Central	163-Medina	56.8	405.5	4.6	51.7
81-South Central	075-Fayette	62.1	385.9	9.3	42.1
81-South Central	045-Colorado	42.1	397.3	7.5	42.5
81-South Central	128-Karnes	29.7	322.6	5.4	44.3
82-Coastal Bend	137-Kleberg	48.5	266.3	3.6	54.5
82-Coastal Bend	178-Nueces	53.6	313.3	4.3	36.7
82-Coastal Bend	004-Aransas	62.3	353.3	2.1	33.0
82-Coastal Bend	205-San Patricio	49.8	260.8	5.6	44.2
82-Coastal Bend	196-Refugio	40.6	247.7	13.4	12.7
90-Upper Coast	101-Harris	58.8	390.9	5.2	43.5
90-Upper Coast	123-Jefferson	51.1	375.5	4.4	40.0
90-Upper Coast	181-Orange	41.5	341.4	4.3	40.1
90-Upper Coast	084-Galveston	61.3	415.0	5.9	32.3
90-Upper Coast	036-Chambers	32.8	279.3	7.3	46.1
90-Upper Coast	020-Brazoria	60.1	442.6	5.7	34.9
90-Upper Coast	079-Fort Bend	55.6	307.6	4.3	39.4
90-Upper Coast	146-Liberty	58.4	357.3	4.6	34.8
90-Upper Coast	235-Victoria	61.1	356.4	4.4	52.2
90-Upper Coast	029-Calhoun	43.3	391.1	2.6	33.5
90-Upper Coast	158-Matagorda	53.3	416.8	2.8	36.9
90-Upper Coast	241-Wharton	50.6	345.3	11.1	43.9
90-Upper Coast	120-Jackson	58.2	310.6	0.0	42.1
96-South Texas	124-Jim Hogg	33.9	171.6	0.0	112.3
96-South Texas	131-Kenedy	0.0	297.0	0.0	0.0
96-South Texas	240-Webb	47.7	268.4	4.2	32.7
96-South Texas	159-Maverick	50.1	278.6	3.8	55.2
96-South Texas	253-Zapata	61.5	261.0	11.2	11.2
96-South Texas	024-Brooks	81.2	251.3	0.0	19.6
96-South Texas	007-Atascosa	30.7	270.9	5.7	36.2
96-South Texas	139-La Salle	12.8	218.5	0.0	60.3
96-South Texas	082-Frio	44.0	289.0	0.0	13.8
96-South Texas	125-Jim Wells	44.0	263.9	8.6	21.1
96-South Texas	254-Zavala	53.3	199.2	0.0	18.3
96-South Texas	064-Dimmit	44.3	208.4	0.0	35.1
96-South Texas	162-McMullen	0.0	197.2	0.0	0.0
96-South Texas	149-Live Oak	37.7	241.3	5.6	9.8
96-South Texas	066-Duval	44.4	363.4	4.4	48.1
97-Lower Valley	031-Cameron	38.7	249.7	4.6	36.8
97-Lower Valley	108-Hidalgo	42.5	251.2	4.7	46.0
97-Lower Valley	214-Starr	34.2	234.1	5.7	34.5

Code/District	Counties	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
97-Lower Valley	245-Willacy	45.4	228.7	8.5	47.7

[a] Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services, 2006a.

Table 3-2

Agricultural Statistical District Breast and Ovarian Cancer Incidence Rates for Women 54 Years Old and Younger and 55 Years Old and Older (1998-2002) U.S. 2000 Age-Adjusted [a]

District	Breast 0-54	Breast 55+	Ovarian 0-54	Ovarian 55+
11-Northern High Plains	54.0	351.9	5.0	41.9
12-Southern High Plains	46.0	352.7	5.5	35.8
21-Northern Low Plains	43.4	353.2	7.1	39.1
22-Southern Low Plains	56.2	346.3	6.8	41.8
30-Cross Timbers	49.1	351.4	5.3	39.2
40-Blacklands	56.1	390.5	4.9	40.5
51-North East Texas	58.6	378.3	5.4	42.9
52-South East Texas	52.2	356.2	4.2	39.0
60-Trans-Pecos	53.1	333.2	5.7	44.6
70-Edwards Plateau	55.6	382.9	5.1	36.5
81-South Central	59.3	379.0	5.3	38.2
82-Coastal Bend	53.1	305.1	4.5	37.9
90-Upper Coast	57.8	386.3	5.1	41.7
96-South Texas	45.7	264.8	4.5	33.3
97-Lower Valley	40.6	251.0	4.8	41.5
99-Texas	55.4	367.6	5.1	40.3

[a] Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services, 2006a.

Table 3-3

County Atrazine Exposure Variables Grouped by Agricultural Statistical Districts

Code/District	Counties	Total Population [a,c]	Ai (lbs)/ SqMi [d]	Total Ai (lbs) [a,d]	Ai [f] (lbs)/ Person [d]	% Rural [b,c]	% Surface Water PWS [a,e]
11-Northern High Plains	188-Potter	113546	1.17	1059.26	0.01	9.00	6.70
11-Northern High Plains	191-Randall	104312	7.90	7219.42	0.07	13.50	6.90
11-Northern High Plains	117-Hutchinson	23857	7.90	7005.79	0.29	23.40	9.10
11-Northern High Plains	090-Gray	22744	7.90	7328.77	0.32	20.90	6.70
11-Northern High Plains	106-Hemphill	3351	1.17	1059.78	0.32	100.00	0.00
11-Northern High Plains	148-Lipscomb	3057	1.17	1085.91	0.36	100.00	0.00
11-Northern High Plains	197-Roberts	887	1.17	1076.56	1.21	100.00	0.00
11-Northern High Plains	171-Moore	20121	32.91	29607.81	1.47	17.10	0.00
11-Northern High Plains	059-Deaf Smith	18561	32.91	49277.13	2.65	17.60	0.00
11-Northern High Plains	095-Hale	36602	108.05	108547.41	2.97	24.00	10.50
11-Northern High Plains	179-Ochiltree	9006	32.91	30196.57	3.35	14.60	0.00
11-Northern High Plains	006-Armstrong	2148	7.90	7213.11	3.36	100.00	0.00
11-Northern High Plains	219-Swisher	8378	32.91	29633.15	3.54	39.50	33.30
11-Northern High Plains	023-Briscoe	1790	7.90	7107.47	3.97	100.00	60.00
11-Northern High Plains	077-Floyd	7771	32.91	32652.97	4.20	50.40	50.00
11-Northern High Plains	033-Carson	6516	32.91	30382.18	4.66	96.40	0.00
11-Northern High Plains	180-Oldham	2185	7.90	11847.47	5.42	100.00	0.00
11-Northern High Plains	098-Hansford	5369	32.91	30270.62	5.64	43.30	0.00
11-Northern High Plains	056-Dallam	6222	32.91	49519.35	7.96	26.00	0.00
11-Northern High Plains	103-Hartley	5537	32.91	48122.65	8.69	57.10	0.00
11-Northern High Plains	185-Parmer	10016	108.05	95258.95	9.51	61.00	0.00

Code/District	Counties	Total Population [a,c]	Ai (lbs)/ SqMi [d]	Total Ai (lbs) [a,d]	Ai [f] (lbs)/ Person [d]	% Rural [b,c]	% Surface Water PWS [a,e]
11-Northern High Plains	211-Sherman	3186	32.91	30376.92	9.53	100.00	0.00
11-Northern High Plains	035-Castro	8285	108.05	97057.90	11.71	48.10	0.00
12-Southern High Plains	156-Martin	4746	0.00	0.00	0.00	47.50	40.00
12-Southern High Plains	165-Midland	116009	1.17	1048.79	0.01	12.90	3.70
12-Southern High Plains	114-Howard	33627	1.17	1051.81	0.03	21.60	57.10
12-Southern High Plains	152-Lubbock	242628	7.90	7101.47	0.03	12.50	5.80
12-Southern High Plains	002-Andrews	13004	1.17	1748.25	0.13	19.10	0.00
12-Southern High Plains	058-Dawson	14985	7.90	7121.76	0.48	18.00	25.00
12-Southern High Plains	141-Lamb	14709	7.90	8022.98	0.55	57.60	100.00
12-Southern High Plains	223-Terry	12761	7.90	7025.52	0.55	27.80	14.30
12-Southern High Plains	083-Gaines	14467	7.90	11861.05	0.82	58.50	0.00
12-Southern High Plains	251-Yoakum	7322	7.90	6314.03	0.86	40.10	0.00
12-Southern High Plains	054-Crosby	7072	7.90	7101.63	1.00	100.00	66.70
12-Southern High Plains	153-Lynn	6550	7.90	7041.39	1.08	56.90	33.30
12-Southern High Plains	110-Hockley	22716	32.91	29891.49	1.32	40.60	7.10
12-Southern High Plains	040-Cochran	3730	7.90	6120.36	1.64	100.00	0.00
12-Southern High Plains	009-Bailey	6594	32.91	27206.37	4.13	36.40	0.00
12-Southern High Plains	087-Glasscock	1406	7.90	7111.34	5.06	100.00	0.00
21-Northern Low Plains	078-Foard	1622	0.00	0.00	0.00	100.00	100.00
21-Northern Low Plains	243-Wichita	131664	1.17	731.22	0.01	7.50	100.00
21-Northern Low Plains	244-Wilbarger	14676	1.17	1131.28	0.08	23.20	25.00
21-Northern Low Plains	038-Childress	7688	1.17	827.55	0.11	33.60	100.00
21-Northern Low Plains	099-Hardeman	4724	1.17	810.12	0.17	40.80	100.00
21-Northern Low Plains	085-Garza	4872	1.17	1043.33	0.21	35.70	25.00

