# Evaluation of Environmental Health Status Along the Arizona-Sonora Border

2017

## Table of Contents

## Authors, Contributors, and Reviewers

**Authors**
Aminata Kilungo, Sonora Environmental Research Institute, Inc.
Marco Gallegos, Sonora Environmental Research Institute, Inc.
Ann Marie Wolf, Sonora Environmental Research Institute, Inc.
Palmira Henriquez, Sonora Environmental Research Institute, Inc.
Paloma Beamer, The University of Arizona
Rietta Wagoner, The University of Arizona

**Contributors**
Raquel Brazo-Clouzet, Arizona Department of Health Services, Office of Border Health

**Reviewer**
Robert Guerrero, Arizona Department of Health Services, Office of Border Health
Diane Austin, The University of Arizona
Ted Gould, Pima Department of Environmental Quality

**Acknowledgements**
Rigoberto Ochoa, El Colef, Nogales
Ursula Kramer, Pima Department of Environmental Quality
Edna Mendoza, Arizona Department of Environmental Quality
Ashley Asburry, Arizona Department of Health Services

## Background Information

### About this Report

The purpose of this project was to describe the current status of environmental health along the Arizona-Sonora border; identify trends and gaps; and provide recommendations. The status of environmental health was evaluated by collecting existing data from different sources including health agencies and literature. Data was analyzed to identify trends and compare with regional and national data along the Arizona and Sonora border region, and the United States (U.S.) and Mexico. Environmental health indicators such as those established by U.S. Environmental Protection Agency (U.S EPA) and published in the 3rd edition of the *America's Children and the Environment* (ACE3)[1] report were used to guide data collection and analysis activities. Data analysis and reporting followed similar format as the ACE3 to ensure systematic interpretation and easy comparison of similar data in the future, whenever possible. Indicators analyzed in this report include environment and contaminants (water and contaminants, Criteria Air Pollutants (CAPs), Hazardous Air Pollutants (HAPs), and pesticides in foods), biomonitoring (lead in blood) and health (childhood cancer and adverse birth outcomes). Current status, data gaps, and recommendations for these indicators are presented in this report.

[1] http://www.epa.gov/ace/

## Introduction

The United States (U.S)-Mexico Border region is defined as the area within 100 km from either side of the border. The Arizona-Sonora Border extends 350 miles (Robinson et al., 2010)[1], and includes four border counties; Cochise, Pima, Santa Cruz, and Yuma. There several sister cities along border region; Yuma San Luis Arizona and San Luis Rio Colorado Sonora; Nogales Arizona and Nogales Sonora; Naco Arizona and Naco Sonora; and Douglas Arizona and Agua Prieta Sonora. [2]. As a result, the population along the border share similar environment, culture and social characteristics. The population of the Arizona border counties is approximately 1,378,269 million, of which 7% are under 5 years; 25% are under 18 years; and 17 % are 65 years and older[3,4]. The population in the state of Sonora is approximately 2.6 million. Approximately 450,000 of the population residing in sister cities on the Sonora side; 37% are under 18 years of age and 6% are 65 years and over[5]. These particular groups are at increased risk of health complications associated with environmental exposures, especially for children under 5 years of age since they are still in developmental stages. Communities along border regions tend to be predominantly low income with high poverty rate, underserved, and due to their socioeconomic status, need resources the most. Unincorporated communities also known as *colonias* still exist along the border. They tend to have inadequate housing, roads, sewage systems and drainage, and lack of potable water supplies (Robinson et al., 2010). Resources to provide relief and to alleviate poverty, environmental and health burdens, do not easily reach these communities. Children are usually more affected than the rest of the population due to their developmental stages and their small sizes, which make the harmful effects more concentrated. Children's body systems such as the nervous, endocrine, reproductive, respiratory and immune systems are in developmental stages making them more susceptible to damage. Even when the effect of harmful environmental exposure is not immediately evident, effects may become evident years after development.

Data collected and analyzed will benefit children under 18 years of age, including 5 years, as well as the general population along the border. Information will shed light on the current state of the environmental health, especially where children are concerned, so resources, education, and expertise can be directed where needed. Also, data analyzed will provide information to allow agencies and other stakeholder's advocate for policies to alleviate environmental exposure burdens for particular groups that may be most at risk.

---

[1] Robinson, K., Ernst, K., Johnson, B., Rosales, C. (2010). Health Status of Southern Arizona border counties: a Healthy Border 2010 midterm review. Revista Panamericana de Salud Publica.
[2] https://www.epa.gov/border2020/cross-border-contingency-plans-us-mexico-sister-cities
[3] http://www.census.gov
[4] http://www.azdhs.gov/diro/borderhealth/pdf/health_indicators (2010)
[5] http://www.inegi.org.mx/

## Key Findings, Data Gaps, and Recommendations

Key findings, data gaps and recommendation summarize the information collected and analyzed on environment and contaminants, biomonitoring and health data indicators along the Arizona-Sonora Border. For more detailed information, refer to the full report.

### Environment and contaminants

#### Water and contaminants

*Key findings*

- There was an overall downward trend for all categories of health-based violations between 2006 and 2014.
- Between 2006 and 2014, the estimated percentage of total Arizona Border population supplied by public water systems that had any health-based violation varied between 8% in 2006 and 11% in 2008. This is below the national average at 13% and 7% between 2003 and 2009 respectively.
- Between 2000 and 2014, the estimated percentage of total Arizona Border population supplied by public water systems that had any type of monitoring and reporting violation averaged between 15% and 20% except in 2006-2007, similar to the national average (U.S EPA, 2013).

*Data gaps*

- No water quality monitoring data was obtained for the Mexico side. Even though similar Drinking Water Quality Monitoring Standards exist in Mexico, it is not clear if data are available to the public.
- Data submitted to the Safe Drinking Water Information System (SDWIS) are voluntary, and may not fully capture water quality issues.

*Recommendations*

- Work collaboratively to develop a system for sharing water quality information binationally. Arizona-Sonora Border region share similar watershed. Poor water quality or water contamination on one side of the border may pose health risks to the border population.

#### Criteria Air Pollutants

*Key findings*

- Percentage of children ages 0-17 lived in counties with particulate matter 10 micrometers or less ($PM_{10}$), above the level of the current $PM_{10}$ 24-hr standard at least one day during the year, increased from 28% in 2005 to 100% in 2013. This is much higher compared to the national average of 3-5% between 1999-2009 (U. S EPA, 2013). The percentage significantly decreased to 26% between 2013 and 2015.
- Between 2005-2009, on the average 30% of children ages 0-17 lived in counties with particulate matter 2.5 micrometers ($PM_{2.5}$) above the levels of the current 24-hr $PM_{2.5}$ standards at least once a year, compared to the national average of between 60-32% during 2005-2009 respectively. From 2010 to 2015, no children ages 0-17 lived in counties with $PM_{2.5}$ levels above the National Ambient Air Quality Standards along the Arizona Border region.

- Between 2005-2015, the percentage of children living in counties with ozone concentrations above the levels of the current 8-hr ozone standard at least one day decreased from 48% to 26%. This is lower than the national average of 50-65% between 1999-2009 respectively (U.S EPA, 2013).
- Along the Arizona Border counties, 80% of children ages 0-17 years live in counties with no air quality monitoring for carbon monoxide, nitrogen oxides, sulfur oxide, or lead.
- Along the Arizona Border counties, 29% of children live in counties with no air quality monitoring for ozone, compared to the national level of 27% (U.S EPA, 2013)
- On average, between 1996-2008, 100% of the children in Nogales, Sonora lived in a municipality with $PM_{10}$ above the U.S. National Ambient Air Quality Standards.
- A total of 75% of children ages 0-17 years live in municipalities with no $PM_{10}$ air quality monitoring, while 100% live in municipalities with no $PM_{2.5}$, carbon monoxide, sulfur dioxide, nitrogen dioxide or lead air quality monitoring.
- For all the four Arizona Border counties, only 1% of days were designated as unhealthy in 2005 compared to the national levels of 5-2% between 2005 and 2009.

*Data gaps*

- Only Pima County monitors for all six criteria air pollutants.
- Santa Cruz and Cochise do not monitor for sulfur dioxide, nitrous oxide, carbon monoxide, or lead. In addition, Santa Cruz does not monitor for ozone.
- Since the beginning of 2007, Yuma does not monitor for sulfur dioxide, nitrous oxide, or carbon monoxide.
- Approximately, 75% of the population along the Arizona Border live in counties where sulfur dioxide, nitrogen dioxide or lead are not monitored.
- Along the Mexico side of the border, only Nogales, Sonora monitors for $PM_{10}$, and data were available up until 2009. The remaining municipalities (San Luis Colorado, Naco, and Agua Prieta) do not monitor for air quality.

*Recommendations*

- Work binationally to monitor for all six criteria pollutants along the Sonora side of the border. The Arizona-Sonora Border share a similar air shed. Air pollution on one side of the border affect border population on both sides of the border.
- Monitor for sulfur dioxide, nitrous oxide, and carbon monoxide in Santa Cruz, Cochise, and Yuma.

### Hazardous Air Pollutants

*Key findings*

- 99.3% and 100% of the entire Arizona Border region children population lived in census tracts where total cancer risk of HAPs summed to exceed the 1-in-100,000 cancer risk benchmark for 2005 and 2011 respectively. Similarly, national data demonstrates that 99.9% of all children in the country live in census tracts where concentrations of HAPs summed to surpass the 1-in-100,000 cancer risk benchmark for 2005 (U.S EPA, 2013).
- All children in both 2005 and 2011 in the Arizona Border region attended schools located in census tracts where total cancer risk summed to exceed the 1-in-100,000 cancer risk benchmark. These are the same results as the national scale.

- ❖ No children attended school located in a census track where at least one HAP exceeded the benchmark for non-cancer health effects in 2005 or 2011 compared to 56% for the national average in 2005 (U.S EPA, 2013).

*Data gaps*
- ❖ There are limited HAPs data for the Sonoran Border Region.
- ❖ NATA does not include possible HAPs emissions from Mexico that could impact the ambient concentration in the Arizona-Sonora Border region. Thus, health risk estimates for census tracts on the U.S side of the Border are likely to be underestimated (EPA, 2015).

*Recommendations*
- ❖ NATA should include HAPs emissions from the Sonora border region. HAPs emitted on one side of the border may potentially affect population on either side of the border.

**Pesticides in foods**

*Key findings*
- ❖ Yuma County had the highest percentage of sampled meals with detectable residues for 10 of the 18 pesticides. This could be due to agricultural activities and pesticide applications in Yuma County, compared to the other two counties.
- ❖ More than 50% of sampled meals in households for all three counties had atrazine, fluorene-D10 and heptachlor residues.
- ❖ 100% of Yuma households were found to have atrazine residues, while 97% and 96% of households in Cochise and Santa Cruz had atrazine residues, respectively.

*Data gaps*
- ❖ Data were collected in 1997-1998 and no recent data were available.
- ❖ Arizona is not part of the 10 State Pesticide Data Program, limiting comparisons to national data.
- ❖ National data available looks at pesticides for specific food groups, compared to the NHEXAS U.S. Border 2012 Program, which was done by looking at an entire meal rather than food categories. Therefore, it is difficult to compare with national data as well.
- ❖ The study for 24-hr solid food duplicate diet did not include Pima county.
- ❖ Even though there is data for pesticides residue on grains in Sonora (Aldana-Madrid, et. al, 2008) raw data could not be obtained despite multiple attempts.
- ❖ Data from the NHEXAS U.S. Border 2012 Program are reported as percentage detectable, which does not necessarily explain risk.
- ❖ The NHEXAS data does not provide an explanation of whether or not the produce was washed by the participant before analysis.

*Recommendations*
- ❖ Include Arizona in the USDA Pesticide Data Program to collect data for pesticides in food to be able to compare with national data or collect most recent data for pesticides in food in Arizona for NHEXAS follow-up (replicate NHEXAS data).

- ❖ Create a platform for sharing pesticides in foods information binationally. Mexico, including the state of Sonora is the top supplier of fresh foods and vegetables in the United States, especially in the winter months.

## Biomonitoring

### Blood lead

*Key findings*

- ❖ Overall decrease in the percentage of children with BLL > 5 µg/dL between 2005 to 2014 (based 20% screening rate)
- ❖ The percentage of children screened with BLL > 5 µg/dL remained 2% between 2009 to 2015 except for Cochise county, compared to the national average of 2.8-6% (CDC, 2016) during the same period.
- ❖ There is a slight increasing trend in the percentage of screened children with BLL > 5 µg/dL beginning in 2015 for Cochise and Yuma counties. We speculate this may well be due to the initiatives to increase screening rates

*Data gaps*

- ❖ In Arizona, the screening rate is very low and therefore number of children with elevated BLL may be underestimated.
- ❖ There is a need to establish a current geometric mean BLL for Arizona and along the border counties to measure progress of current health initiatives to address blood lead in children.
- ❖ Even though data for BLL may be available in the State of Sonora, data were not accessible. The available data conducted by Cowan et al. (2006) that collected from both side of the border were old. This limits the ability to better understand the current status of BLLs along the Arizona-Sonora Border as a whole.
- ❖ The screening is based on at risk index, mostly the Latino population. However, it is important to note that Yuma and Santa Cruz counties are made up of 80 and 60% Hispanic populations, respectively. Conversely, approximately 30% of Pima and Cochise counties' populations are Hispanic. Targeting Hispanic population in Santa Cruz may yield representative data for the population while the same approach may not be ideal for Pima.

*Recommendations*

- ❖ Even though less than 15% of the homes along the border are pre-1978; shared cultural practices especially those related to food including ceramic imports for food preparation, may all increase the potential risks for elevated BLLs for children along the border, especially of Hispanic origin. More recent data, such as a follow-up study by Cowan et al. (2006) will provide a snapshot of the current status of BLL for children along the Arizona-Sonora Border.
- ❖ Continue to target older homes with campaign to emphasize on repairing old paint and other lead mitigations.

## Health

### Childhood cancer

*Key findings*

- The age-adjusted cancer incidence in children between the years 2000 and 2013 for each county ranged from 31 to 484 cases per million. For the most part, all four counties were below the national average with exceptions of some peak years. The national average ranged from 157 to 175 cases per million children
- Leukemia was the most common diagnosis in all four counties between 2000-2013, accounting for approximately 28% of all cancer cases for those years respectively. National average was 28% from 2004-2006 (U.S EPA, 2013).
- The age-adjusted childhood cancer mortality in children between the years 2000 and 2013 for the entire state of Arizona ranged from 21 to 39 cases per million children compared to the national rates of 20.5 to 24.8 cases per million.
- The childhood cancer incidence for Mexico has slowly increased from 2008 to 2014 from 91 to 112 cases per million children.
- The childhood cancer incidence for Sonora has been below the national average from 2008 to 2013 ranging from 70 to 94 cases per million children. In 2014, the cancer incidence for the state surpassed the national childhood cancer incidence by 15 cases to 127 cases per million children.
- The childhood cancer mortality in children in Sonora has remained above or at the same level as the national level for 5 out of the 7 years illustrated in Figure 4 ranging from 36 to 61 cancer cases per million children between 2008 to 2014.

*Data gaps*

- Some data in the ACR are not complete and thus cancer cases may be underreported or underestimated.
- Statewide childhood cancer mortality case data were available in the ACR for analysis but not for the individual Arizona border region counties of interest.
- Queries in the ACR for age could only be done from 0-4 years, 5-14 years and 15-24 years. The latter age group had to be excluded from analysis due to a mixture of adult and children data. Thus, relevant data for this indicator for children between the ages of 15-19 is missing.
- Childhood cancer incidence and mortality are not comparable between the United States and Mexico due to different age groups analyzed in this report.

*Recommendations*

- Work collaboratively to develop a system for sharing cancer information binationally, that also allows comparison within similar age groups by cancer types.
- Improve the Arizona Cancer Registry to allow greater flexibility to query data by different age groups, by counties and ethnicities.

## Adverse birth outcomes

*Key findings*

- Percentage of infants delivered at term with low birth weight has remained relatively the same between 2000-2014 for the Arizona Border region and the state of Arizona at 7% and nationally at 8%.
- The percentage of infants delivered at term with low birth weight along the Sonora border region, and the state of Sonora are relatively similar between 3-6%, which is below the Mexico national average of 5-8% during 2008 and 2014.
- The U.S, Arizona and along the Arizona side of the border have higher percentages of birth delivered pre-term (9-11%), compared to Mexico, the state of Sonora and the Sonora side of the border (5-7%).

*Data gaps*

- Arizona county data for preterm and LBW births are not available by race/ethnicity to allow comparisons of these adverse birth outcomes by county and race/ethnicity.
- The percentage of mothers in rural municipalities who have birth in their homes due to lack of access to transportation to health facilities is unknown and is not reflected in the data for Mexico.
- It is not clear why percentage of preterm birth in the U.S and Arizona are higher than Mexico and along the Sonora Border.

*Recommendations*

- Even though health agencies may collect data by race, income and age by county, most of the time data were not easily available on their websites. Being able to analyze data for preterm and low birth weight by race/ethnicity would allow comparisons of these adverse birth outcomes by county and race/ethnicity. This will shed light on where to focus efforts to further lower cases of preterm and low birth weight, to improve overall children's health. Preterm and low birth weight can cause long-term health problems for babies and have long-lasting effects into adulthood.

## Drinking Water Contaminants

Clean drinking water is essential for life. Water security[1] is of a great concern along the Arizona-Sonora Border in particular due to its semi-arid climate. Both Arizona and Sonora have identified managing water resources as a high priority to ensure water availability and quality in the present and in the future. The primary drinking water sources are groundwater and surface waters, including the Colorado River. Approximately 43% of Arizona drinking water comes from groundwater (Arizona Department of Water Resources (ADWR, n.d.). In Sonora, drinking water comes from groundwater and surface water, and in Ambos Nogales[2] 50% of potable water comes from the Santa Cruz aquifer (Sprouse, 2005). The border-counties in Arizona and northern Sonora share a similar watershed. Water pollution, water quality degradation, and water stress in one country has an impact on the other. Due to its semi-arid climate[3], the Arizona-Sonora border region receives less annual precipitation compared to other regions and, as a result, experiences low recharge to its aquifers and high-water stress (Mumme, 1999; Statistics on Water in Mexico (SWM), 2010 Edition). Arid and semi-arid regions will be to a greater extent impacted by climate change due to rise in temperatures and increase in drought with lower stream flows, which in turn will result in water scarcity and degradation of water quality (IPCC, 2007; Gleick, 2010; Spring 2014).

### Drinking Water and Contaminants along the Arizona-Sonora Border Region

Economic development and increase in population growth all add pressure on the drinking water supply systems. Between 2000 and 2007, the U.S-Mexico border region as a whole grew by 10%, of which 2.2% increase was from the Arizona side, while the Sonora side saw a decrease of less than 1% (Pavlakovish-Kochi & Lim, 2009). However, there was a profound increase previously, between 1990 and 2000, during which time population along the border grew 17.9% along the Arizona side of the Border, while the Sonora of the border saw a 3% decrease (Pavlakovish-Kochi, 2005). While population on the U.S side has continued to grow, that of the Sonora Border region has remained relatively the same. The northern part of Mexico has experienced health concerns due to lack of proper sanitation and clean water, in addition to water scarcity concerns (SWM, 2010 Edition). Moreover, deficiencies in wastewater treatment, disposal of effluent, and inadequate operations and maintenance of treatment plants have all posed health risks due to potential contamination of both the surface and groundwater in urban and rural border communities (Arizona Department of Environmental Quality (ADEQ), n.d.; Pan American Health Organization (PAHO), 2012).

While the United States has seen continuous improvements in water quality and delivery from the early 1970s following the Clean Water Act, the Arizona-Sonora Border region has not kept up the same pace. While 98% of the households have access to piped drinking water in the U.S

---

[1] Water security is defined as the capacity of population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socioeconomic development, to ensure protection against water-borne pollution and water-related disasters, and for preserving ecosystem in a climate of peace and political stability (UN-Water, 2013)

[2] Ambos Nogales refers to the twin sister cities of Nogales Arizona and Nogales Sonora

[3] Semi-arid climate is characterized by light rainfall and having from about 10 to 20 inches of annual precipitation (Merriam-Webster dictionary)

border cities overall, only 78% have such access in border cities like Nogales, Sonora (PAHO, 2012). In Sonora, Mexico, piped tap water is received intermittently and is not available to all neighborhoods even in urban areas. In some cases, people rely on 'pipas' water supply as a delivery system, especially in the *Colonias*[4] with no access to piped water (Norman, 2012). 'Pipas' are diesel trucks that haul large metal containers filled with water that are used to fill large containers owned by homeowners via a hose. The pipas system may be operated though Organismo Operador Municipal de Agua Potable (OOMAPAS)[5], a water utility company that is responsible for both distribution and water monitoring or through private vendors (Norman et al, 2012). While those served by pipas from the municipality may adhere to better water quality standards, private pipas delivery system may not necessarily adhere to water quality standards (Norman, et al., 2012) or the storage tanks may be contaminated rendering people ill (Caldera, 2011). In addition, there is a population that use domestic wells. In the U.S., users of domestic wells are not required by law to monitor water quality. As of 2007, it was estimated that 5% of the U.S border population were on domestic wells (Artiola and Uhlman, 2009). The Arizona – Sonora Border region has a long history of environmental pollution, including water contamination (Sanchez, 1995; U.S Department of Health and Human Services (DHHS), 2006). As a result, the Border population has a perceived idea that it is safer to consume water from purchased water bottles as opposed to consuming drinking water supplied by the utility company. Not surprisingly, Mexico is one of the largest consumers of bottled water per capita than any other country in the world (Rodwan, 2014; Victory, n.d.).

In Arizona, the U.S EPA and the ADEQ are responsible to ensure water supply for public use is safe and meets drinking water quality standards set by U.S EPA. The drinking water standards require public water suppliers to be disinfected and monitored to protect public health. The U.S EPA has set standards to monitor for microbial, organic and inorganic chemicals pollutants, as well as monitoring for physical parameters such as turbidity. In the U.S, violations of these standards are voluntarily reported by the water supply system to the U.S EPA. This information is also available to the public, through the Safe Drinking Water Information System (SDWIS) on the U.S EPA website. Similarly, the EPA requires U.S community water systems to provide consumers with annual drinking water quality reports, termed "Consumer Confidence Reports". In the Sonora Border region, the Secretariat of the Environment and Natural Resources (SERMANAT) sets limits of the type and quantity of pollutants allowed in water for agricultural purposes (Official Mexican NOM-001-ECOL-1996) (Comisión National del Agua (CONAGUA) n.d.), while the drinking water monitoring standards are set by the Ministry of Health. The Ministry of Health has established requirements for water supply systems, transportation of drinking water, as well as sampling procedures. The standards established by the Ministry of Health to ensure safety of drinking water for human use include; monitoring for inorganics and organic chemicals, microbial as well as physical parameters (The Joint Academies Committees on the Mexico City Water Supply, 1995).

[4] *Colonia* is an unincorporated housing development, characterized by high poverty rate and may lack basic community infrastructure (PAHO, 2012).

### Safe Drinking Water Information System (SDWIS)

The Safe Drinking Water Information System also known SDWIS is U.S EPA database for drinking water violations (monitoring, reporting or health-based). Information is provided to the U.S EPA voluntarily by the drinking water supply system. Water supply systems are required by law to monitor for certain drinking water contaminants and where these requirements are not met, they are required to report these violations back to the state. The state then reports back to the U.S EPA. For each public water system, it provides the county, the city and population it serves, the type of water source and a unique water system ID, as well as the type of violation.

### Health Based Violation

Health based violation indicator represents violations where surface water was not treated properly or a monitored contaminant exceeded a safety standard (i.e., Maximum Contaminant Level (MCL)). (U.S EPA SDWIS). These violations are grouped as follows:

- Surface water treatment: includes violations of guidelines within the Surface Water Treatment Rule and the Interim Enhanced Surface Water Treatment Rule. Both rules stipulate maintenance proceedings as well as treatment types for public water systems in order to prevent drinking water contamination through microbes.

- Chemical and radionuclide: includes violations of MCLs for organic and inorganic chemicals based on the Chemical Contaminant Rules. These include chemicals like: benzene, carbon tetrachloride, cadmium, endrin and glyphosate. Violations for radionuclides are also included based on the Radionuclides Final Rule, which include uranium and radium.

- Lead and copper: includes violations to guidelines implemented for the control of lead and copper in drinking water including water treatment requirements.

- Total coliforms: includes violations in the health goal (Maximum Contaminant Level Goal (MCLG)) and the legal limits (MCL)) for total coliform bacteria, which EPA considers an indicator for other pathogens in drinking water.

- Nitrate/nitrite: includes violations of the MCL’s for nitrates and nitrites.

- Disinfectants and disinfection byproducts: includes violations of disinfectant standards, which include chloramines, chlorine and chlorine dioxide. Violations for disinfection byproducts are also accounted, which include bromate, chlorite, haloacetic acids (HAA5) and total trihalomethanes (TTHM’s).

### Monitoring and Reporting Violations

This indicator represents violation of monitoring and reporting where a system failed to complete all samples or a sample in a timely manner, or had another non-health-based violation. An example would be a water system that failed to take a large percentage of the required samples or the water system failed to take some of the required samples (U.S EPA SDWIS)

## Data Presented in the Indicators

Health indicator (Figure 1) presents the estimated percentage of the total Arizona border population served by community water systems with violations of drinking water monitoring and reporting requirements. The statistics are based on data reported to SDWIS on violations between the years 2000 and 2015. The indicator is calculated by first obtaining all public water systems with any violations in the EPA SDWIS database within each Arizona Border county (Cochise, Pima, Santa Cruz and Yuma). The percentage population was obtained by adding the number of people supplied by the water supply systems who reported violations. Water suppliers that served less than 500 people were excluded (approximately 44,711 people). The total number of people served by each water system with violations for each county was then summed up. U.S. census data were used to estimate the total percentage of children exposed to water served by water systems with violations.