Code/District	Counties	Total Population [a,c]	Ai (lbs)/ SqMi [d]	Total Ai (lbs) [a,d]	Ai [f] (lbs)/ Person [d]	% Rural [b,c]	% Surface Water PWS [a,e]
21-Northern Low Plains	065-Donley	3828	1.17	1083.18	0.28	100.00	66.70
21-Northern Low Plains	096-Hall	3782	1.17	1052.09	0.28	100.00	57.10
21-Northern Low Plains	044-Collingsworth	3206	1.17	1070.40	0.33	100.00	0.00
21-Northern Low Plains	063-Dickens	2762	1.17	1053.40	0.38	100.00	100.00
21-Northern Low Plains	051-Cottle	1904	1.17	1049.87	0.55	100.00	0.00
21-Northern Low Plains	173-Motley	1426	1.17	1152.63	0.81	100.00	0.00
21-Northern Low Plains	132-Kent	859	1.17	1051.21	1.22	100.00	0.00
21-Northern Low Plains	242-Wheeler	5284	7.90	7218.08	1.37	100.00	0.00
21-Northern Low Plains	017-Borden	729	1.17	1047.09	1.44	100.00	0.00
21-Northern Low Plains	135-King	356	1.17	1062.82	2.99	100.00	0.00
22-Southern Low Plains	208-Scurry	16361	1.17	1051.41	0.06	33.00	42.90
22-Southern Low Plains	221-Taylor	126555	7.90	7228.90	0.06	13.60	88.20
22-Southern Low Plains	177-Nolan	15802	1.17	1062.46	0.07	29.00	57.10
22-Southern Low Plains	168-Mitchell	9698	1.17	1060.20	0.11	31.50	66.70
22-Southern Low Plains	076-Fisher	4344	1.17	1049.85	0.24	100.00	100.00
22-Southern Low Plains	012-Baylor	4093	1.17	1014.45	0.25	33.00	0.00
22-Southern Low Plains	127-Jones	20785	7.90	7350.17	0.35	60.70	100.00
22-Southern Low Plains	217-Stonewall	1693	1.17	1070.25	0.63	100.00	50.00
22-Southern Low Plains	200-Runnels	11495	7.90	8295.51	0.72	36.90	100.00
22-Southern Low Plains	042-Coleman	9235	7.90	9949.28	1.08	49.40	100.00
22-Southern Low Plains	104-Haskell	6093	7.90	7128.95	1.17	52.70	87.50
22-Southern Low Plains	138-Knox	4253	7.90	6702.86	1.58	100.00	85.70
30-Cross Timbers	111-Hood	41100	1.17	491.18	0.01	37.90	19.40
30-Cross Timbers	184-Parker	88495	1.17	1052.59	0.01	65.60	12.50
30-Cross Timbers	249-Wise	48793	1.17	1053.87	0.02	81.30	22.50
30-Cross Timbers	025-Brown	37674	1.17	1099.59	0.03	41.70	88.90

Code/District	Counties	Total Population [a,c]	Ai (lbs)/ SqMi [d]	Total Ai (lbs) [a,d]	Ai [f] (lbs)/ Person [d]	% Rural [b,c]	% Surface Water PWS [a,e]
30-Cross Timbers	213-Somervell	6809	1.17	218.05	0.03	100.00	0.00
30-Cross Timbers	072-Erath	33001	1.17	1265.57	0.04	43.20	16.70
30-Cross Timbers	182-Palo Pinto	27026	1.17	1110.16	0.04	47.60	77.80
30-Cross Timbers	067-Eastland	18297	1.17	1078.80	0.06	59.00	93.30
30-Cross Timbers	169-Montague	19117	1.17	1084.22	0.06	53.70	21.40
30-Cross Timbers	252-Young	17943	1.17	1074.51	0.06	31.90	83.30
30-Cross Timbers	030-Callahan	12905	1.17	1046.89	0.08	73.70	66.70
30-Cross Timbers	215-Stephens	9674	1.17	1042.26	0.11	35.10	100.00
30-Cross Timbers	005-Archer	8854	1.17	1059.80	0.12	88.80	100.00
30-Cross Timbers	039-Clay	11006	1.17	1278.96	0.12	73.10	55.60
30-Cross Timbers	119-Jack	8763	1.17	1067.85	0.12	51.80	33.30
30-Cross Timbers	167-Mills	5151	1.17	871.55	0.17	100.00	28.60
30-Cross Timbers	209-Shakelford	3302	1.17	1064.75	0.32	100.00	100.00
30-Cross Timbers	047-Comanche	14026	7.90	7403.06	0.53	70.00	71.40
30-Cross Timbers	224-Throckmorton	1850	1.17	1062.88	0.57	100.00	100.00
40-Blacklands	057-Dallas	2218899	7.90	6944.44	0.00	0.90	77.50
40-Blacklands	161-McLennan	213517	0.00	0.00	0.00	25.10	26.20
40-Blacklands	220-Tarrant	1446219	7.90	6816.70	0.00	1.80	27.60
40-Blacklands	071-Ellis	111360	1.17	1095.00	0.01	41.10	20.40
40-Blacklands	129-Kaufman	71313	1.17	915.74	0.01	66.20	95.70
40-Blacklands	061-Denton	432976	7.90	7015.02	0.02	11.50	19.10
40-Blacklands	140-Lamar	48499	1.17	1068.08	0.02	45.80	0.00
40-Blacklands	199-Rockwall	43080	7.90	1016.80	0.02	20.40	100.00
40-Blacklands	126-Johnson	126811	7.90	5758.77	0.05	45.00	10.60
40-Blacklands	043-Collin	491675	32.91	27893.20	0.06	10.10	67.50
40-Blacklands	091-Grayson	110595	7.90	7370.06	0.07	46.30	20.00
40-Blacklands	116-Hunt	76596	7.90	6640.96	0.09	55.30	88.50
40-Blacklands	050-Coryell	74978	7.90	8303.65	0.11	17.50	81.30
40-Blacklands	014-Bell	237974	32.91	34875.39	0.15	18.40	96.60
40-Blacklands	246-Williamson	249967	32.91	36950.36	0.15	16.50	28.30
40-Blacklands	175-Navarro	45124	7.90	7955.48	0.18	48.70	95.80
40-Blacklands	049-Cooke	36363	7.90	6897.31	0.19	57.60	4.50
40-Blacklands	147-Limestone	22051	7.90	7175.61	0.33	53.20	57.10
40-Blacklands	060-Delta	5327	7.90	2187.55	0.41	100.00	71.40
40-Blacklands	018-Bosque	17204	7.90	7809.50	0.45	79.10	0.00
40-Blacklands	097-Hamilton	8229	7.90	6597.93	0.80	64.60	16.70
40-Blacklands	074-Fannin	31242	32.91	29337.62	0.94	69.00	8.30
40-Blacklands	109-Hill	32321	32.91	31671.27	0.98	75.00	21.40
40-Blacklands	073-Falls	18576	32.91	25310.75	1.36	57.40	41.70
40-Blacklands	166-Milam	24238	32.91	33459.93	1.38	51.30	33.30
51-North East Texas	080-Franklin	9458	0.00	0.00	0.00	93.80	57.10
51-North East Texas	092-Gregg	111379	0.00	0.00	0.00	20.00	64.70
51-North East Texas	019-Bowie	89306	1.17	1034.37	0.01	33.20	72.70
51-North East Texas	107-Henderson	73277	1.17	1018.49	0.01	54.60	60.90
51-North East Texas	212-Smith	174706	1.17	1081.56	0.01	38.20	10.00
51-North East Texas	001-Anderson	55109	1.17	1247.47	0.02	41.30	30.00

Code/District	Counties	Total Population [a,c]	Ai (lbs)/ SqMi [d]	Total Ai (lbs) [a,d]	Ai [f] (lbs)/ Person [d]	% Rural [b,c]	% Surface Water PWS [a,e]
51-North East Texas	032-Camp	11549	1.17	230.10	0.02	60.20	25.00
51-North East Texas	102-Harrison	62110	1.17	1047.00	0.02	59.30	22.70
51-North East Texas	172-Morris	13048	1.17	296.50	0.02	80.00	42.90
51-North East Texas	174-Nacogdoches	59203	1.17	1102.99	0.02	47.60	43.80
51-North East Texas	201-Rusk	47372	1.17	1075.94	0.02	67.30	10.30
51-North East Texas	225-Titus	28118	1.17	478.27	0.02	52.20	57.10
51-North East Texas	230-Upshur	35291	1.17	684.60	0.02	80.50	7.10
51-North East Texas	234-Van Zandt	48140	1.17	988.67	0.02	79.40	21.70
51-North East Texas	250-Wood	36752	1.17	757.51	0.02	79.50	11.50
51-North East Texas	037-Cherokee	46659	1.17	1225.82	0.03	61.00	20.70
51-North East Texas	112-Hopkins	31960	1.17	911.50	0.03	59.10	64.30
51-North East Texas	190-Rains	9139	1.17	270.34	0.03	100.00	100.00
51-North East Texas	034-Cass	30438	1.17	1092.01	0.04	81.30	33.30
51-North East Texas	183-Panola	22756	1.17	933.07	0.04	74.70	31.80
51-North East Texas	210-Shelby	25224	1.17	925.14	0.04	77.90	50.00
51-North East Texas	113-Houston	23185	1.17	1433.99	0.06	71.20	44.00
51-North East Texas	194-Red River	14314	1.17	1223.46	0.09	74.60	62.50
51-North East Texas	155-Marion	10941	32.91	12545.62	1.15	100.00	19.00
52-South East Texas	170-Montgomery	293768	1.17	1216.29	0.00	36.00	0.60
52-South East Texas	228-Trinity	13779	0.00	0.00	0.00	100.00	8.70
52-South East Texas	003-Angelina	80130	1.17	933.82	0.01	44.70	0.00
52-South East Texas	236-Walker	61758	1.17	917.38	0.01	36.30	15.00
52-South East Texas	100-Hardin	48073	1.17	1041.89	0.02	57.40	0.00
52-South East Texas	237-Waller	32663	1.17	598.38	0.02	63.40	0.00
52-South East Texas	021-Brazos	152415	7.90	4624.73	0.03	12.80	0.00
52-South East Texas	121-Jasper	35604	1.17	1092.07	0.03	77.50	8.00
52-South East Texas	187-Polk	41133	1.17	1231.71	0.03	80.00	2.50
52-South East Texas	204-San Jacinto	22246	1.17	664.81	0.03	100.00	2.80
52-South East Texas	093-Grimes	23552	1.17	924.54	0.04	67.30	3.30
52-South East Texas	154-Madison	12940	1.17	547.14	0.04	69.20	0.00
52-South East Texas	202-Sabine	10469	1.17	571.16	0.05	100.00	33.30
52-South East Texas	229-Tyler	20871	1.17	1075.18	0.05	81.00	0.00
52-South East Texas	081-Freestone	17867	1.17	1022.21	0.06	58.60	8.00
52-South East Texas	176-Newton	15072	1.17	1086.58	0.07	100.00	0.00
52-South East Texas	203-San Augustine	8946	1.17	614.97	0.07	100.00	21.40
52-South East Texas	145-Leon	15335	1.17	1248.93	0.08	100.00	0.00
52-South East Texas	198-Robertson	16000	7.90	6746.75	0.42	72.60	0.00
60-Trans-Pecos	022-Brewster	8866	0.00	0.00	0.00	33.50	12.50
60-Trans-Pecos	052-Crane	3996	0.00	0.00	0.00	10.40	0.00
60-Trans-Pecos	055-Culberson	2975	0.00	0.00	0.00	100.00	0.00
60-Trans-Pecos	122-Jeff Davis	2207	0.00	0.00	0.00	100.00	0.00
60-Trans-Pecos	151-Loving	67	0.00	0.00	0.00	100.00	0.00
60-Trans-Pecos	189-Presidio	7304	0.00	0.00	0.00	42.60	0.00
60-Trans-Pecos	195-Reeves	13137	0.00	0.00	0.00	17.50	33.30
60-Trans-Pecos	222-Terrell	1081	0.00	0.00	0.00	100.00	0.00

Code/District	Counties	Total Population [a,c]	Ai (lbs)/ SqMi [d]	Total Ai (lbs) [a,d]	Ai [f] (lbs)/ Person [d]	% Rural [b,c]	% Surface Water PWS [a,e]
60-Trans-Pecos	238-Ward	10909	0.00	0.00	0.00	32.60	0.00
60-Trans-Pecos	248-Winkler	7173	0.00	0.00	0.00	19.10	0.00
60-Trans-Pecos	068-Ector	121123	1.17	1049.73	0.01	9.20	9.50
60-Trans-Pecos	070-El Paso	679622	32.91	33341.45	0.05	3.00	39.40
60-Trans-Pecos	186-Pecos	16809	1.17	5549.65	0.33	41.10	0.00
60-Trans-Pecos	115-Hudspeth	3344	1.17	5325.22	1.59	100.00	0.00
70-Edwards Plateau	016-Blanco	8418	0.00	0.00	0.00	100.00	28.60
70-Edwards Plateau	053-Crockett	4099	0.00	0.00	0.00	26.10	0.00
70-Edwards Plateau	069-Edwards	2162	0.00	0.00	0.00	100.00	0.00
70-Edwards Plateau	118-Irion	1771	0.00	0.00	0.00	100.00	0.00
70-Edwards Plateau	160-McCulloch	8205	0.00	0.00	0.00	35.90	11.10
70-Edwards Plateau	193-Real	3047	0.00	0.00	0.00	100.00	11.00
70-Edwards Plateau	216-Sterling	1393	0.00	0.00	0.00	100.00	0.00
70-Edwards Plateau	218-Sutton	4077	0.00	0.00	0.00	20.30	0.00
70-Edwards Plateau	233-Val Verde	44856	0.00	0.00	0.00	9.50	0.00
70-Edwards Plateau	130-Kendall	23743	1.17	771.74	0.03	62.70	5.30
70-Edwards Plateau	133-Kerr	43653	1.17	1288.63	0.03	39.20	1.90
70-Edwards Plateau	010-Bandera	17645	1.17	922.37	0.05	100.00	2.20
70-Edwards Plateau	086-Gillespie	20814	1.17	1236.13	0.06	54.10	0.00
70-Edwards Plateau	150-Llano	17044	1.17	1089.00	0.06	55.50	32.40
70-Edwards Plateau	226-Tom Green	104010	7.90	12016.98	0.12	15.30	10.70
70-Edwards Plateau	206-San Saba	6186	1.17	1321.65	0.21	59.50	0.00
70-Edwards Plateau	041-Coke	3864	1.17	1047.11	0.27	100.00	50.00
70-Edwards Plateau	157-Mason	3738	1.17	1085.86	0.29	100.00	0.00
70-Edwards Plateau	134-Kimble	4468	1.17	1457.05	0.33	40.60	20.00
70-Edwards Plateau	192-Reagan	3326	1.17	1369.22	0.41	14.80	0.00
70-Edwards Plateau	231-Upton	3404	1.17	1446.56	0.42	100.00	0.00
70-Edwards Plateau	164-Menard	2360	1.17	1050.73	0.45	100.00	0.00
70-Edwards Plateau	136-Kinney	3379	1.17	1588.41	0.47	100.00	0.00
70-Edwards Plateau	207-Schleicher	2935	1.17	1526.86	0.52	100.00	0.00
70-Edwards Plateau	142-Lampasas	17762	32.91	23433.24	1.32	60.60	0.00
70-Edwards Plateau	048-Concho	3966	7.90	7827.50	1.97	100.00	33.30
70-Edwards Plateau	232-Uvalde	25926	32.91	51226.06	1.98	32.10	0.00
70-Edwards Plateau	027-Burnet	34147	108.05	107616.06	3.15	54.70	20.70
81-South Central	227-Travis	812280	7.90	7810.52	0.01	7.00	41.00
81-South Central	011-Bastrop	57733	1.17	1034.93	0.02	67.10	0.00
81-South Central	239-Washington	30373	1.17	709.74	0.02	54.20	7.40
81-South Central	008-Austin	23590	1.17	760.27	0.03	62.80	0.00
81-South Central	015-Bexar	1392931	32.91	41032.85	0.03	6.00	2.50
81-South Central	105-Hays	97589	7.90	5351.78	0.05	42.20	7.00
81-South Central	046-Comal	78021	7.90	4432.65	0.06	43.00	5.60
81-South Central	028-Caldwell	32194	7.90	4308.54	0.13	45.80	38.50
81-South Central	094-Guadalupe	89023	32.91	23403.62	0.26	41.80	36.80
81-South Central	026-Burleson	16470	7.90	5254.44	0.32	83.80	0.00
81-South Central	144-Lee	15657	7.90	4962.01	0.32	70.50	0.00
81-South Central	062-De Witt	20013	7.90	7177.98	0.36	52.80	0.00

Code/District	Counties	Total Population [a,c]	Ai (lbs)/ SqMi [d]	Total Ai (lbs) [a,d]	Ai [f] (lbs)/ Person [d]	% Rural [b,c]	% Surface Water PWS [a,e]
81-South Central	143-Lavaca	19210	7.90	7657.36	0.40	81.80	0.00
81-South Central	089-Gonzales	18628	7.90	8429.89	0.45	63.10	28.60
81-South Central	247-Wilson	32408	32.91	26558.04	0.82	82.60	0.00
81-South Central	013-Bee	32359	32.91	28965.41	0.90	30.60	18.20
81-South Central	088-Goliad	6928	7.90	6738.54	0.97	100.00	0.00
81-South Central	163-Medina	39304	32.91	43696.58	1.11	55.70	0.00
81-South Central	075-Fayette	21804	32.91	31265.49	1.43	63.90	0.00
81-South Central	045-Colorado	20390	32.91	31690.68	1.55	60.40	0.00
81-South Central	128-Karnes	15446	32.91	24693.03	1.60	38.60	0.00
82-Coastal Bend	137-Kleberg	31549	7.90	6876.31	0.22	18.70	40.00
82-Coastal Bend	178-Nueces	313645	108.05	90306.17	0.29	5.60	84.20
82-Coastal Bend	004-Aransas	22497	32.91	8288.71	0.37	33.80	30.80
82-Coastal Bend	205-San Patricio	67138	108.05	74729.32	1.11	21.00	68.00
82-Coastal Bend	196-Refugio	7828	32.91	25347.61	3.24	60.90	0.00
90-Upper Coast	101-Harris	3400578	7.90	13649.03	0.00	1.80	6.80
90-Upper Coast	123-Jefferson	252051	1.17	1052.62	0.00	8.30	71.00
90-Upper Coast	181-Orange	84966	1.17	415.21	0.00	35.20	3.90
90-Upper Coast	084-Galveston	250158	7.90	3145.92	0.01	8.40	39.40
90-Upper Coast	036-Chambers	26031	1.17	698.20	0.03	64.20	15.90
90-Upper Coast	020-Brazoria	241767	7.90	10945.63	0.05	28.40	7.90
90-Upper Coast	079-Fort Bend	354452	32.91	28784.40	0.08	10.10	0.00
90-Upper Coast	146-Liberty	70154	7.90	9155.67	0.13	64.10	0.00
90-Upper Coast	235-Victoria	84088	32.91	29043.08	0.35	27.20	4.00
90-Upper Coast	029-Calhoun	20647	32.91	16860.12	0.82	41.80	41.20
90-Upper Coast	158-Matagorda	37957	32.91	36676.88	0.97	34.00	0.00
90-Upper Coast	241-Wharton	41188	108.05	117783.10	2.86	49.70	0.00
90-Upper Coast	120-Jackson	14391	108.05	89622.25	6.23	59.70	0.00
96-South Texas	124-Jim Hogg	5281	0.00	0.00	0.00	17.60	0.00
96-South Texas	131-Kenedy	414	0.00	0.00	0.00	100.00	0.00
96-South Texas	240-Webb	193117	1.17	3910.71	0.02	4.20	27.30
96-South Texas	159-Maverick	47297	1.17	1491.28	0.03	10.80	75.00
96-South Texas	253-Zapata	12182	1.17	1161.23	0.10	29.60	100.00
96-South Texas	024-Brooks	7976	1.17	1098.92	0.14	27.10	0.00
96-South Texas	007-Atascosa	38628	7.90	9727.59	0.25	60.40	0.00
96-South Texas	139-La Salle	5866	1.17	1734.51	0.30	23.70	60.00
96-South Texas	082-Frio	16252	7.90	8945.19	0.55	24.50	0.00
96-South Texas	125-Jim Wells	39326	32.91	28451.35	0.72	36.70	15.40
96-South Texas	254-Zavala	11600	7.90	10251.50	0.88	37.30	0.00
96-South Texas	064-Dimmit	10248	7.90	10507.53	1.03	37.50	0.00
96-South Texas	162-McMullen	851	1.17	1296.65	1.52	100.00	33.30
96-South Texas	149-Live Oak	12309	32.91	34104.63	2.77	79.90	8.30
96-South Texas	066-Duval	13120	32.91	58997.76	4.50	48.20	0.00
97-Lower Valley	031-Cameron	335227	108.05	97862.84	0.29	12.70	91.70
97-Lower Valley	108-Hidalgo	569463	108.05	169603.64	0.30	6.60	78.80
97-Lower Valley	214-Starr	53597	32.91	40249.59	0.75	20.70	84.60
97-Lower Valley	245-Willacy	20082	108.05	64468.29	3.21	49.00	100.00

[a] Population Weighted-Averages
[b] County Weighted-Averages
[c] 2000 U.S. Census data, 2005.
[d] Battaglin and Goolsby, 1995.
[e] TCEQ Water Utility Database, 2005c.
[f] Ai is Atrazine.

Table 3-4

Agricultural Statistical District Atrazine Exposure Variables

Code	District	Counties	Total Population [a,c]	Ai [f] (lbs)/ SqMi [a,d]	Ai [f] (lbs)/SqMi [b,d]	Total Ai (lbs) [a,d]	Ai [f] (lbs) /Person [a,d]	% Rural [b,c]	% Surface Water PWS [a,e]
11	Northern High Plains	23	64,978	24.32	30.41	24363.29	1.68	77.6	41.2
12	Southern High Plains	16	143,940	7.13	8.80	6552.58	0.26	65.5	60.5
21	Northern Low Plains	16	93,675	1.34	1.55	984.49	0.11	92.4	87.5
22	Southern Low Plains	12	75,392	6.38	4.68	5996.37	0.23	69.5	85.2
30	Cross Timbers	19	41,042	1.39	1.55	1231.07	0.06	74.2	78.7
40	Blacklands	25	1,239,306	11.76	14.43	10767.19	0.05	58.3	70.5
51	North East Texas	24	75,964	1.36	1.83	1010.07	0.03	72.3	53.7
52	South East Texas	19	140,005	2.38	1.76	1725.69	0.03	80.4	19.5
60	Trans-Pecos	14	543,307	25.64	1.28	26061.33	0.05	79.8	30.7
70	Edwards Plateau	28	44,791	14.66	6.35	16364.83	0.52	83.6	29.5
81	South Central	21	917,678	21.95	17.89	25266.14	0.11	64.6	31.3
82	Coastal Bend	5	235,947	95.76	60.09	76680.34	0.46	40.5	64.0
90	Upper Coast	13	2,438,857	11.08	30.23	14622.55	0.07	46.7	45.7
96	South Texas	15	105,370	7.35	8.39	9458.90	0.41	62.3	67.0
97	Lower Valley	4	449,668	103.93	86.65	135778.20	0.38	34.1	89.5

[a] Population Weighted-Averages
[b] County Weighted-Averages
[c] 2000 U.S. Census data, 2005.
[d] Battaglin and Goolsby, 1995.
[e] TCEQ Water Utility Database, 2005c.
[f] Ai is Atrazine.