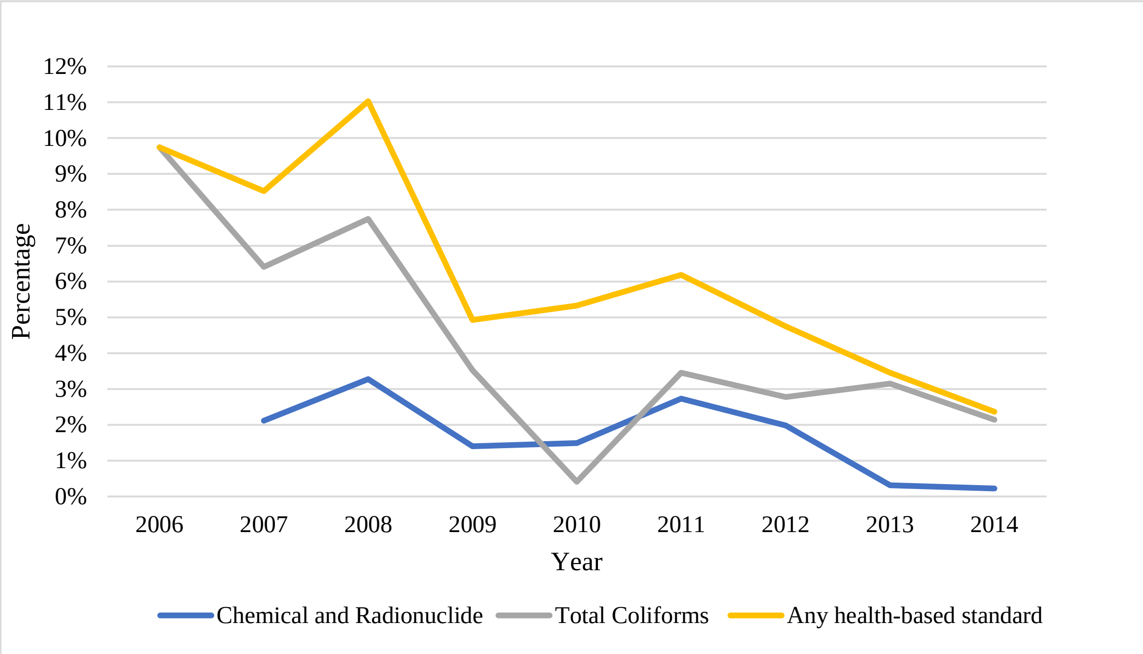
Figure 2. shows the estimated percentage of the total Arizona border population served by community water systems that failed to meet health-based drinking water standards between the years 2006 to 2015. The data were also obtained from SDWIS and the same procedures used to determine reporting and monitoring violation shown on figure 2. However, it must be noted that the categories nitrates/nitrites, lead and copper and surface water treatment are not present in the table because there were no health-based violations in these categories.

Both Figure 1 and 2 illustrate comparable data throughout the 10-year period between 2006-2015. However, there were some changes in drinking water standards that are reflected in the analysis. Changes in the surface water treatment rule were made in 2006 (U.S EPA). This includes changes to arsenic levels in drinking water supply systems. In 2007, there were changes to the lead and copper rule (U.S EPA). It should also be noted that low number of violations for health-based standards could be due to under-reporting. According to the U.S. Government Accountability Office (GAO) Report to Congressional Requesters (2011), data reported to EPA are unreliable and fail to reflect water system performance. Furthermore, the report illustrated that 97% of all discrepancies found in the SDWIS database were due to underreporting, and this may also affect monitoring and what is known about health based violations (GAO, 2011).

It must be noted that both monitoring and reporting, and health based indicators fail to provide a direct measure of people's exposure to contaminants in drinking water. Data was analyzed to only estimate the percentages of people served by these water systems using U.S. census data and the SDWIS database.

**About the indicators:** Data for both indicators; health based violation (figure 1) and monitoring and reporting violation (figure) were obtained through EPA's Safe Drinking Water Information System database. The data are voluntarily reported by the water supply systems. Since data are voluntarily reported, the data may be inaccurate or underreported. Figure 1 represents the percentage of total Arizona Border population served by community water systems that did not meet all applicable health-based drinking water standards. Figure 1 is aligned with the America's Child and the Environmental (ACE3), indicator E7. Figure 2 shows the percentage of the total Arizona Border population served by community water systems that violated the drinking water monitoring and reporting requirements. Figure 2 is also aligned with ACE3 indicator E8.

**Figure 1: Estimated percentage of total Arizona border population served by community water systems that did not meet all applicable health-based drinking water standards, 2006-2015**




Data: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System

**Data Characterization**

- Data was downloaded from the U.S EPA Safe Drinking Water Information System (SDWIS) by county. However, not all violations are reported and may therefore be underestimated.
- Drinking water standards have changed over time and may therefore some violations may not be comparable.
- About 5% (300,000) of the population in Arizona were on private wells as of 2007 (Artiola & Uhlman, 2009). Private wells are not regulated and therefore not included in this report.
- For reference, the following are the statistics for percent of the population for children under 18 years of age in the four Border counties: 21.9% (Pima), 28.3% (Santa Cruz), 26.2% (Yuma), 22.4% (Cochise) (U.S Census, 2011)

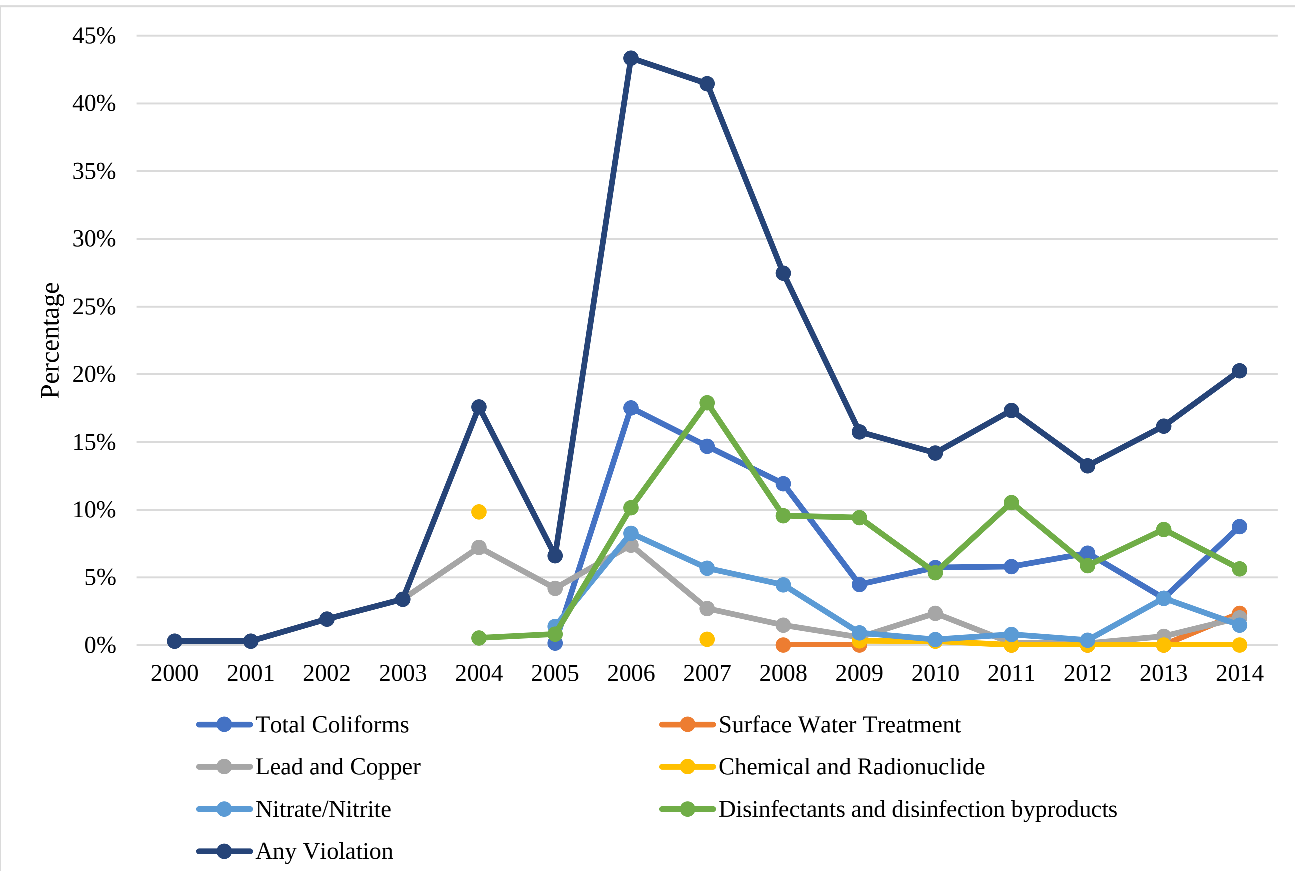
**Key Findings**

- ❖ There was an overall downward trend for all categories of health-based standards between 2006 and 2014.
- ❖ Between 2006 and 2014, the estimated percentage of total Arizona Border population supplied by public water systems that had any health-based violation varied between 8% in 2006 and 11% in 2008. This is below the national average at 13% and 7% between 2003 and 2009 respectively.
- ❖ There was an increase in number of violations between 2007-2008 from 8% to 11%.
- ❖ The estimated percentage of Arizona Border population supplied by public water systems that failed to meet health-based standards for chemical and radionuclides was about 2% in

2006 and decreased to 0.2% in 2014. The national average has been steady at less than 2% from 1993-2009 (U.S EPA, 2013)

- ❖ The estimated percentage of Arizona Border population supplied by public water systems that failed to meet health-based standards for total coliforms was about 10% in 2006 and decreased to 2% in 2014 compared to the national level which averaged 4% between 1997-2009 (U.S EPA, 2013).

**Figure 2: Estimated percentage of total Arizona Border population served by community water systems with violations of drinking water monitoring and reporting requirements, 2000-2015.**




Data: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System

**Data Characterization**

- Data was downloaded from the U.S EPA Safe Drinking Water Information System (SDWIS) by county. However, not all violations are reported and may therefore be underestimated.
- Drinking water standards have changed over time and may therefore some violations may not be comparable.

## Key Findings

- ❖ From 2009 onward, violations of drinking water monitoring and reporting requirements remained relatively constant.
- ❖ Between 2000 and 2014, the estimated percentage of total Arizona Border population supplied by public water systems that had any type of monitoring and reporting violation averaged between 15% and 20% except in 2006-2007, similar to the national average (U.S EPA, 2013).
- ❖ In 2005 and 2006 43% of the Arizona Border population were supplied by public water systems with monitoring and reporting violation, compared to the national average of approximately 23% during similar period.

## Data Gaps

- ❖ No water quality monitoring data was obtained for the Mexico side. Even though similar Drinking Water Quality Monitoring Standards exist in Mexico, it is not clear if data are available to the public.
- ❖ Data submitted to the Safe Drinking Water Information System (SDWIS) are voluntary, and may not fully capture water quality issues.

## Recommendations

- ❖ Work collaboratively to develop a system for sharing water quality information binationally. Arizona-Sonora Border region share a similar watershed. Poor water quality or water contamination on one side of the border may pose health risks to population on both sides of the border.

## Criteria Air Pollutants

The Clean Air Act (CAA), which was enacted in 1970 and was later amended in 1977 and 1990, allows the United States Environmental Protection Agency (U.S. EPA, 2016) to establish the National Ambient Air Quality Standards (NAAQS) to protect public health. The CAA identifies two types of national ambient air quality standards. The primary standards provide public health protection and protect the health of those considered vulnerable such as those with asthma, children and the elderly. The secondary standards protect the public welfare including protection against decreased visibility, damage to crops and vegetation, animals as well as buildings (U.S EPA, n.d). The U.S EPA has national air quality standards for six Criteria Air Pollutants (CAP). The six criteria air pollutants which are also the common air pollutants are ground-level ozone ($O_3$), particulate matter (PM), carbon monoxide (CO), sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), and lead (Pb).

**Ozone ($O_3$)**: ground-level ozone is not directly emitted into the air but rather forms because of chemical reactions between nitrogen oxides (NOx) and Volatile Organic Compounds (VOCs) in the presence of sunlight. Major sources of NOx and VOCs include: industrial facilities, electrical utilities, motor vehicles, gasoline, and others (U.S EPA, n.d). Breathing ozone may trigger respiratory problems especially for the elderly, children and those with lung and asthma diseases (U.S EPA, 2016; McBride et al., 1994). Ozone may cause premature deaths; developmental, reproductive, and cardiovascular harm; asthma attacks; wheezing and coughing; susceptibility to infections; and lung redness and swelling. (American Lung Association, 2016).

**Particulate matter (PM):** is a mixture of particulates such as nitrates and sulfate acids, organic chemicals, metals, soil, dust particles and liquid droplets. The U.S EPA is particularly concerned with $PM_{10}$ and $PM_{2.5}$. $PM_{10}$ are inhalable particles such as those from dust, are larger than 2.5 micrometers and smaller than 10 micrometers. $PM_{2.5}$ includes fine particles 2.5 micrometers and smaller such as those from smoke, haze, and gases from industries (U.S EPA, 2016). Particulate matter is of concern to human health. There is a correlation between the size of the particulate matter and health. When inhaled, these particles are small enough to get into the lungs and may exacerbate respiratory symptoms, irritate airways, cause difficulty breathing, aggravate asthma, and contribute to the development of Chronic Obstructive Pulmonary Diseases (COPD). (Hansel et al., 2016; Gorai et al., 2014; Delfino et al.,1996). Furthermore, some particles are small enough that they may enter the bloodstream (U.S EPA, 2016).

**Carbon monoxide (CO):** The majority of outdoor carbon monoxide emissions come from mobile sources emitted from combustion processes and indoor sources include chimneys, gas stoves, and gas-fueled space heaters (U.S EPA, 2016). Carbon monoxide is a colorless and odorless gas that reduces oxygen delivery to vital organs such as the heart and the brain when inhaled (U.S EPA, 2016). At high levels, carbon monoxide may cause death. Carbon monoxide poisoning symptoms includes headache, dizziness, upset stomach, confusion and vomiting. The Center for Disease Control (CDC) estimates 20,000 visits a year to emergency rooms due to carbon monoxide poisoning and 4,000 hospitalizations (CDC, 2015).