Table 4-1

Pounds of Atrazine Per Person in County Correlations

			TtlAiLbs PerPerson	BCA54 Below	BCA55 Above	OCA54 Below	OCA55 Above
Spearman	TtlAiLbs Per Person	Correlation Coefficient	1.000	-.193(**)	-.119	-.113	-.026
		Sig. (2-tailed)	.	.002	.058	.071	.675
		N	254	254	254	254	254
	BCA54 Below	Correlation Coefficient	-.193(**)	1.000	.229(**)	.068	.007
		Sig. (2-tailed)	.002	.	.000	.277	.914
		N	254	254	254	254	254
	BCA55 Above	Correlation Coefficient	-.119	.229(**)	1.000	.130(*)	.081
		Sig. (2-tailed)	.058	.000	.	.038	.197
		N	254	254	254	254	254
	OCA54 Below	Correlation Coefficient	-.113	.068	.130(*)	1.000	-.027
		Sig. (2-tailed)	.071	.277	.038	.	.669
		N	254	254	254	254	254
	OCA55 Above	Correlation Coefficient	-.026	.007	.081	-.027	1.000
		Sig. (2-tailed)	.675	.914	.197	.669	.
		N	254	254	254	254	254

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4-2

Average Pounds of Atrazine by Square Mile in County Correlations

			AiLbsby SqMi	BCA54 Below	BCA55 Above	OCA54 Below	OCA55 Above
Spearman	AiLbsby SqMi	Correlation Coefficient	1.000	.017	-.018	.074	.105
		Sig. (2-tailed)	.	.789	.779	.238	.094
		N	254	254	254	254	254
	BCA54 Below	Correlation Coefficient	.017	1.000	.229(**)	.068	.007
		Sig. (2-tailed)	.789	.	.000	.277	.914
		N	254	254	254	254	254
	BCA55 Above	Correlation Coefficient	-.018	.229(**)	1.000	.130(*)	.081
		Sig. (2-tailed)	.779	.000	.	.038	.197
		N	254	254	254	254	254
	OCA54 Below	Correlation Coefficient	.074	.068	.130(*)	1.000	-.027
		Sig. (2-tailed)	.238	.277	.038	.	.669
		N	254	254	254	254	254
	OCA55 Above	Correlation Coefficient	.105	.007	.081	-.027	1.000
		Sig. (2-tailed)	.094	.914	.197	.669	.
		N	254	254	254	254	254

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4-3

Total Pounds of Atrazine in County Correlations

			TtlLbsAi	BCA54 Below	BCA55 Above	OCA54 Below	OCA55 Above
Spearman	TtlLbsAi	Correlation Coefficient	1.000	-.019	-.014	.050	.082
		Sig. (2-tailed)	.	.762	.822	.429	.191
		N	254	254	254	254	254
	BCA54 Below	Correlation Coefficient	-.019	1.000	.229(**)	.068	.007
		Sig. (2-tailed)	.762	.	.000	.277	.914
		N	254	254	254	254	254
	BCA55 Above	Correlation Coefficient	-.014	.229(**)	1.000	.130(*)	.081
		Sig. (2-tailed)	.822	.000	.	.038	.197
		N	254	254	254	254	254
	OCA54 Below	Correlation Coefficient	.050	.068	.130(*)	1.000	-.027
		Sig. (2-tailed)	.429	.277	.038	.	.669
		N	254	254	254	254	254
	OCA55 Above	Correlation Coefficient	.082	.007	.081	-.027	1.000
		Sig. (2-tailed)	.191	.914	.197	.669	.
		N	254	254	254	254	254

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4-4

Average Pounds of Atrazine by Square Mile in Agricultural Statistical District Weighted by Area and Population Correlations

			AvgAi Lbs bySqMi WtBy Area	AvgAi Lbs bySqMi WtBy Pop	BCA54 Under	BCA55 Above	OCA54 Under	OCA55 Above
Spearman	AvgAiLbs bySqMi WtBy Area	Correlation Coefficient	1.000	.654(**)	.104	-.059	-.519(*)	-.152
		Sig. (2-tailed)	.	.008	.713	.835	.048	.589
		N	15	15	15	15	15	15
	AvgAiLbs bySqMi WtByPop	Correlation Coefficient	.654(**)	1.000	.027	-.293	-.396	.046
		Sig. (2-tailed)	.008	.	.924	.289	.144	.869
		N	15	15	15	15	15	15
	BCA54 Under	Correlation Coefficient	.104	.027	1.000	.620(*)	.162	.349
		Sig. (2-tailed)	.713	.924	.	.014	.564	.203
		N	15	15	15	15	15	15
	BCA55 Above	Correlation Coefficient	-.059	-.293	.620(*)	1.000	.111	.014
		Sig. (2-tailed)	.835	.289	.014	.	.694	.960
		N	15	15	15	15	15	15
	OCA54 Under	Correlation Coefficient	-.519(*)	-.396	.162	.111	1.000	.344
		Sig. (2-tailed)	.048	.144	.564	.694	.	.210
		N	15	15	15	15	15	15
	OCA55 Above	Correlation Coefficient	-.152	.046	.349	.014	.344	1.000
		Sig. (2-tailed)	.589	.869	.203	.960	.210	.
		N	15	15	15	15	15	15

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4-5

Total Pounds of Atrazine in Agricultural Statistical District Weighted by Population

Correlations

			TtlAiLbs WtByPop	BCA54 Under	BCA55 Above	OCA54 Under	OCA55 Above
Spearman	TtlAiLbs WtByPop	Correlation Coefficient	1.000	.055	-.279	-.374	.025
		Sig. (2-tailed)	.	.845	.315	.169	.930
		N	15	15	15	15	15
	BCA54 Under	Correlation Coefficient	.055	1.000	.620(*)	.162	.349
		Sig. (2-tailed)	.845	.	.014	.564	.203
		N	15	15	15	15	15
	BCA55 Above	Correlation Coefficient	-.279	.620(*)	1.000	.111	.014
		Sig. (2-tailed)	.315	.014	.	.694	.960
		N	15	15	15	15	15
	OCA54 Under	Correlation Coefficient	-.374	.162	.111	1.000	.344
		Sig. (2-tailed)	.169	.564	.694	.	.210
		N	15	15	15	15	15
	OCA55 Above	Correlation Coefficient	.025	.349	.014	.344	1.000
		Sig. (2-tailed)	.930	.203	.960	.210	.
		N	15	15	15	15	15

* Correlation is significant at the 0.05 level (2-tailed).

Table 4-6

Pounds of atrazine Per Person in Agricultural Statistical District Weighted by Population Correlations

			AoLbsPer Person WtbyPop	BCA54 Under	BCA55 Above	OCA54 Under	OCA55 Above
Spearman	AoLbsPer Person WtbyPop	Correlation Coefficient	1.000	-.241	-.374	-.198	-.397
		Sig. (2-tailed)	.	.387	.169	.478	.142
		N	15	15	15	15	15
	BCA54 Under	Correlation Coefficient	-.241	1.000	.620(*)	.162	.349
		Sig. (2-tailed)	.387	.	.014	.564	.203
		N	15	15	15	15	15
	BCA55 Above	Correlation Coefficient	-.374	.620(*)	1.000	.111	.014
		Sig. (2-tailed)	.169	.014	.	.694	.960
		N	15	15	15	15	15
	OCA54 Under	Correlation Coefficient	-.198	.162	.111	1.000	.344
		Sig. (2-tailed)	.478	.564	.694	.	.210
		N	15	15	15	15	15
	OCA55 Above	Correlation Coefficient	-.397	.349	.014	.344	1.000
		Sig. (2-tailed)	.142	.203	.960	.210	.
		N	15	15	15	15	15

* Correlation is significant at the 0.05 level (2-tailed).

Table 4-7

Percent Rural Population in County Correlations

			rural pop	BCA54 Below	BCA55 Above	OCA54 Below	OCA55 Above
Spearman	ruralpop	Correlation Coefficient	1.000	-.188(**)	-.103	-.155(*)	-.153(*)
		Sig. (2-tailed)	.	.003	.102	.013	.014
		N	254	254	254	254	254
	BCA54 Below	Correlation Coefficient	-.188(**)	1.000	.229(**)	.068	.007
		Sig. (2-tailed)	.003	.	.000	.277	.914
		N	254	254	254	254	254
	BCA55 Above	Correlation Coefficient	-.103	.229(**)	1.000	.130(*)	.081
		Sig. (2-tailed)	.102	.000	.	.038	.197
		N	254	254	254	254	254
	OCA54 Below	Correlation Coefficient	-.155(*)	.068	.130(*)	1.000	-.027
		Sig. (2-tailed)	.013	.277	.038	.	.669
		N	254	254	254	254	254
	OCA55 Above	Correlation Coefficient	-.153(*)	.007	.081	-.027	1.000
		Sig. (2-tailed)	.014	.914	.197	.669	.
		N	254	254	254	254	254

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4-8

Percent Rural Population in Agricultural Statistical District Correlations

			Percent Rural Wt ByPop	BCA54 Under	BCA55 Above	OCA54 Under	OCA55 Above
Spearman	PercentRural WtByPop	Correlation Coefficient	1.000	.106	.395	.365	.029
		Sig. (2-tailed)	.	.708	.145	.181	.919
		N	15	15	15	15	15
	BCA54Under	Correlation Coefficient	.106	1.000	.620(*)	.162	.349
		Sig. (2-tailed)	.708	.	.014	.564	.203
		N	15	15	15	15	15
	BCA55Above	Correlation Coefficient	.395	.620(*)	1.000	.111	.014
		Sig. (2-tailed)	.145	.014	.	.694	.960
		N	15	15	15	15	15
	OCA54Under	Correlation Coefficient	.365	.162	.111	1.000	.344
		Sig. (2-tailed)	.181	.564	.694	.	.210
		N	15	15	15	15	15
	OCA55Above	Correlation Coefficient	.029	.349	.014	.344	1.000
		Sig. (2-tailed)	.919	.203	.960	.210	.
		N	15	15	15	15	15

* Correlation is significant at the 0.05 level (2-tailed).