**Sulfur dioxide ($SO_2$):** EPA's NAAQS for sulfur dioxide is to protect the population from the entire group of sulfur oxides (SOx). $SO_2$ is the compound of greatest concern and is used to represent the group. SOx react with other chemicals to form smaller particles that may get into the lungs and exacerbate respiratory diseases and heart diseases (U.S EPA, 2016). One of the major sources of sulfur oxide is fossil fuel combustion in power plants and industrial facilities (U.S EPA, 2016). People with lung diseases, children, and older adults may be more sensitive to sulfur oxide. Sulfur oxide is also linked to a number of respiratory diseases.

**Nitrogen dioxide ($NO_2$):** is the indicator compound for another group of highly reactive gases known as nitrogen oxides (NOx). The $NO_x$ group also includes nitrous acid and nitric acid. Nitrogen dioxide is a combustion-generated oxidant gas that is present both indoors and outdoors (Samet and Bell, 2004). The major source for outdoors is from combustion engines and power generators. The U.S EPA NAAQS use the nitrogen oxides group to monitor a large group of nitrogen oxides such as nitrous and nitric acid. Indoor nitrogen oxide levels are also of a concern to health, as short-term exposures can irritate the respiratory system and lead to complications (U.S EPA, 2016). Indoor nitrogen oxides at levels below the NAAQS levels have shown to increase asthma morbidity in children (Belanger et. al., 2013).

**Lead (Pb):** is a naturally-occurring metal that is used in various industrial settings. Sources of lead in the air may include ores in metal processing, waste incinerators, utilities and lead-acid battery manufacture. Prior to 1980, sources of lead in the air were primarily from combustion of leaded gasoline (EPA, 2016). However, EPA's regulatory efforts to curb the use of lead in gasoline, the amount of lead in the air has reduced by 98% from 1980-2014 (EPA, 2016). Lead intake into the body can affect the nervous system, immune system, kidneys and the capacity for the blood to carry oxygen into the body. Children are more sensitive to lead exposure, even at lower concentrations because it can affect childrens' brain development and may also cause behavioral problems (EPA, 2016).

### Air Quality along the Arizona-Sonora Border

The two types of air pollution that dominate in the U.S are ozone and particulate matter. In the U.S., over 166 million people live in counties with unhealthy levels of one or both of these pollutants (American Lung Association, 2016). In the U.S., progress has been made to improve air quality over the years. However, challenges still exist to continuously tackle air quality along the border region, including along the Arizona-Sonora Border. The Border Region shares a common air shed. Poor air quality along one side of the border impacts the population on the other side of the border. PM pollution is of a particular concern along the border region due to unpaved roads, poorly maintained and aging vehicles, and the maquiladora industries along the border communities. In Ambos Nogales, unpaved roads were identified as one of the largest source of particulate matter (ADEQ, 2005). The semi-arid environmental condition and high winds all elevate the PM levels in the regions. Even though there is an extensive network of Ambient Air Quality Monitoring along the U.S. side of the border, efforts have been lagging especially along the Mexico side of the border.

Along the Arizona side of the border, not all CAPs are monitored in each of the four counties. Pima County monitors all six of the CAPs. Cochise and Yuma Counties monitor for ozone, $PM_{2.5}$, and $PM_{10}$, while Santa Cruz only monitors for $PM_{2.5}$ and $PM_{10}$. Along the Mexico side of the border, only Nogales, Sonora monitors for $PM_{10}$ and $PM_{2.5}$[1]. Several studies have been conducted over the years to set up groundwork for air quality monitoring on the Mexico side of the border. These studies have collected data for $PM_{10}$, Air Emissions Inventory, and human health risk assessment (ADEQ, 2012) to establish future air quality monitoring efforts. These efforts are underway and ongoing. Currently, The Sonora Commission on Ecology and Sustainable Development (CEDES), the Secretariat of Environment and Natural Resources (SERMANAT), U.S EPA Border 2020, and ADEQ are working together to establish Air Quality Monitoring Network along the Arizona-Sonora Border.

**Data Presented in the Indicators**

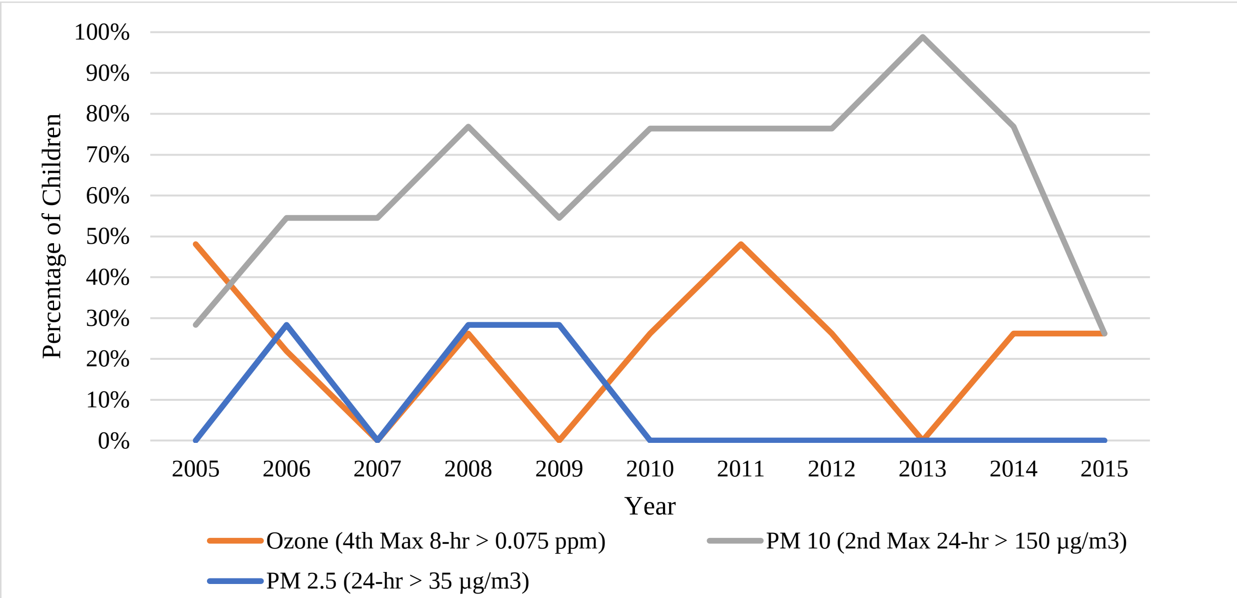
Data presented for Figures 1-4 were downloaded from the U.S. EPA Air Quality Data, Air Quality Statistics Report. Data were queried by year and county and include exceptional events. Data presented in Figure 1 show children 0-17 years of age living in counties with criteria air pollutants above the National Ambient Air Quality Standards[2] including exceptional events[3]. Data for children ages 0-17 years of age were obtained from census data for the four border counties presented herein. Data presented in Figures 2-4 show the criteria air pollutants by county, including exceptional events. Data presented in Figure 5 for Nogales Sonora were obtained from the Arizona Department of Environmental Quality (ADEQ) Office of Border Health. Data presented in the graph are also for $PM_{10}$ concentrations by year, including exceptional events.

**About the indicators:** Figure 1 represents the percentage of children living in counties where measured ambient concentrations of criteria pollutants were greater than the levels of the Clean Air Act health-based standards at any time during a year. Figure 1 presents results for criteria pollutant for each year, and is aligned with the third America's Child and the Environment (ACE3) report. Figures 2-4 show the concentrations of the monitored Criteria Air Pollutants by county. Figure 5 shows the concentrations $PM_{10}$ of the monitored Criteria Air Pollutants in Nogales, Sonora municipality.

---

[1] Data for $PM_{2.5}$ from Nogales Sonora were not included in this report.
[2] National Ambient Air Quality Standards: https://www.epa.gov/criteria-air-pollutants/naaqs-table#3
[3] Exceptional events are unusual or naturally occurring events that affect air quality. These events may not be reasonably controlled using techniques that the agencies have put in place to attain the NAAQS (U.S EPA).

**Figure 1: Percentage of children ages 0 to 17 years living in the Arizona Border counties with pollutant concentrations above the levels of air quality standards, by pollutant, 2005–2015**




Data source: U.S EPA, Outdoor Air Quality Data, Air Quality Statistics Report.

## Data Characterization

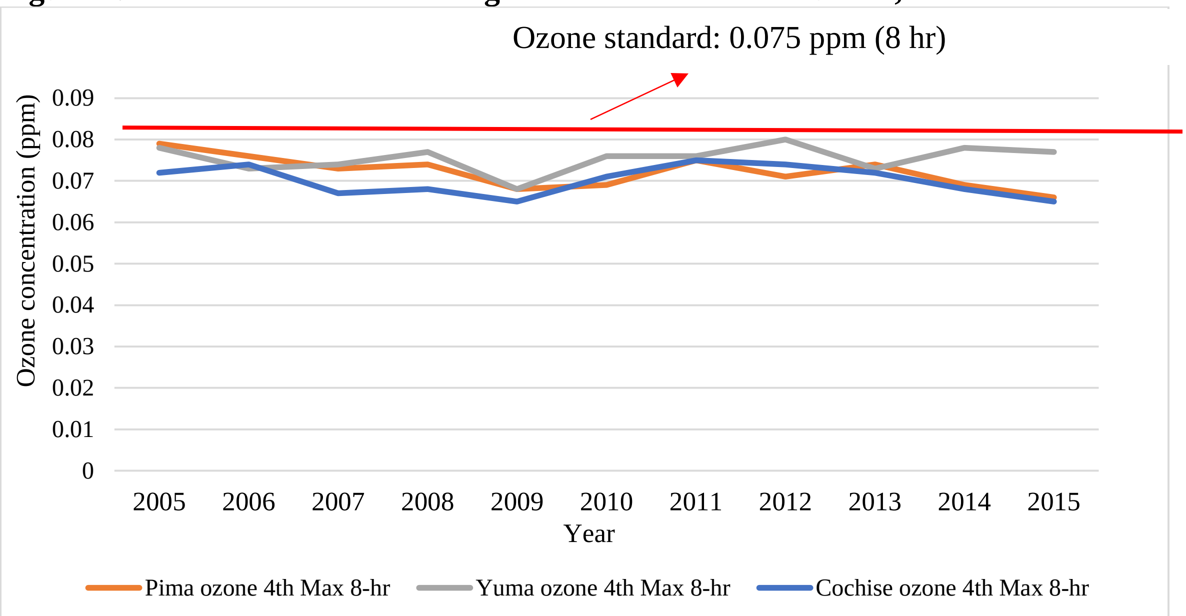
- Data were queried from AirData, Air Quality Statistics Report by year, county, and exceptional event. Exceptional event data were included to provide daily information when NAAQS were not met.
- Ozone data are based on Pima, Yuma and Cochise counties. Santa Cruz does not monitor for ozone. Therefore, the percentage of children population for Santa Cruz is not accounted for ozone exposure. As a result, the percentage of children living in counties with ozone above the levels of current air quality standards may be underestimated.
- $PM_{10}$ and $PM_{2.5}$ based on all four border counties.

## Key Findings

- ❖ Percentage of children ages 0-17 lived in counties with $PM_{10}$ above the national air quality standard above the level of the current $PM_{10}$ 24-hr standard at least one day during the year, increased from 28% in 2005 to 100% in 2013. This is much higher compared to the national average of 3-5% between 1999-2009 (U. S EPA, 2013). The percentage significantly decreased to 26% between 2013 and 2015.
- ❖ Between 2005-2009, on the average 30% of children ages 0-17 lived in counties with $PM_{2.5}$ above the levels of the current 24-hr $PM_{2.5}$ standards at least once a year, compared to the national average of between 60-32% during 2005-2009 respectively. From 2010 to 2015, no children ages 0-17 lived in counties with $PM_{2.5}$ levels above the National Ambient Air Quality Standards along the Arizona Border region.

- ❖ Between 2005-2015, the percentage of children living in counties with Ozone concentrations above the levels of the current 8-hr ozone standard at least one day decreased from 48% to 26%. This is lower than the national average of 50-65% between 1999-2009 respectively (U.S EPA, 2013).
- ❖ Along the Arizona Border counties, 80% of children ages 0-17 years live in counties with no air quality monitoring for carbon monoxide, nitrogen oxides, sulfur oxide, or lead.
- ❖ Along the Arizona Border counties, 29% of children live in counties with no air quality monitoring for ozone, compared to the national level of 27% (U.S EPA, 2013)

**Figure 2: Ozone concentration along the Arizona Border counties, 2005-2015**




Data source: U.S EPA, Outdoor Air Quality Data, Air Quality Statistics Report.