Table 4-9

Percent Surface Water Public Water Systems in County Correlations

			SW PWS	BCA54 Below	BCA55 Above	OCA54 Below	OCA55 Above
Spearman	SWPWS	Correlation Coefficient	1.000	.037	-.025	.181(**)	.104
		Sig. (2-tailed)	.	.557	.695	.004	.097
		N	254	254	254	254	254
	BCA54 Below	Correlation Coefficient	.037	1.000	.229(**)	.068	.007
		Sig. (2-tailed)	.557	.	.000	.277	.914
		N	254	254	254	254	254
	BCA55 Above	Correlation Coefficient	-.025	.229(**)	1.000	.130(*)	.081
		Sig. (2-tailed)	.695	.000	.	.038	.197
		N	254	254	254	254	254
	OCA54 Below	Correlation Coefficient	.181(**)	.068	.130(*)	1.000	-.027
		Sig. (2-tailed)	.004	.277	.038	.	.669
		N	254	254	254	254	254
	OCA55 Above	Correlation Coefficient	.104	.007	.081	-.027	1.000
		Sig. (2-tailed)	.097	.914	.197	.669	.
		N	254	254	254	254	254

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4-10

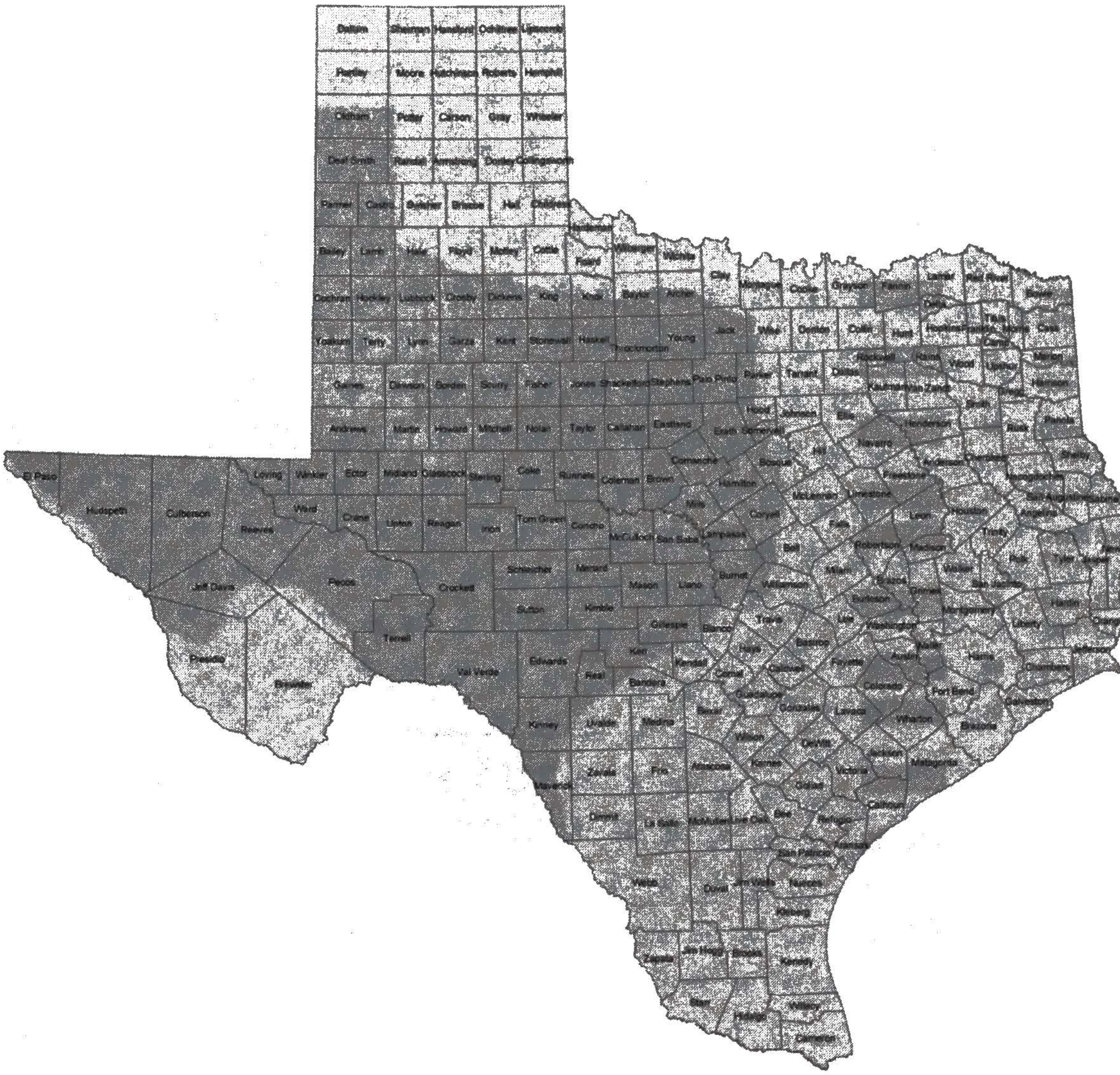
Percent Surface Water Public Water Systems in Agricultural Statistical District

Correlations

			Percent SWPWS WtByPop	BCA54 Under	BCA55 Above	OCA54 Under	OCA55 Above
Spearman	Percent SWPWS WtByPop	Correlation Coefficient	1.000	-.218	-.336	.124	.021
		Sig. (2-tailed)	.	.435	.221	.661	.940
		N	15	15	15	15	15
	BCA54 Under	Correlation Coefficient	-.218	1.000	.620(*)	.162	.349
		Sig. (2-tailed)	.435	.	.014	.564	.203
		N	15	15	15	15	15
	BCA55 Above	Correlation Coefficient	-.336	.620(*)	1.000	.111	.014
		Sig. (2-tailed)	.221	.014	.	.694	.960
		N	15	15	15	15	15
	OCA54 Under	Correlation Coefficient	.124	.162	.111	1.000	.344
		Sig. (2-tailed)	.661	.564	.694	.	.210
		N	15	15	15	15	15
	OCA55 Above	Correlation Coefficient	.021	.349	.014	.344	1.000
		Sig. (2-tailed)	.940	.203	.960	.210	.
		N	15	15	15	15	15

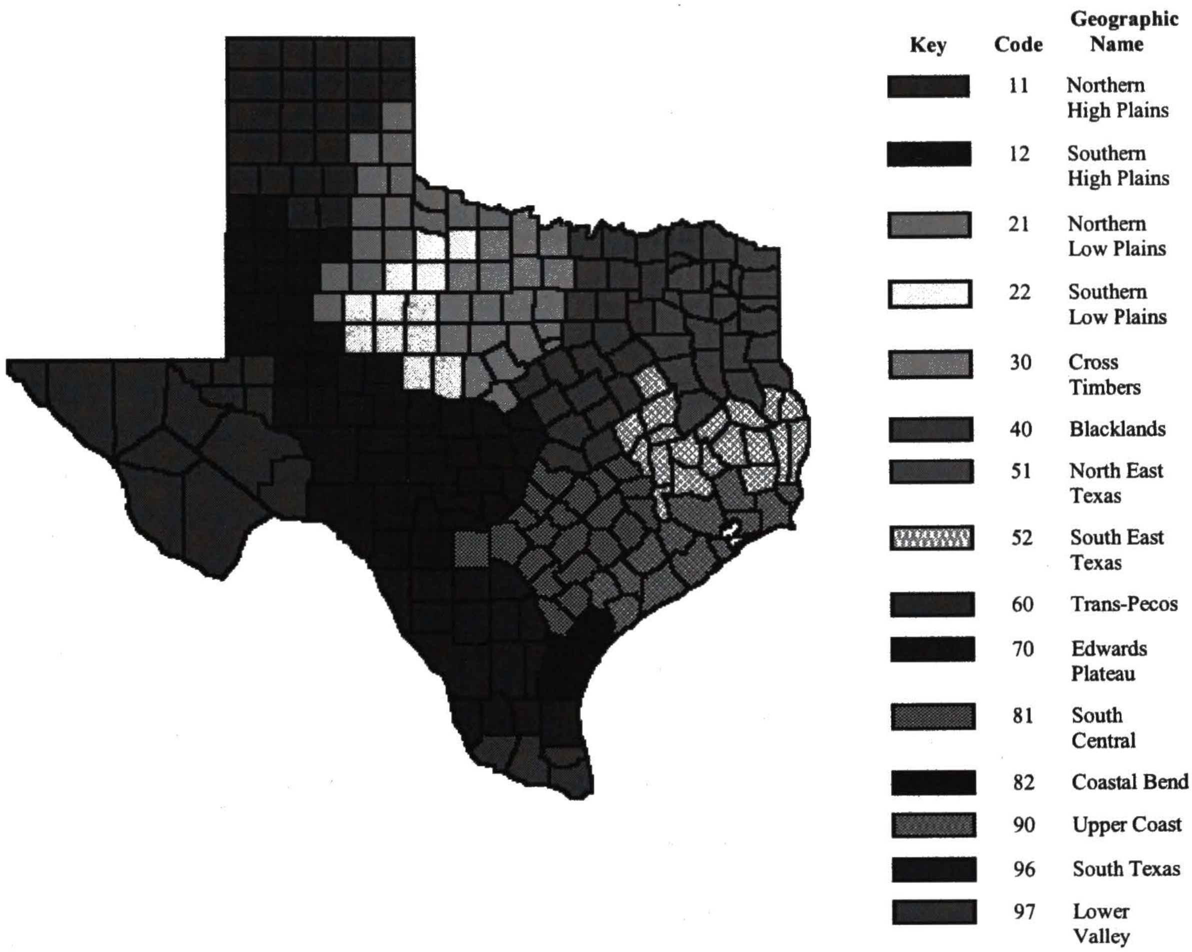
* Correlation is significant at the 0.05 level (2-tailed).

Figure 2-1. Digital Atlas of Texas Counties.



Texas Tech University, 2004.

Figure 2-2. USDA-NASS Texas's 254 Counties Grouped into 15 Agricultural Statistical Districts.



USDA-NASS, 2005b

Figure 4-1. Pounds of Atrazine Per Person vs Breast Cancer Incidence Rates (County Level).