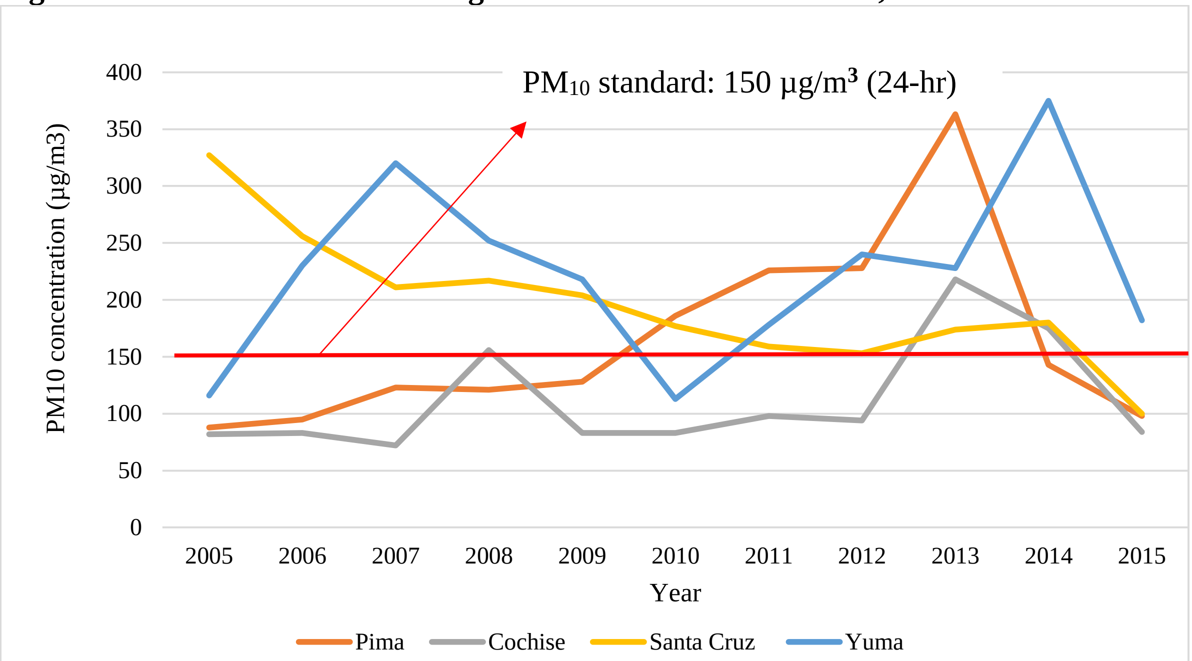
## Data Characterization

- Data were queried from AirData, Air Quality Statistics Report by year, county, and exceptional event. Exceptional event data were included to provide daily information when NAAQS where not met.
- Ozone data were based on Pima, Yuma and Cochise Counties. Santa Cruz does not monitor for ozone.

## Key Findings

- ❖ Only Pima, Yuma, and Cochise Counties monitor for ozone
- ❖ Pima has maintained ozone levels below 0.075 ppm since 2006 while Yuma has had at least one 4$^{th}$ maximum 8-hour concentration above the current standard for seven out of the eleven years between 2005-2015.
- ❖ Ozone in Cochise County has stayed relatively below the National Ambient Air Quality Standards.

**Figure 3: $PM_{10}$ concentration along the Arizona Border counties, 2005-2015**




Data source: U.S EPA, Outdoor Air Quality Data, Air Quality Statistics Report.

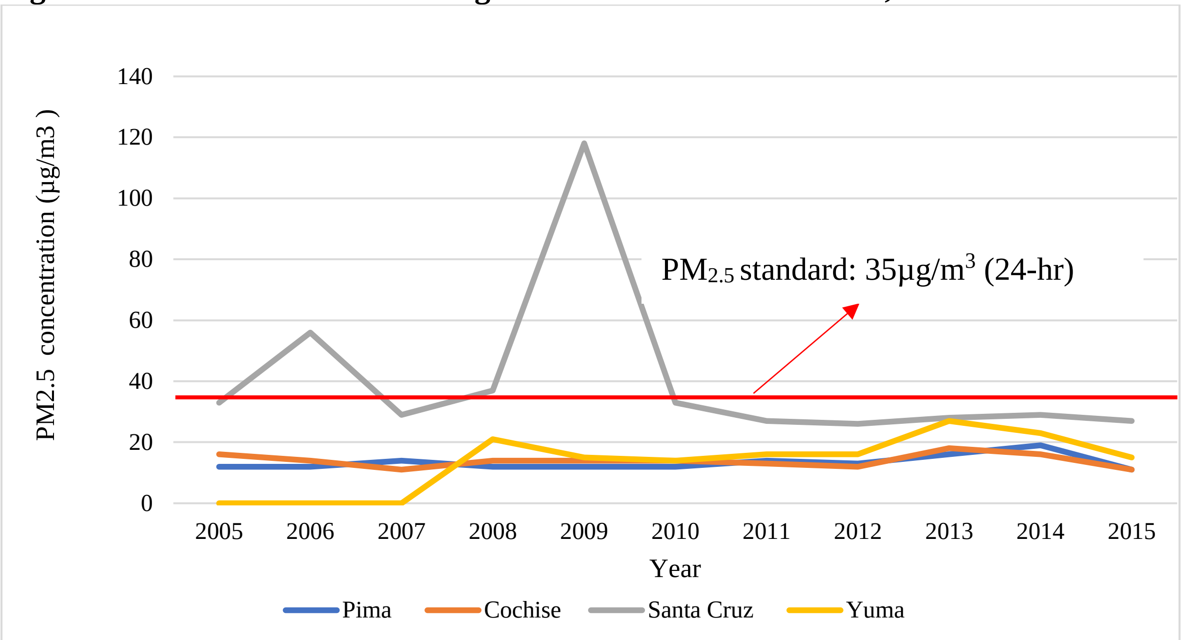
## Data Characterization

- Data were queried from AirData, Air Quality Statistics Report by year, county, and exceptional event. Exceptional event data were included to provide daily information when NAAQS where not met.
- $PM_{10}$ data are based on all four border counties; Pima, Yuma, Santa Cruz and Cochise.

## Key Findings

- ❖ On average, Yuma and Santa Cruz had at least one day of $PM_{10}$ $2^{nd}$ maximum above the national standard annually between 2005-2015.
- ❖ Pima County had at least one day of $PM_{10}$ $2^{nd}$ maximum above the standard between 2010-2013.
- ❖ Cochise maintained $PM_{10}$ levels below the National Ambient Air Quality Standard except in 2013.

**Figure 4: $PM_{2.5}$ concentration along the Arizona Border counties, 2005-2015**




Data source: U.S EPA, Outdoor Air Quality Data, Air Quality Statistics Report.

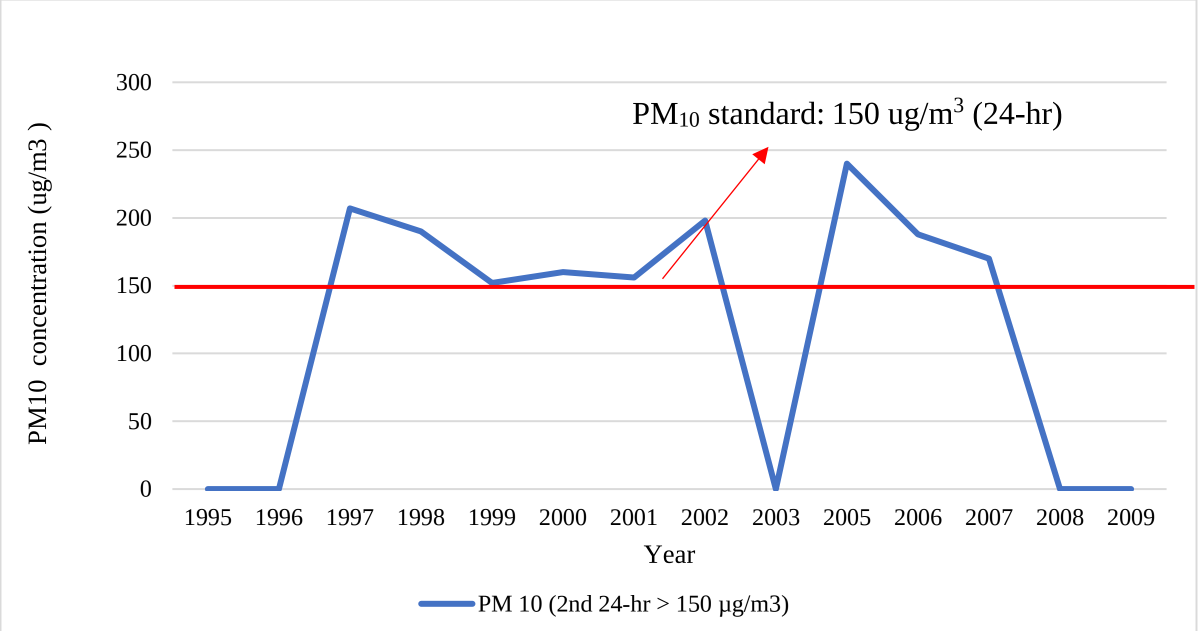
**Data Characterization**

- Data were queried from AirData, Air Quality Statistics Report by year, county, and exceptional event. Exceptional event data were included to provide daily information when NAAQS where not met.
- $PM_{2.5}$ data were based on all four border counties; Pima, Cochise, Santa Cruz and Yuma.

**Key Findings**

❖ All counties maintained $PM_{2.5}$ below the National Ambient Air Quality Standard except for Santa Cruz. In 2009, at least one day the measured $PM_{2.5}$ concentration was more than three times higher than the national standard.

**Figure 5: $PM_{10}$ concentration above the levels of air quality standards along the Nogales Sonora Border, 1995-2009.**




Data source: Arizona Department of Environmental Quality (ADEQ), Office of Border Health.

## Data Characterization

- Raw data for 2010 were available, but were not quality assured and therefore not included.
- Raw data for all other years that were available from 1995-2009 were plotted taking into account only the $2^{nd}$ 24-hr >150 µg/$m^3$.

## Key Findings

- On average, between 1997-2007, Nogales Sonora had at least one day of $2^{nd}$ maximum above the standard except for 2003[4].
- On average, between 1996-2008, 100% of the children in Nogales, Sonora lived in a municipality with $PM_{10}$ above the U.S. National Ambient Air Quality Standards.
- A total of 75% of children ages 0-17 years live in municipalities with no $PM_{10}$ air quality monitoring, while 100% live in municipalities with no $PM_{2.5}$, carbon monoxide, sulfur dioxide, nitrogen dioxide or lead air quality monitoring.

[4] In 2003, there was only one day where $PM_{10}$ concentration was above the standard. The $PM_{10}$ concentration above the standard was 182.6 µg/$m^3$.

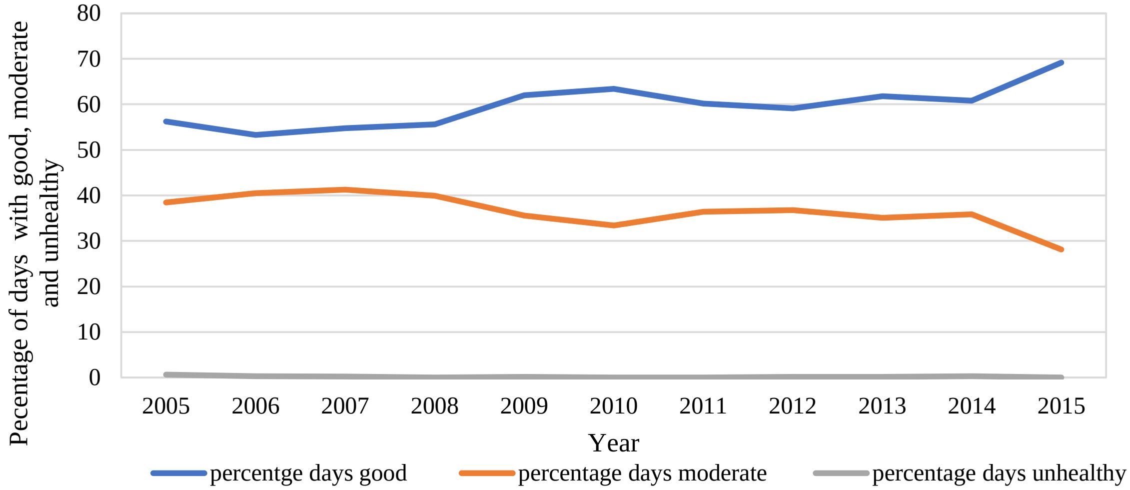
**Air Quality Index**

The AQI is based on daily measurements of up to six air criteria pollutants (carbon monoxide, ozone, nitrogen dioxide, particulate matter, and sulfur dioxide), excluding lead. Lead is not included because it requires averaging concentrations over three-months period, and samples may take several weeks to be analyzed (EPA, 2013). Pollutants included in the AQI depend on the air criteria pollutant monitored in the area each day. Each pollutant is given a value on a scale relative to the air quality standard for the pollutant. The daily AQI value of 50 is defined as either the level of the annual standard, if one has been established, or a concentration equal to one-half the value of the short-term standard used to define index value of 100 (U.S EPA, 2013). EPA divides AQI into scales; good, moderate, unhealthy for sensitive groups, and unhealthy. Air quality is considered good (code green), if the AQI is between 0-50, posing little risk or no risk. Code yellow refers to moderate air quality with AQI between 51-100. Air quality designated as code yellow may pose health effects to a small number of individuals. Code orange refers to air quality that presents moderate health concerns at AQI between 101-150. Air quality designated as code orange may pose health effects to some sensitive groups such as the children. Between AQI 151-200 (code red), the general population may experience health effects, while AQI values between 201-300 are designed very unhealthy (code purple). Values between 301-500 are considered hazardous (code maroon) (U.S. EPA, 2016).

Data presented in Figure 6 were queried from the Outdoor Air Quality, Air Quality Index report by year and by county. The report provides AQI annual summaries, which includes the AQI value and the count of days in each AQI category. Data for the number of days good, moderate or unhealthy were averaged by year for the four border counties.

**About the Indicators:** Figure 6 represents Air Quality Index (AQI) values for counties along the Arizona Border Region, and is aligned with the ACE3 (E3). AQI is an indicator of the overall air quality, and takes into account criteria air pollutants measured in a geographic area (U.S. EPA). Even though AQI includes all available pollutants measurements, it is important to keep in mind that some areas have air monitoring stations and some do not.

**Figure 6: Percentage of days with good, moderate, or unhealthy air quality along the Arizona Border Region, 2005-2015**




Data source: Data dowloanded from the U.S EPA Outdoor Air Quality Data, Air Quality Index Report.

## Data Characterization

- AQI are based on daily monitoring data for the five air criteria pollutants.
- Data presented include the average days of AQI for Pima, Santa Cruz, Cochise and which were above 300 days per year between 2005-2015.

## Key Findings

- ❖ For all the four Arizona Border counties, only 1% of days were designated as unhealthy in 2005 compared to the national levels of 5-2% between 2005 and 2009.
- ❖ The percentage of days designated as moderate stayed at or below 40 % between 2005 and 2014, and dropped to 28% in 2015, compared to national levels of between 10-15% in 2005 and 2009.
- ❖ The percentage of days designated as days with good air quality increased from 53-62 % between 2005 and 2009, compared to national average of 41-57% during same period. The days designated with good air quality further improved to 69% in 2014.

## Data Gaps

- ❖ Only Pima County monitors for all six criteria air pollutants.
- ❖ Santa Cruz and Cochise do not monitor for sulfur dioxide, nitrous oxide, or carbon monoxide, or lead. In addition, Santa Cruz does not monitor for ozone.
- ❖ Since the beginning of 2007, Yuma does not monitor for sulfur dioxide, nitrous oxide, or carbon monoxide

- Approximately, 75% of the population along the Arizona Border live in counties where sulfur dioxide, nitrogen dioxide or lead are not monitored.
- Along the Mexico side of the border, only Nogales, Sonora monitors for $PM_{10}$, and data were available up until 2009. The remaining municipalities (San Luis Colorado, Naco, and Agua Prieta) do not monitor for air quality.

**Recommendations**

- Work binationally to monitor for all six criteria pollutants along the Sonora side of the border. The Arizona-Sonora Border share a similar air shed. Air pollution on one side of the border affect border population on both sides of the border.
- Monitor for sulfur dioxide, nitrous oxide, and carbon monoxide in Santa Cruz, Cochise, and Yuma.

## Hazardous Air Pollutants

Hazardous Air Pollutants (HAPs) are toxic air pollutants that may cause cancer and other detrimental health issues (Windham et al., 2006). The detrimental effect can range from reproductive adverse effects to respiratory complications or neurological issues. Currently, a total of 187 HAPs are controlled by the United States Environmental Protection Agency (U.S EPA) under the Clean Air Act. These include: asbestos, benzene, trichloroethylene (TCE), arsenic compounds, beryllium and many others.

Sources of HAPs may include mobile sources such as emissions from cars and trucks; stationary sources such power plants; and indoor sources such as building materials (U.S EPA, n.d.). Other sources such as the wildfires common in the U.S. Southwest may also contribute to hazardous air pollutants emissions. The amount of HAPs released by any of these sources largely depends on the size of the source. For example, major sources such as facilities like copper smelters, advanced manufacturing and defense industries typically account for a large portion of HAPs released into the air (Kampa et al., 2008). However, when HAP concentrations released into the air by small businesses are summed together, the overall contribution is significant. Common sources of HAPs are abundant. Gasoline, a ubiquitous commodity in our daily lives, contains benzene. Low levels of benzene have been proven to cause genotoxic effects in workers (Nilsson et al., 1996). Gasoline has also been associated with acute myeloid leukemia in children (Nordlinder et al., 1997). Many adults and children spend most of their time indoors, and numerous studies have documented that indoor HAPs concentration are often higher than ambient due to additional indoor sources such as cleaning products (Spengler and Sexton, 1983; Jones, 1999). There are no available data to measure the concentrations of HAPs in these indoor sources (U.S EPA, 2015).

In the United States, EPA sets standards through the Clean Air Act to control emissions of HAPs. The states work with EPA to ensure monitoring is done following the set standards. In Mexico, the Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT) is responsible for setting limits for HAPs, many of which are similar to U.S. standards set by EPA. However, limited HAPs data exist for the Sonora Border region.

## National Air Toxics Assessment

The National-Scale Air Toxics Assessment (NATA) is an ongoing EPA evaluation of air toxic emissions in the United States. Its purpose is to help estimate potential human exposure to hazardous air pollutants and the risk of adverse health effects, such as cancer from these exposures by census tract. Although the assessment is comprehensive on a national level, modeled concentrations of HAPs in regions where monitors are lacking serve only as estimates and might not be accurate. Every three years, EPA compiles and updates air toxics emissions in the United States which are then analyzed and verified to make available for the public. EPA's NATA modeling allows for estimation of HAP concentrations in areas where monitors might not be present. This allows the Agency to estimate ambient concentrations for these air toxics and their dispersion. Screening-level inhalation exposure modeling is used to estimate the people affected. The National Emissions Inventory (NEI), along with the dispersion model AERMOD (in HEM-3) and the chemical transport model CMAQ, were all used to determine modeled concentrations of HAPs for 2005 and 2011 (U.S. EPA, n.d.). HAPEM7 or hazardous air pollutant exposure model was used in NATA 2011 to model inhalation exposures.

In the 2005 NATA, information on a total of 178 air toxics or HAPs was compiled for that year. Emissions sources included: stationary sources such as large industrial facilities, mobile sources such as cars, background such as long-range transport and secondary formation of pollutants created from other pollutants. Secondary formation was the largest contributor to cancer risks (U.S. EPA, n.d.). In the 2011 NATA, information on a total of 180 air toxics or HAPs was compiled for that year. Emissions sources included: stationary sources, mobile sources, background, secondary formation, events such as wildfires and biogenics such as naturally-occurring emissions. This version of NATA combined both a long-range transport and chemistry model as well as a near-field model in order to provide more accurate air quality estimates. This includes better predictions on air pollution transport, secondary pollution formation and location conditions close to specific sources (U.S. EPA, n.d.).

It must be noted that NATA estimates of health risks from HAPs is based only upon inhalation exposure, and not through dermal or ingestion exposure. Exposures to diesel particulate matter (diesel PM) were not accounted in the 2005 NATA due to unavailability of unit risk estimate during the time of publication (U.S. EPA, 2011). NATA for 2011 includes diesel PM, but only for non-cancer health effects (U.S. EPA, n.d.). NATA estimates exclude emission sources from Mexico, which are crucial in order to assess the air quality in the Arizona-Sonora Border region. Thus, the NATA estimates for the Border Region is likely to underestimate the risks to those communities.

### Health Benchmark for Hazardous Air Pollutants

EPA uses three health benchmarks to identify HAPs that are of concern (U.S. EPA, 2015). Of the three health benchmarks, two are health benchmarks for cancer risk at levels 1: 100,000 and 1: 10,000. The third health benchmark estimates exposure to the HAPs that may cause minimal risk for adverse non-cancer health effects (Caldwell et al., 1998; U.S EPA, 2015). Exposures to HAPs concentrations above this benchmark can lead to neurological, respiratory, reproductive or developmental adverse effects. Based on how every individual reacts to chemical exposures differently, it is possible that no adverse effects are observed even if an individual is exposed to HAPs concentrations above the benchmark. The same concept may also mean that some susceptible individuals may have adverse health effects if they were exposed to HAPs concentrations below the health benchmark. Health benchmarks come from animal testing as well as epidemiological studies of workers who have been exposed to HAPs. However, benchmarks have been established for some HAPs but not all. There is limited data and studies on many of them. Furthermore, benchmarks are generally based on the possible health risks for adults and not children. If children would be considered, some health benchmarks would have to be lowered based on their increased exposure and susceptibility to HAPs due to their physiology, behaviors and other factors (Hubal et al., 2000; Collins, 2008). For the 2005 and 2011 NATA, a total of 87 HAPs were classified as cancer-causing, 105 were considered as causing adverse health effects, excluding cancer, and some HAPs caused both cancer and non-cancer effects.

Figure 1. presents the potential cancer risk of 1-in-100,000 people as well as 1-in-10,000. The indicator represents the probability of 1 person contracting cancer in 100,000 or 10,000 people if exposed 24 hours a day to modeled concentrations over a period of 70 years. This cancer case would be an addition to the cancer cases of the unexposed population within that timeframe. Both cancer risk benchmarks include data for HAP's that are considered carcinogenic to humans, possibly carcinogenic or those that show evidence of carcinogenicity. They also only take into consideration long-term exposure rather than acute exposures at high concentrations (U.S EPA, 2015).

**Data Presented in the Indicator**

The HAP indicator presents modeled concentrations of hazardous air pollutants in the air for three health benchmarks for both 2005 and 2011. Figure 1 shows the percentage of children ages 0 to 17 years living in census tracts where estimated hazardous air pollutant concentrations were greater than the 1-in-100,000 cancer benchmarks in 2005 and 2011 in the Arizona Border Region. However, it excludes the potential cancer benchmark of 1-in-10,000 because there was no census tract with a cancer risk at this level in the Arizona-Sonora border region. There was also no census tract in the region that exceeded the health benchmark for non-cancer adverse health effects, and therefore this is not shown in figure 1. In order to determine the indicator, modeled concentrations of each census tract (about 4,000 residents) were compared to benchmark concentrations.

For each census track, the cancer risk for each carcinogen HAP are summed up to determine if a particular census tract surpassed either of the two cancer risk benchmarks. The non-cancer adverse effect benchmark for all HAPs combined takes into consideration each HAP individually. If a HAP modeled concentration exceeds a non-cancer benchmark specifically for that HAP, then the census tract and the county as a whole exceed the non-cancer adverse effects benchmark.

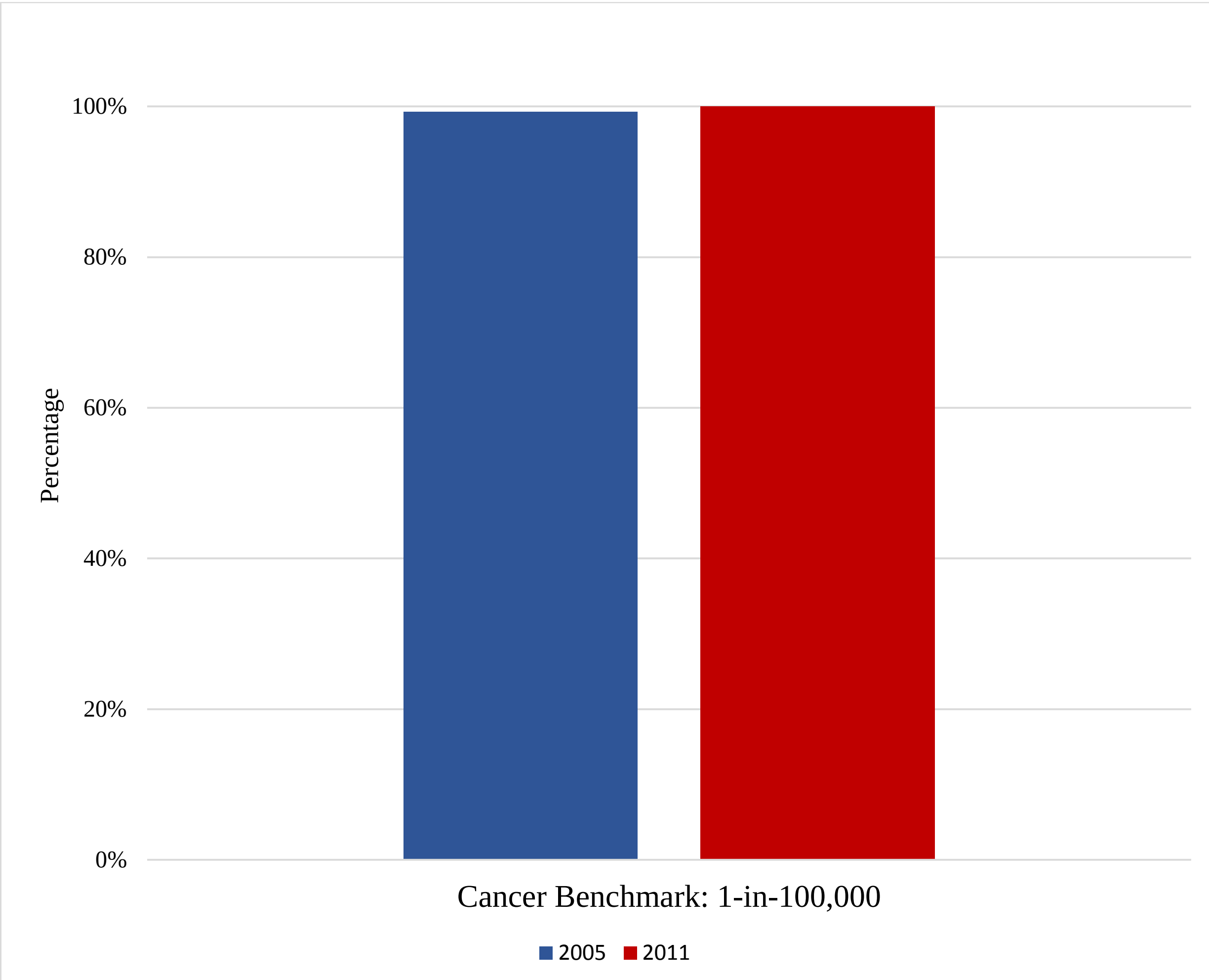
According to EPA, estimates of risks in NATA tend to generally overestimate rather than underestimate impacts in order to make them "health protective" (U.S. EPA, 2015). However, the reports for both 2005 and 2011 also state that certain guidelines EPA follows for modeled HAP concentrations can lead to underestimates as well (U.S. EPA, 2015). Therefore, the results demonstrated in this indicator may either underestimate or overestimate the percentage of children living in census tracts that exceed either of the three health benchmarks discussed. The indicator (health benchmarks) shown in figure 1 are not to compare NATA results from 2005 and 2011 to show trend, but rather to provide information for both years. It is advised by EPA to not compare NATA estimates between years because improvements in methodology make comparisons meaningless and may be the reason for increases or decreases in modeled concentrations of HAPs rather than changes in emissions. However, methodology improvements, including models used, were minimal between 2005 and 2011 (U.S. EPA, 2015).