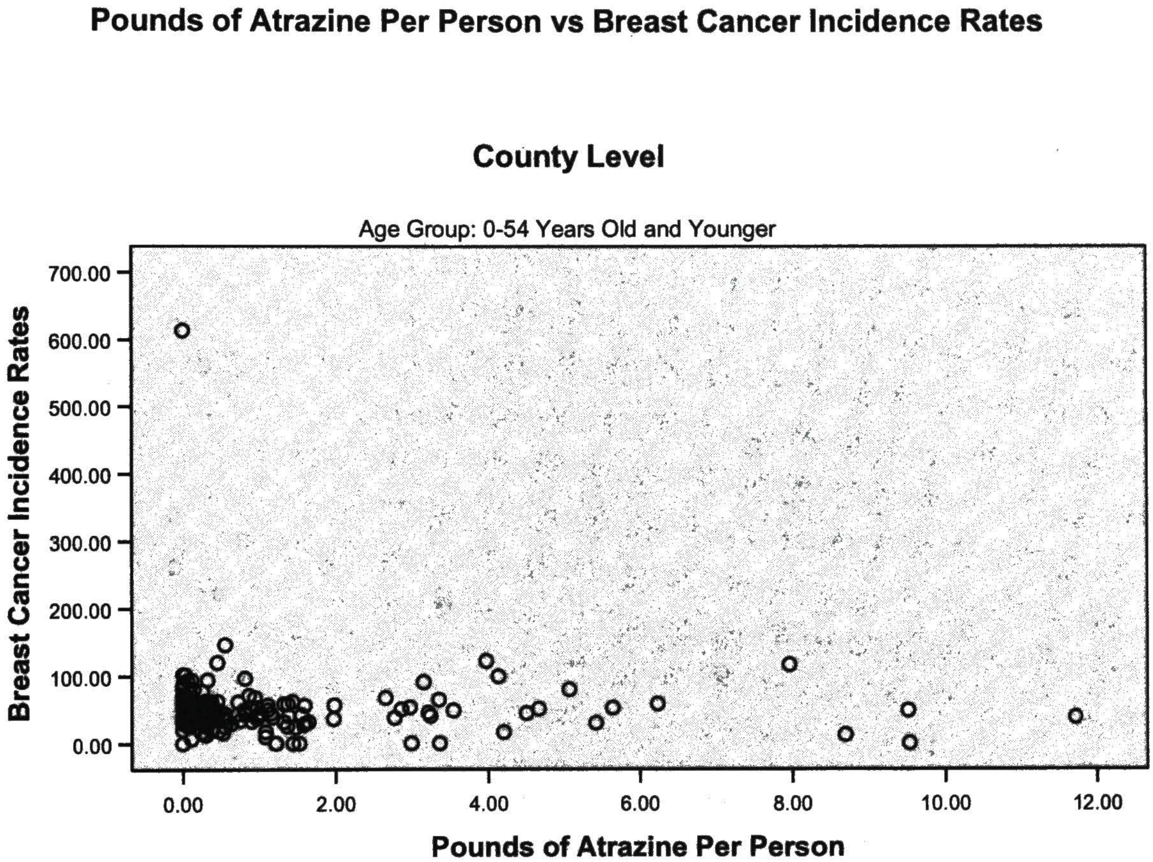


Figure 4-2. Average Pounds of Atrazine by Square Mile Weighted by Area vs Ovarian Cancer Incidence Rates (Agricultural Statistical District Level).

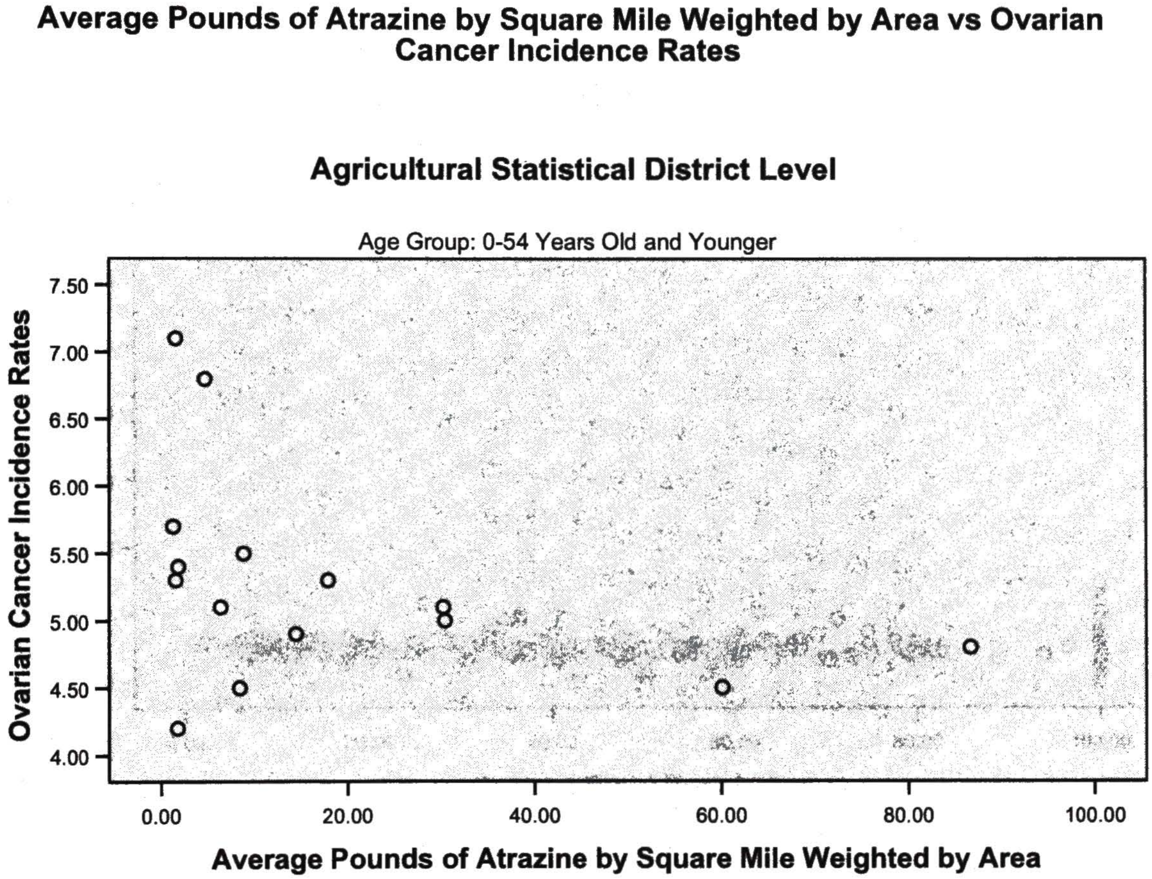


Figure 4-3. Percent Rural Population vs Breast Cancer Incidence Rates (County Level).

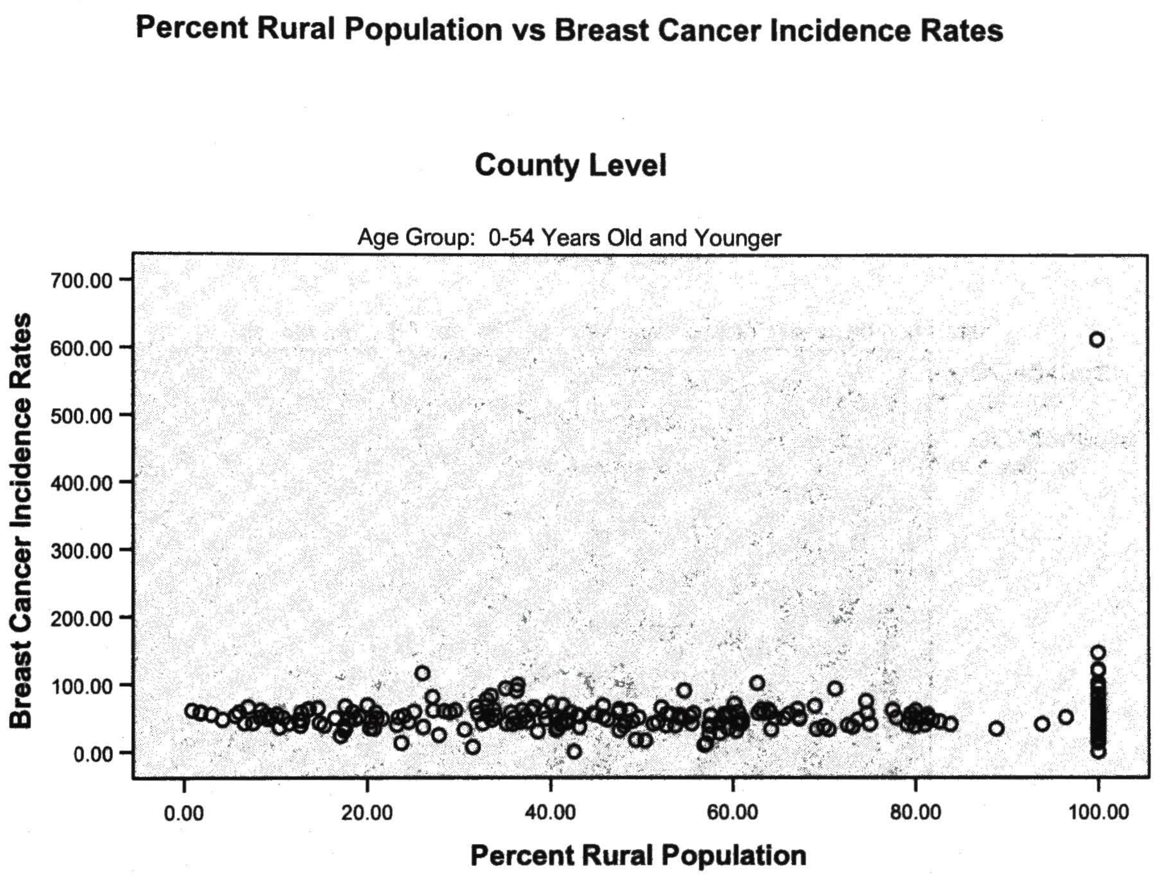


Figure 4-4. Percent Rural Population vs Ovarian Cancer Incidence Rates (County Level).

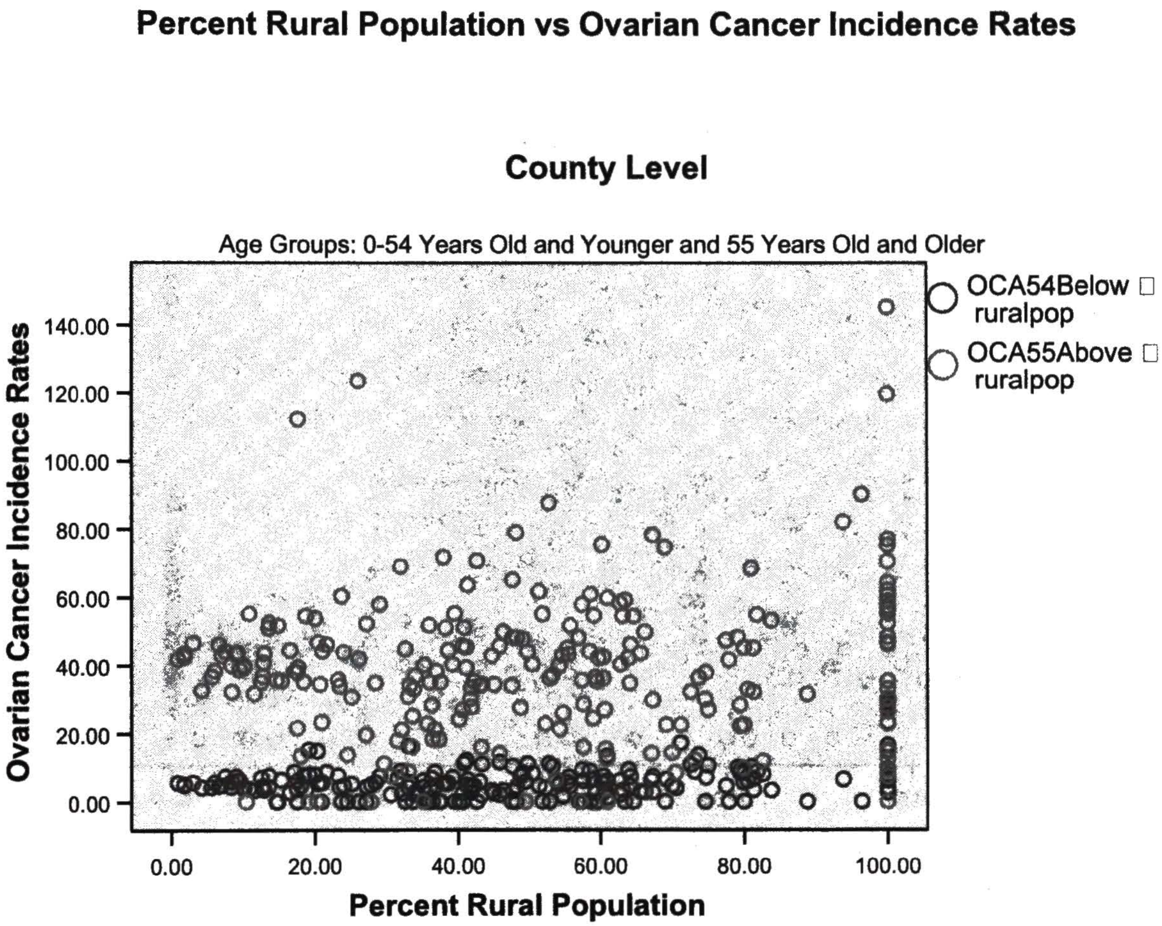
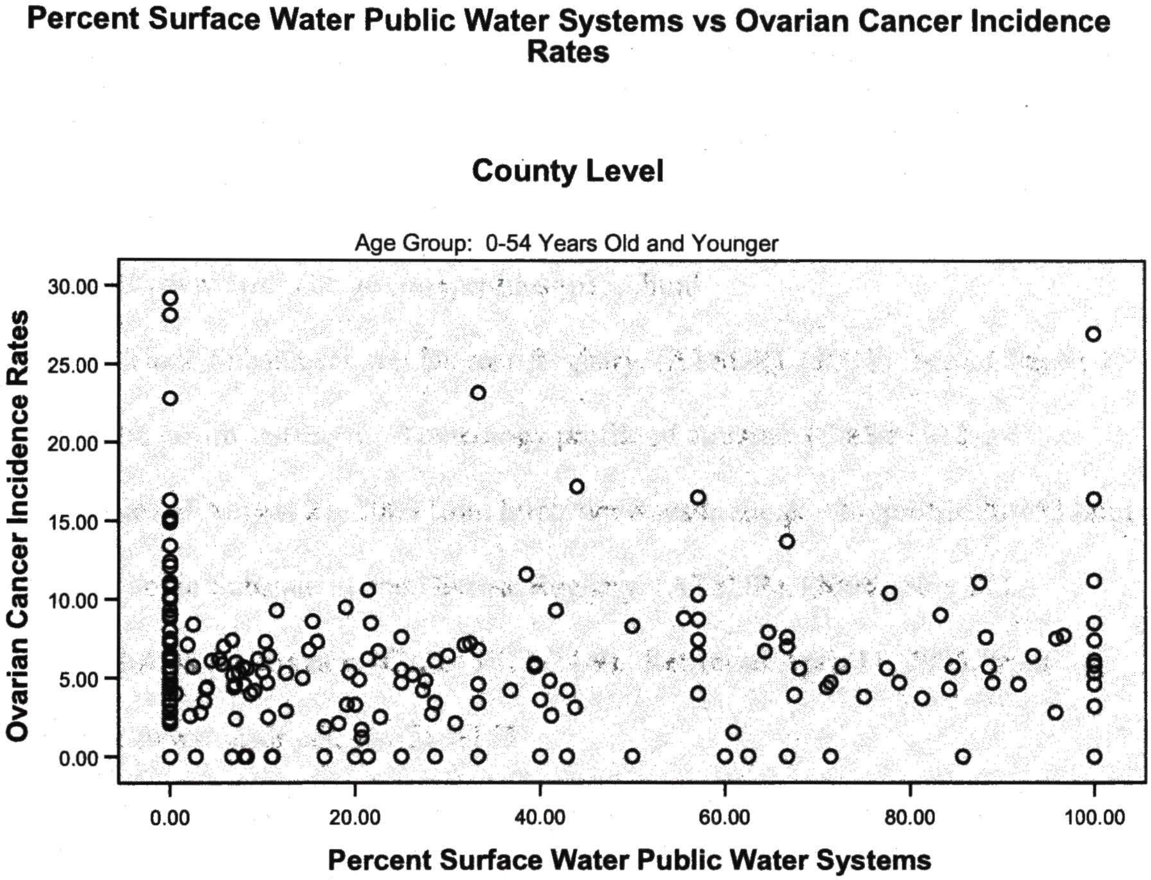


Figure 4-5. Percent Surface Water Public Water Systems vs Ovarian Cancer Incidence Rates (County Level).



REFERENCES

Agency for Toxic Substances and Disease Registry. (ATSDR).(2003a. Sep). Chapter 5: Production, import, use, and disposal. Toxicology profile of atrazine. (CAS# 1912-24-9). Retrieved August 21, 2005 from http://www.atsdr.cdc.gov/toxprofiles/tp153.html

Agency for Toxic Substances and Disease Registry. (ATSDR). (2003b. Sep). Chapter 1: Public health statement. Toxicology profile of atrazine. (CAS# 1912-24-9). Retrieved August 21, 2005 from http://www.atsdr.cdc.gov/toxprofiles/tp153.html

Agency for Toxic Substances and Disease Registry. (ATSDR). (2004. Nov 22). ToxFAQs for atrazine. (CAS# 1912-24-9). Retrieved April 11, 2005, from http://www.atsdr.cdc.gov/facts153

American Cancer Society. (2006). Leading sites for new cancer cases and deaths. Retrieved March 5, 2006 from http://www.cancer.org/downloads/stt/CAFF06EsCsMcLd.pdf

Battaglin, W.A., Goolsby, D.A. (1995). Spatial Data in Geographic Information System Format on Agricultural Chemical Use, Land Use, and Cropping Practices in the United States. U.S. Geological Survey Water-Resources Investigations Report 94-4176. Reston, VA:U.S. Geological Survey. Retrieved August 7, 2005 from http://water.usgs.gov/pubs/wri/wri944176/

The Breast Cancer Fund. (2004). Chemical fact sheets: Atrazine. Retrieved April 6, 2005, from http://www.breastcancerfund.org/site/ pp.asp?c=kwKXLdPaE&b=84500

Brown, L.M., Burmeister, L.F., Everett, G.D., Blair, A. (1993). Pesticide exposures and multiple myeloma in Iowa men. *Cancer Causes Control.* 4:153–56.

Burmeister, L.F. (1990). Cancer in Iowa farmers: recent results. *Am J Ind Med.* 18:295–301.

Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services. (2006a). Breast and ovarian cancer incidence data. Texas Cancer Registry. 1100 W. 49th Street, Austin, Texas, 78756 Retrieved March 31, 2006, from http://www.dshs.state.tx.us/tcr/default.shtm

Cancer Epidemiology and Surveillance Branch, Texas Department of State Health Services. (2006b. Jan.). Expected new cancer cases and deaths by primary site, Texas , 2006. Retrieved March 13, 2006, from http://www.dshs.state.tx.us/tcr/expected-2006.shtm

The Center for Regulatory Effectiveness. (2003). Human impacts. Retrieved April 11, 2005, from http://www.thecre.com/atrazine/humanimpacts

De Roos, A.J., Zahm, S.H., Cantor, K.P., Weisenburger, D.D., Holmes, F.F., Burmeister, L.F. et al. (2003). Integrative assessment of multiple pesticides as risk factors for non-Hodgkin's lymphoma among men. *Occup Environ Med.* 60: E11.

Donna, A., Betta, P., Gagliardi, F., Ghiazza, G., Gallareto, M., Gabutto, V. (1981). Preliminary experimental contribution to the study of possible carcinogenic activity of two herbicides containing atrazine-simazine and trifuralin as active principles. *Pathologica*. 73: 707-21.

Donna, A., Betta, P., Robutti, F., Crosignani, P., Berrino, F., Bellingeri, D. (1984). Ovarian mesothelial tumors and herbicides: a case-control study. *Carcinogenesis* 5: 941-2.

Donna, A., Betta, P., Robutti, F., Bellingeri, D. (1986). Carcinogenicity testing of atrazine: preliminary report on a 13-month study on male Swiss albino mice treated by intraperitoneal administration. *G Ital Med Lav*. 8: 119-21.

Donna, A., Crosignani, P., Robutti, F., Betta, P., Bocca, R., Mariani, N., Ferrario, F., Fissi, R., Berrino, F. (1989). Triazine herbicides and ovarian epithelial neoplasms. *Scand J Work Environ Health* 15: 47-53.

Environmental Protection Agency. (EPA). (1992. July). Secondary drinking water regulations: Guidance for nuisance chemicals. (EPA 810/K-92-001). Retrieved April 6, 2005, from http://www.epa.gov/safewater/consumer/2ndstands

Environmental Protection Agency. (EPA). (1998. August). Consumer confidence reports: Final rule. (EPA 816-F-98-007) Retrieved March 25, 2005, from http://www.epa.gov/safewater/ccr/ccrfact

Environmental Protection Agency. (EPA). (2003). Atrazine interim reregistration eligibility decision (IRED) addendum Q & A-October 2003. Retrieved April 11, 2005, from http://www.epa.gov/pesticides/factsheets/atrazine_addendum

Environmental Protection Agency. (EPA). (2004. June). Safe drinking water act 30th anniversary understanding the safe drinking water act. (EPA 816-F-04-030) Office of Ground Water and Drinking Water. Retrieved March 25, 2005, from http://www.epa.gov/safewater/sdwa/30th/factsheets/understand

Environmental Protection Agency. (EPA). (2005a). Atrazine background. Office of Ground Water and Drinking Water. Retrieved August 14, 2005 from http://www.epa.gov/pesticides/factsheets/atrazine_background.html

Environmental Protection Agency. (EPA). (2005b). Atrazine: evaluation of carcinogen potential. HED DOC. NO 014431. p. 3. Retrieved August 30, 2005 from http://www.epa.gov/oppsrrd1/reregistration/atrazine/carc-rpt.pdf

Environmental Protection Agency. (EPA). (2005c). Consumer factsheet on: Atrazine. Retrieved April 6, 2005 from http://www.epa.gov/safewater/contaminants/dw_contamfs/atrazine.html

Environmental Protection Agency. (EPA). (2005d. Feb 14). National primary drinking water regulations: Technical factsheet on atrazine. Office of Ground Water and Drinking Water. Retrieved April 6, 2005, from http://www.epa.gov/safewater/contaminants/dw_contamf/atrazine

Environmental Protection Agency. (EPA). (2005e). Public drinking water systems programs. Office of Ground Water and Drinking Water. Retrieved August 9, 2005 from http://www.epa.gov/safewater/pws/pwss.html

Environmental Protection Agency. (EPA). (2006). List of Drinking Water Contaminants & MCLs. Office of Ground Water and Drinking Water. Retrieved April 8, 2006 from http://www.epa.gov/safewater/mcl.html#mcls

Environmental Working Group. (2000. June 27). Atrazine classified "likely human carcinogen" in tap water. Retrieved April 11, 2005, from http://www.mindfully.org/Water/Atrazine-Classified-Likely

Gianessi, L., & Puffer, C. (1991). Herbicide use in the United States: Washington, D.C., Resources for the Future, December 1990 (revised April 1991), 128 p.