The indicator reflects exposure to HAPs concentrations through inhalation. Other exposure routes are not included which could lead to increases in actual exposures to children and potential health risks. Furthermore, modeled concentrations are only snapshots and do not take into considerations the actual day-to-day variations of HAP concentrations in a particular census tract. Children do spend the majority of their time indoors with a combination of home and school (Franklin, 2007). Indoor modeled HAP concentrations are not included in NATA for either year. It only takes into account HAPs released into the outdoor air, which could lead to increases or decreases in ambient HAP concentration exposures. HAP sources in other neighboring countries such as Mexico are not included in NATA- underestimating modeled HAP concentrations in the border region in Arizona.

The pollutant that contributed the most to cancer risk was benzene, but the concentrations were not large enough to have any significant effect for this benchmark. Benzene is considered to be carcinogenic to humans (Wiwanitkit, 2008). The pollutant acetonitrile contributed hazard indices at the highest levels (about .0028). However, these levels are below the 1 threshold. Metabolism of acetonitrile can produce hydrogen cyanide, producing delayed toxicity in humans (Muller et al., 1997).

**About the Indicator**: Figure 1 illustrates the percentage of children living in census tracts where estimated hazardous air pollutant concentrations were greater than the 1-in-100,000 cancer benchmark. Modeled concentrations were obtained from the National Air Toxics Assessment for 2005 and 2011 for census tracts in the Arizona-Sonora Border Region.

**Figure 1. Percentage of children ages 0 to 17 years living in census tracts where estimated hazardous air pollutant concentrations were greater than the 1-in-100,000 cancer benchmark in 2005 and 2011 in the Arizona-Sonora Border Region**




Data: U.S. Environmental Protection Agency, National Air Toxics Assessment 2005 and 2011

**Data Characterization**

- Data for this indicator on outdoor air hazardous air pollutant concentrations were obtained through EPA's National Air Toxics Assessment computer model predictions for 2005 and 2011. Due to improvements in methodology in the assessment, EPA notes that it is not meaningful to compare assessments. NATA 2005 and 2011 assessment are shown above to provide the status of HAPs over the last 10 years and are not meant not to compare between the two assessments.
- Hazardous air pollutant concentration estimates are given for every census tract in the Arizona Border Region

## Key Findings

- 99.3% and 100% of the entire Arizona Border region children population lived in census tracts where total cancer risk of HAPs summed to exceed the 1-in-100,000 cancer risk benchmark for 2005 and 2011 respectively. Similarly, national data demonstrates that 99.9% of all children in the country live in census tracts where concentrations of HAPs summed to surpass the 1-in-100,000 cancer risk benchmark for 2005 (U.S EPA, 2013).
- No children lived in census tracts where total cancer risk of HAPs summed to exceed the 1-in-10,000 cancer risk benchmark for 2005 or 2011, compared to the national data where 6.6% of the children population in the country lived in census tracts where total cancer risk of HAPs summed to surpass the 1-in-10,000 cancer risk benchmark for 2005 (U.S. EPA, 2013).
- No children lived in census tracts in the Arizona Border Region where the total wholebody hazard index of an individual HAP exceeded the benchmark for other health effects for 2005 or 2011. National data shows that 56.4% of children in the U.S lived in census tracts where the total wholebody hazard index of an individual HAP exceeds the benchmark for other health effects for 2005 (U.S. EPA, 2013).
- All children in both 2005 and 2011 in the Arizona Border region attended schools located in census tracts where total cancer risk summed to exceed the 1-in-100,000 cancer risk benchmark. These are the same results as the national scale.
- No children attended school located in a census tract where the total cancer risk summed to exceed the 1-in-10,000 cancer risk compared to 7% for the national average (U.S. EPA, 2013)
- No children attended school located in a census track where at least one HAP exceeded the benchmark for non-cancer health effects in 2005 or 2011 compared to 56% for the national average in 2005 (U.S EPA, 2013).

## Data Gaps

- There are limited data for the Sonoran Border Region on HAPs.
- NATA does not include possible HAP emissions from Mexico that could impact the ambient concentration in the Arizona-Sonora Border region. Thus, health risk estimates for census tracts on the U.S side of the Border are likely to be underestimated (EPA, 2015).

## Recommendations

- NATA should include HAPs emissions from the Sonora border region. Arizona-Sonora Border share a similar air shed. HAPs emitted on one side of the border may pose health risks to the population on either side of the border.

## Pesticides in Food

Chemicals have been used throughout history for insect control. Systematic studies into the use of chemical for food protection began in the middle of the nineteenth century (World Health Organization (WHO), 1990)). During the first and second world war, the number and complexity of chemicals for food protection increased. Pesticides such as organochlorines and chlordane were introduced in the United States (U.S.) as early as 1945. Pesticides are used to prevent and control pests, weeds and other plant pathogens and can increase crop yield and improve crop quality when properly applied (United States Department of Agriculture (USDA), 2014). However, pesticide exposures may potentially cause adverse health effects such as cancer and endocrine disruption (Sugeng et al., 2014; WHO, 2016). There is toxicological evidence that even at repeated low exposures, pesticides such as organophosphates (OP) may affect neurodevelopment and growth in animals (Eskanazi et al., 1999). Children are especially vulnerable to pesticide exposures due to their less-developed detoxification pathways and developing bodies (NRC, 1993; Eskanazi et al., 1999).

With the projected increase in global population to 8.5 billion by the year 2030 (United Nation (UN), 2015), there is a concern for global food security. An increase in population means more demand for food. Food producers have invested in new methods and technologies thought to heighten food production efficiency. The demand for current and future food demand brings additional concern including potential increase in pesticide use. The term “pesticides” refers to products designed to control pests and includes herbicides, insecticides, and fungicides, among others. For example, herbicides are designed to control other plants that may hinder the growth of a crop whereas insecticides target various insects that may eat, destroy, or otherwise damage crops. The United States Department of Agriculture (USDA) found in its Economic Research Service report summary that the use of pesticides in 21[1] selected crops in U.S. agriculture have decreased between 1960-2008 (USDA, 2014). In 1960, 58% of pesticides applied by farmers in the U.S were categorized as insecticides and only 18% were herbicides. By 2008, the usage had reversed, with insecticides and herbicides accounting for 6% and 76% of the pounds of pesticides applied respectively (USDA, 2014).

## Pesticides in Food along the Arizona-Sonora Border Region

Food can become contaminated by chemicals or microorganisms through various sources. Although there are U.S. federal agencies and programs that protect the safety of our food chain such as the Food and Drug Administration, the Food Safety and Inspection Service, the Center for Disease Control and Prevention, and the U.S Environmental Protection Agency (U.S EPA) under the Food Quality Protection Act (FQPA), food contamination still occurs every year. The latter is especially true in agricultural regions around the U.S. where pesticides are used intensively. Yuma County in the Arizona border region is one of among many agricultural hubs in the Southwest, ranking third in the nation for largest vegetable producer. It is also the supplier for 90% of the Nation’s leafy vegetables during the winter. The agricultural sector in the Mexican state of Sonora is also considered one of the most developed and one of the most productive in Mexico (Quintanar et al., 2014) where they also produce fruits, vegetables, and

[1] The 21 crops included; corn, soybeans, potatoes, cotton, wheat, sorghum, oranges, peanuts, tomatoes, grapes, rice and others.

grains, among others. It is also important to note that vegetable production for food is pesticide intensive (Pérez-Olvera et al., 2011).

In the U.S., three federal agencies are responsible for the regulation of pesticides: the U.S Environmental Protection Agency (U.S EPA), the Federal Drug Administration (FDA), and the U.S Department of Agriculture (USDA) (FDA, 2013). The U.S EPA registers and approves the use of pesticides and establishes the maximum amount of pesticide residue allowed (i.e. tolerance) in human or animal foods. The FDA enforces the tolerance in domestic and imported foods, except for meat, poultry and some egg products for which USDA is responsible (Neff et al., 2012). While the FDA has a sampling program to enforce the tolerance for both domestic and imported foods, the Mexican government has limited monitoring capabilities for their produce exports and relies on the private sector to conduct monitoring (U.S Government Accountability Office (GAO), 1992). Even though the U.S. has programs to enforce these tolerances, there are critical information gaps regarding pesticide residues on foods imported into the U.S. The USDA inspects less than 1% of the foods imported into the U.S even though 15% of the food in the U.S is imported (Neff et al., 2012). In respect to all foods tested in 2014, 41% of the samples had no detectible pesticides, and 99% had residues below the tolerance levels set by the U.S EPA. Of these samples, 75.5 % were domestic and 30% were imported (USDA, 2014).

The State of Sonora in Mexico is known for its agricultural activities such as the production and exportation of grains and a variety of vegetable crops. However, there is limited information on pesticide residues on foods in Mexico (Aldana-Madrid et al., 2008; Pérez-Olvera et al., 2011). Even though there are research studies on pesticides residue in crops, most of the information on pesticide residues in crops grown in Mexico comes from countries importing their agricultural products. Most of this information is from rejected shipment of crops, where pesticide residue levels were above the allowed levels (Pérez-Olvera et al., 2011).

There is limited data on chemicals in food for the Border region. In this chapter, we report an indicator presented for 20 different pesticides in “solids foods” as measured by the National Human Exposure Assessment Survey (NHEXAS) Border Project conducted between 1996 and 2002. The 20 pesticides were grouped in six different chemical types classified based on toxicity by the World Health Organization (WHO). This includes organophosphates, carbamates, organochlorine compounds, dinitroanilines, triazines and polycyclic aromatic hydrocarbons (PAHs).

### Organophosphates

Many of the chemicals important to the survival of humans are organophosphates. They have been part of our genetic makeup for centuries, ranging from DNA containing hereditary material to ATP used up by cells for energy. Currently, these chemicals have been used as solvents, pesticides, and even nerve agents during war. As insecticides, organophosphates target the enzyme acetylcholinesterase by inhibiting it in an irreversible manner, impairing nerve functionality essential for life (Katz et al., 2015). Organophosphates are problematic because of their ability to accumulate in the environment and have toxic effects on organisms. Toxic effects of organophosphates have been found in the fish we eat (Narra et al., 2012). In humans, it has been found to cause spermatotoxicity in males as well as cancer (Suzuki et al., 2013; Baldi et al., 2001). Chemicals in this category include acephate, malathion, diazinon, chlorpyrifos and methyl parathion.

### Carbamates

Carbamates are organic compounds that are used by various industries. They are components of polyurethanes, pesticides, wood preservatives, cosmetics and even pharmaceutical drugs (Badreshia et al., 2002). One of their major uses is in the formulation of insecticides. They include chemicals such as: carbaryl, methomyl, and propoxur. Unlike organophosphates, carbamates function by reversibly inactivating acetylcholinesterase in insects, which ultimately kills them (Aigueperse et al., 2005). This group of pesticides can cause neural adverse effects in the body as well as hormonal changes that can be detrimental to human health (Karami-Mohajeri et al., 2010).

### Organochlorines

Organochlorines are organic compounds with a covalently attached chlorine atom. Organochlorine compounds such as polychlorinated biphenyls (PCBs) have been used as insulators; chloromethanes have been used as solvents; vinyl chloride has been used in PVC piping and DDT and its derivatives; and dieldrin, heptachlor, chlordane and hexachlorocyclohexane have been used as pesticides. These chemicals cause leakage of sodium ions that in turn causes repeated discharges of neurons ultimately causing tremors and seizures (Bradbury et al., 1989). Other studies have found that occupational exposure of organochlorine compounds has led to increased risk of certain cancers (Purdue et al., 2007).

### Dinitroanilines

Pendimethalin and trifluralin are both herbicides classified as dinitroanilines, which are created using aniline and dinitrobenzenes. This class of chemical compounds are used in the preparation of dyes. Dinitroanilines also work as herbicides by inhibiting cell division by targeting microtubules, specifically in plants (Morrissette et al., 2004). Pendimethalin exposure associated with increased risk of lung cancer in pesticide applicators (Alavanja et al., 2004). Trifluralin can result in the synthesis of nitrosamines, which are known to cause cancer in animals (West et al., 1979).

### Triazines

Triazines, such as atrazine, are one of the most widely used herbicides in the U.S. They are also used to synthesize resins and are components of reactive dyes (Sueda et al., 1977). Oil and gas industries also use these chemicals in their operations. Groundwater contaminated with mixtures of chemicals that include atrazine were found to have behavioral, endocrine and immune effects on human health (Jaeger et al., 1999; Brusick, 1994; Cooper et al., 2000). Atrazine contaminated food has also been linked to detrimental reduction in body fat content as well as nutritional well-being (Eason et al., 2002) Chronic exposures have also been linked with mitochondrial dysfunction, and insulin resistance (Lim et al., 2009).