Gojermac, T., Kartal, B., Zuric, M., Kusevic, S., Cvetnic, Z. (1996). Serum biochemical changes associated with cystic ovarian degeneration in pigs after atrazine treatment. *Toxical Letters.* 85(1): 9-15.

Hayes, T., Collins, A., Lee, M., et al. (2002). Hermaphroditic, demasculinized frogs after exposure to the herbicide, atrazine, at low ecologically relevant doses. Proceedings of the National Academy of Sciences (US) 99: 5476-5480.

Health Gate Data Corp. (2003). Risk factors for ovarian cancer. Gynecology and Obstetrics. Emory Healthcare. Retrieved August 14, 2005 from http://www.emoryhealthcare.org/HealthGate/32760.html

Hoar, S., Blair, A., Holmes, F., Boysen, C., Robel, R. (1985). Herbicides and colon cancer. *Lancet.* 1: 1277–8.

Hopenhayn-Rich, C., Stump, M. L., & Browning, S. R. (2002). Regional assessment of atrazine exposure and incidence of breast and ovarian cancers in Kentucky. *Archives of Environmental Contamination and Toxicology*, 42, 127-136.

Illinois Department of Public Health. (2005). Alachlor and atrazine in groundwater fact sheet. Retrieved April 12, 2005 from http://www.idph.state.il.us/cancer/factsheets/alachlor-atrazine.html

Information Ventures, Inc. (1995). Atrazine: pesticide fact sheet. Prepared for the U.S. Department of Agriculture, Forest Service by Information Ventures, Inc. Retrieved August 30, 2005 from http://infoventures.com/e-hlth/pestcide/atrazine.html

Kettles, M., Browning, S., Prince, T., Horstman, S. (1997). Triazine herbicide exposure and breast cancer incidence: an ecological study of Kentucky counties. Environmental Health Perspectives 105 (11): 1222-1227.

Kirsh, J. & Solomon, G. (2000. Jun). A wash in atrazine: herbicides, hormones, and cancer. Breast Cancer Action. Retrieved April 6, 2005, from http://www.bcaction.org/Pages/SearchablePages/2000Newsletters059C

Lowry, R. (2006). Subchapter 3b. rank-order correlation. Retrieved March 5, 2006 from http://faculty.vassar.edu/lowry/ch3b.html

MacLennan, P., Delzell, E., Sathiakumar, N., Myers, S., Cheng, H., Grizzle,W., et al. (2002). Cancer incidence among triazine herbicide manufacturing workers. *J Occup Environ*. 44: 1048–58.

MacLennan, P., Delzell, E., Sathiakumar, N., Myers, S. (2003). Mortality among triazine herbicide manufacturing workers. *J Toxicol Environ Health.* 66: 501–17.

Mills, P. (1998, Nov-Dec). Correlation analysis of pesticide use data and cancer incidence rates in California counties. *Arch Environ Health.* 53(6): 410–3.

Mills, P.K., & Yang, R. (2006. Jan-Feb). Regression analysis of pesticide use and breast cancer incidence in California Latinas. *J Environ Health.* 68(6): 15-22; quiz 43-4.

National Ag Safety Database. (2005). Pieces of the puzzle: Does atrazine affect the risk of cancer? Taken from Pesticide Applied Learning Series (PALS). PowerPoint Text. Retrieved September 8, 2005 from http://www.cdc.gov/nasd/docs/d001601-d001700/d001664/d001664.html

National Cancer Institute (NCI). (2003. 30 Dec). Pregnancy and Breast Cancer Risk. Retrieved August 14, 2005 from http://cis.nci.nih.gov/fact/3_77.html

National Center for Food and Agricultural Policy (NCFAP). (2005). National pesticide use database. Retrieved June 7, 2005, http://cipm.ncsu.edu/croplife/

Osborne, C., Ostir, G., Du, X., et. al. (2005. Sept). The influence of marital status on the stage at diagnosis, treatment, and survival of older women with breast cancer. Breast Cancer Res Treat. 93(1): 41-7. PMID: 16184457.

Oskasha, M. (2005). Epidemiology research. Retrieved April 19, 2005 from http://www.studentbmj.com/back_issues/0801/277.html

Pesticide Management Education Program (PMEP). (2005a). Atrazine (aatrex, atrazine) herbicide profile 3/90. Retrieved July 20, 2005 from http://pmep.cce.cornell.edu/profiles/herb-growthreg/24-d-butylate/atrazine/herb-prof-atrazine.html

Pesticide Management Education Program (PMEP). (2005b). Pesticides and drinking water. Retrieved April 20, 2005 from http://pmep.cce.cornell.edu/issues/pesticides-water.html

Pesticide Management Education Program (PMEP). (2006). Atrazine. Retrieved January 22, 2006 from http://pmep.cce.cornell.edu/profiles/extoxnet/24d-captan/atrazine-ext.html#32

Pinter, A., Torok, G., Borzsonyi, M., Surjan, A., Csik, M., Kelecsenyi, Z., et al. (1990). Long-term carcinogenicity bioassay of the herbicide atrazine in F344 rats. *Neoplasma*.37: 533–44.

Regional Pest Management Centers. (2003. Oct). Crop profile for corn in Texas. Retrieved June 16, 2005, from http://www.ipmcenters.org/cropprofiles/docs/TXcorn.html

Reynolds P., Hurley, S.E., Gunier, R.B., Yerabati, S., Quach, T., Hertz, A. (2005a, Aug). Residential proximity to agricultural pesticide use and incidence of breast cancer in California, 1988-1997. *Environ Health Perspect.* 113(8): 993-1000.

Reynolds P., Hurley, S.E., Quach, T., Rosen, H., Von Behren, J., Hertz, A., Smith, D. (2005b, Mar). Regional variations in breast cancer incidence among California women, 1988-1997. *Cancer Causes Control.* 16(2): 139-50.

Rusiecki, J., De Roos, A., Lee, W., Dosemeci, M., Lubin, J., Hoppin, J., Blair, A., Alavanja, M. (2004, Sept). Cancer incidence among pesticide applicators exposed to atrazine in the agricultural health study. *J Nat. Cancer Institute.* 96 (18).

RxList, Inc. (2005). Clinical Pharmacology. Retrieved August 14, 2005 from http://www.rxlist.com/cgi/generic3/estradiolval_cp.html

Seffernick, J., G. Johnson, M. Sadowsky, & L. Wackett. (2000, Oct). Substrate specificity of atrazine chlorohydrolase and atrazine-catabolizing bacteria. *Appl Environ Microbiol.* 66(10): 4247–4252.

Snedeker, S. (2001). Pesticides and breast cancer risk: an evaluation of atrazine. Program on Breast Cancer and Environmental Risk Factors in New York State. Cornell University, College of Veterinary Medicine. Retrieved August 30, 2005 from http://envirocancer.cornell.edu/Factsheet/Pesticide/fs23.atrazine.cfm

Snedeker, S. & Clark, H. (2005). Program on breast cancer and environmental risk factors in New York State (BCERF): Critical evaluation of atrazine's breast cancer risk. Retrieved August 22, 2005 from http://envirocancer.cornell.edu/criticaleval/pdf/CE.atrazine.pdf

Takeshi, U.S.U.I. (2006). Pharmaceutical prospects of phytoestrogens. *Endocr J.* 53: 7-20. Retrieved April 1, 2006 from http://www.jstage.jst.go.jp/article/endocrj/53/1/53_7/_article

Texas Cancer Data Center. (TCDC). (2005). Leading Cancer Death Rates in Texas. Retrieved August 7, 2005 from http://www.txcancer.org/demo/leadcq.html

Texas Center for Policy Studies. (1999. Jan). Atrazine contamination of Texas drinking water: your right to know. Retrieved April 8, 2005, from http://www.texascenter.org/txpin/atrazine

Texas Center for Policy Studies. (2005). Results of testing drinking water in Texas. *Texas Environmental Profiles*. Retrieved April 11, 2005, from http://www.texasep.org/html/wql/wql_4dwq_rslts

Texas Commission for Environmental Quality. (TCEQ). (2003. Fall). Dealing with atrazine. *Natural Outlook.* Retrieved January 22, 2006 from http://www.tceq.state.tx.us/comm_exec/forms_pubs/pubs/pd/020/03-04/atrazine.html

Texas Commission for Environmental Quality. (TCEQ). (2005a). TCEQ History. Retrieved September 7, 2005 from http://www.tceq.com/about/tceqhistory.html

Texas Commission for Environmental Quality. (TCEQ). (2005b). TCEQ Water Utility Database. Retrieved September 7, 2005 from http://www.tceq.state.tx.us/permitting/water_supply/ud/iwud.html

Texas Commission for Environmental Quality. (TCEQ). (2005c). Water Quality Inventory and 303 (d) List. Retrieved September 7, 2005 from http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/305_303.html

Texas Tech University. (2004). Digital Atlas of Texas Counties. Retrieved January 29, 2006 from http://gis.geog.ttu.edu/txcountyatlas/txcountymap.html

United States Census Bureau. (2005). 2000 Census Fast Facts for Congress. 4700 Silver Hill Road, Washington DC 20233-0001. Retrieved May 30, 2005, http://fastfacts.census.gov/

United States of Department of Agriculture- National Agriculture Statistics Service (USDA-NASS). (2005a). Agriculture Statistics Database. Room 5038-South, Washington, DC 20250 Retrieved May 16, 2005, http://www.nass.usda.gov:81/ipedb/

United States Department of Agriculture- National Agriculture Statistics Service (USDA-NASS). (2005b). Texas agricultural statistical districts map. Texas Field Office. Retrieved June 7, 2005 from http://www.nass.usda.gov/tx/distmap2.htm

Van Leeuwen, J., Waltner-Toews, D., Abernathy, T., Smith, B., Shoukri, M. (1999). Associations between stomach cancer incidence and drinking water contamination with atrazine and nitrate in Ontario (Canada) agroecosystems,1987–1991. *Int J Epidemiol.* 28: 836–40.

Ventura County Air Pollution Control District. (2004. Feb). Triennial plan assessment and update under the California clean air act. Retrieved March 5, 2006 from http://www.vcapcd.org/pubs/Planning/04AQMPUpd-Document.pdf

Wetzel, L., Luempert, L 3rd., Breckenridge, C., Tisdel, M., Stevens, J., Thakur, A., et al. (1994). Chronic effects of atrazine on estrus and mammary tumor formation in female Sprague-Dawley and Fischer 344 rats. *J Toxicol Environ Health.* 43: 169-82.