## Polycyclic aromatic hydrocarbon

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds composed of multiple aromatic rings. They are generally found in fossil fuels and can be produced due to incomplete combustion (Samanta et al., 2002). PAHs such as acenaphthene, phenanpthrene, and fluorene, are used to manufacture pesticides (Abdel-Shafy & Mansour, 2016). They have been found to cause various health issues such as cancer in the lung, stomach and liver (Bostrom et al., 2002). Cardiovascular disease and adverse developmental effects have also been linked to exposure to PAHs (Korashy et al., 2006). Studies point to the presence of polycyclic aromatic hydrocarbons, such as fluorene, in many foods we eat as well (Nieva-Cano et al., 2001; Muntean et al., 2013; Dost et al., 2012).

## NHEXAS U.S. Border 2012 Program Data

As part of the National Human Exposure Assessment Survey (NHEXAS), environmental and personal samples were collected in 954 households from Arizona counties along the U.S.-Mexico Border. Household surveys and food questionnaires were also administered. Sample types included air, water, soil, dust, surface wipes, blood, urine, and 24-hour duplicate diets. Samples were analyzed for pesticides, metals, PAHs, and volatile organic compounds (Robertson, et. al, 1999). The Arizona counties that were included were Cochise, Santa Cruz, and Yuma. The samples were collected from participating households between September 1997 and July 1998. The study looked at pesticides in food consumed in the home.

For pesticides in the home environment, this study looked at occurrence of chlorpyrifos and diazinon pesticides in the indoor and outdoor home environment. The highest concentrations for both pesticides were found indoors. The most frequent indoor chlorpyrifos occurrences were floor dust (88%), indoor air (65%), and sill wipes (54%), with the highest concentrations found on sill wipes (16,000 $\mu g/m^2$). The indoor air and floor dust concentrations ranged from 3.2-3280 $\mu g/m^3$ and <0.004-119 $\mu g/m^2$ respectively. The top two most frequent occurrences for diazinon also occurred indoor, with indoor air (63%) and floor dust (53%). The concentrations for indoor air and floor dust ranged from <2.1-20,500 $\mu g/m^3$ and <0.02-50.5 $\mu g/m^2$ respectively. The study concluded that the concentrations of both chlorpyrifos and diazinon were comparable with those found in Florida, Massachusetts, and Texas, where similar studies were conducted, and also with other similar reported studies in the literature. The study further highlighted these sources were attributed to indoor use rather than outdoor use (Gordon et. al, 1999). These findings shed a light for the potential exposure of pesticides in homes, in addition to concerns of pesticides exposure from foods.

With respect to the study conducted to look at pesticides in foods, a total of 20 pesticides were tested in 86 households, constituting 86 food samples. The respondent in each household collected a duplicate sample of the solid food they consumed within a 24-hour period for the extent of the 4-day food diary they completed. A total of 1,599 different entries (foods) were recorded. These included bread, chili, pop tart, Ensure, beans, and salad (NHEXAS, 2012).

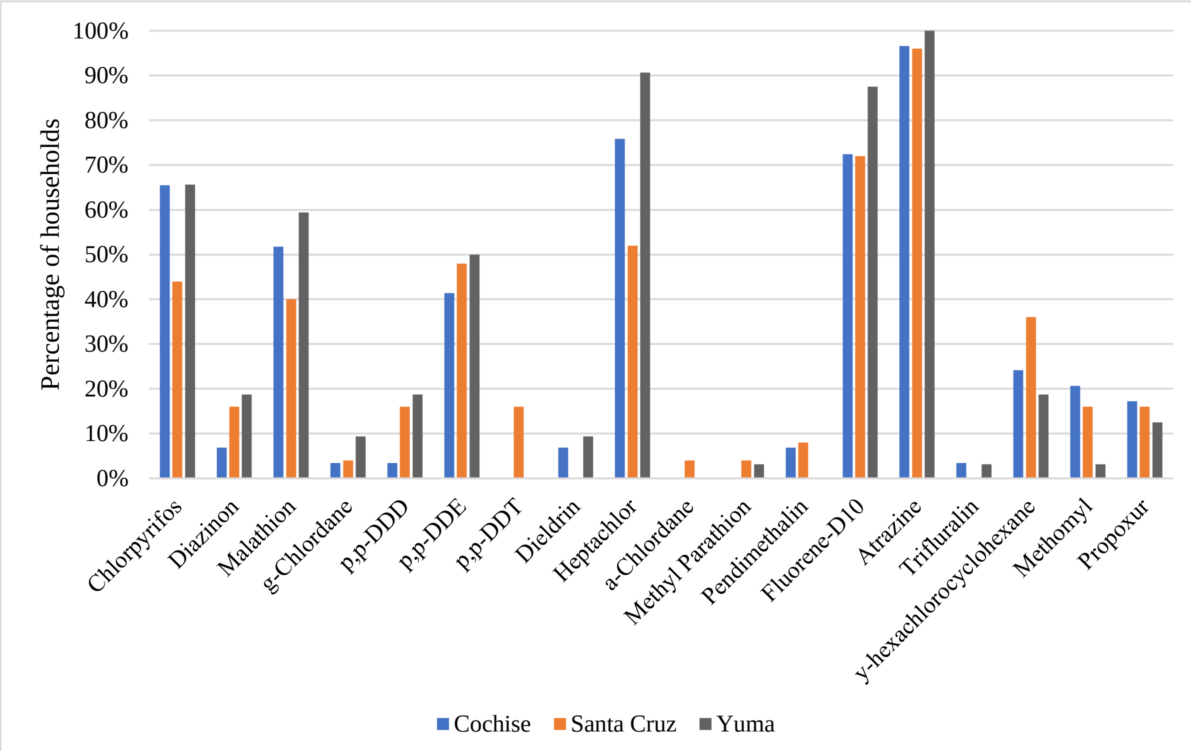
### Data Presented in the Indicator

The 20 different pesticides that were sampled in the study are included in the calculation of the indicator. However, there were some exclusions in each of the counties explained in the data characterization section below.

Even though data was collected for the state of Arizona, data presented herein that considered the pesticides in food, was not conducted for Pima county. Although the U.S. Department of Agriculture collects recent national pesticide data in food through the Pesticide Data Program, Arizona is not part of the 10-state program. Therefore, no more recent pesticide in food data is available for the Arizona border region.

About the indicator: Figure 1. illustrates percentage of sampled meals (solid foods) with detectable residues of a given pesticide from Arizona border county households. Results were reported by the NHEXAS U.S. Border 2012 Program (NHEXAS, 2012). Only food categorized as 'solid food' was used. 'Liquid food' data was unavailable. Liquid food pesticide concentrations may be higher or lower than the solid foods presented in this indicator.

**Figure 1. Percentage of sampled meals in Arizona border county households with detectable residues of a given pesticide**




Data: NHEXAS U.S. Border 2012 Program

## Data Characterization

- Data were collected between September 1997 through July 1998.
- Data for Pima County were not included.
- The research group only included validated data[2].
- 24-hr duplicate diets for 85 households were collected (one per household).
- Results are only for solid food and do not include liquid foods (e.g. soups or beverages).

## Key Findings

❖ Yuma County had the highest percentage of sampled meals with detectable residues for 10 of the 18 pesticides. This could be due to agricultural activities and pesticide applications in Yuma County, compared to the other two counties.

❖ More than 50% of sampled meals in households for all three counties had atrazine, fluorene-D10 and heptachlor residues.

[2] Only data in the Data Quality Flag section categorized ‘valid’ (Group 1) were used. Data in Group 2 (questionable) and Group 3 (invalid) were excluded.

- 100% of Yuma households were found to have atrazine residues, while 97% and 96% of households in Cochise and Santa Cruz had atrazine residues, respectively.

**Data Gaps**

- Data were collected in 1997-1998 and no recent data were available.
- Arizona is not part of the 10 State Pesticide Data Program, limiting comparisons to national data.
- National data available looks at pesticides for specific food groups, compared to the NHEXAS U.S. Border 2012 Program, which was done by looking at an entire meal rather than food categories. Therefore, it is difficult to compare with national data as well.
- The study for 24-hr solid food duplicate diet did not include Pima county.
- Even though there is data for pesticides residue on grains in Sonora (Aldana-Madrid, et. al, 2008) raw data could not be obtained despite multiple attempts.
- Data from the NHEXAS U.S. Border 2012 Program are reported as percentage detectable, which does not necessarily explain risk.
- The NHEXAS data does not provide an explanation of whether or not the produce was washed by the participant before analysis.

**Recommendations**

- Include Arizona in the USDA Pesticide Data Program to collect data for pesticides in food to be able to compare with national data or collect most recent data for pesticides in food in Arizona for NHEXAS follow-up (replicate NHEXAS data).
- Create a platform for sharing pesticides in foods information binationally. Mexico, including the state of Sonora is the top supplier of fresh foods and vegetables in the United States, especially in the winter months.

# 1 References

## Water and Contaminants

Arizona Department of Water Resources (ADWR). (n.d). Securing Arizona's Water Future. Retrieved from
http://www.azwater.gov/AzDWR/PublicInformationOfficer/documents/supplydemand.pdf

Arizona Department of Environmental Quality (ADEQ). (n.d). Binational Water Quality Monitoring Activities along the Arizona-Sonora Border Region. Retrieved from http://acwi.gov/monitoring/nwqmc.org/98proceedings/Papers/34-CAST.html

Artiola, J., & Uhlman, K. (2009). Arizona Well Owners' Guide to Water Supply. Retrieved from https://clu-in.org/conf/tio/srpwir4_072116/Arizona-Well-Owners-Guide-UAz.pdf

Comisión National Del Agua (CONAGUA). (n.d). Official Mexican Standard NOM-001-ECOL-1996, Establishing the Maximum Limits of Pollutants in Wastewaters Discharged in National Waters. Retrieved from
http://www.conagua.gob.mx/CONAGUA07/Publicaciones/Publicaciones/SGAA-15-13.pdf

Caldera, F., O'Rourke, M.K., & Gil, C. (2011). Water and wellness in two *Colonias* of Nogales, Sonora, Mexico. The *International Journal of Health*, Wellness & Society, *1*(3):193-212.

Gleick, P. H. (2010). Roadmap for sustainable water resources in southwestern North America. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(50), 21300–21305.

Intergovernmental Panel on Climate Change (IPCC). (2008). Climate Change and Water. Technical paper. Retrieved from https://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf

Mumme, S. (1999). Managing acute water scarcity on the U.S – Mexico Border: Institutional Issues Raised by 1990's Drought. Nat. Resource Journal, *39* (149).

Norman, L. M., Caldeira, F., Callegary, J., Gray, F., O'Rourke, M. K., Meranza, V., & Van Rijn, S. (2012). Socio-environmental health analysis in Nogales, Sonora, Mexico. *Water Quality, Exposure and Health*, *4*(2), 79-91.

Pan American Health Organization (PAHO) (2012). United States – Mexico Border Area. *Health in the Americas*, 2012 Edition: Country Volume.

Pavlakovich-Kochi, V (2005). The Arizona-Sonora Region: A decade of Transborder Region Building. *Estudios Sociales, 14(*27), 28-55.

Pavlakovich-Kochi, V. & Lim, J. (2009). Arizona-Sonora Region: Economic Indicators and Regional Initiatives. Eller College of Management, University of Arizona. Retrieved from https://ebr.eller.arizona.edu/sites/ebr/files/docs/research-studies/arizona-sonora-region-economic-indicators-regional-initiatives-2009.pdf

# 1 References

Rodwan, J. (2013). Bottled water 2013: sustaining vitality. U.S. and international developments and statistics. BWR. Retrieved from http://www.bottledwater.org/public/2011%20BMC%20Bottled%20Water%20Stats_2.pdf

Sanchez, R. (1995). Water quality problem in Nogales Sonora. *Environ Health Perspect, 103*(1):93-97.

Spring, U. (2014). Water security and national water law in Mexico. *Earth Perspectives Transdisciplinary Enabled*, 1:7 **DOI:** 10.1186/2194-6434-1-7.

Sprouse, T. (2005). An issue paper: Arizona – Mexico Border, The Santa Cruz, San Pedro, and Colorado Rivers. Retrieved from https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/Water%20Issues%20on%20the%20Arizona%20Mexico%20Border.pdf.

The Joint Academies Committees on the Mexico City Water Supply. (1995). Mexico City Water Supply: Improving the outlook for sustainability. National Academies Press. Retrieved from http://www.nap.edu/read/4937/chapter/6 .

U.S Environmental Protection Agency (U.S EPA). (2013). America's Children and the Environment, 3rd edition (ACE3). Retrieved from https://www.epa.gov/ace

U.S Environmental Protection Agency (U.S EPA). (n.d). U.S- Mexico Border. Retrieved from https://archive.epa.gov/region9/socal/web/html/border.html

U.S Department of Health and Human Services (DHHS). (2006). Evaluation of water flows in the Nogales wash, Santa Cruz County, Arizona. Retrieved from http://www.atsdr.cdc.gov/HAC/pha/NogalesWash/NogalesWashHC082106.pdf

United States Government Accountability Office (GAO): Report to Congressional Requesters. (2011). Unreliable State Data Limit EPA's Ability to Target Enforcement Priorities and Communicate Water Systems' Performance. Retrieved from http://www.gao.gov/assets/320/319780.pdf

U.S Environmental Protection Agency (U.S EPA): Safe Drinking Water Information System (SDWIS). (n.d). Retrieved from https://www3.epa.gov/enviro/facts/sdwis/search.html

Victory, K. (n.d). Risk perception, drinking water source and quality in a low-income community along the U.S – Mexico Border. Retrieved from https://wsp.arizona.edu/sites/wsp.arizona.edu/files/file/Victory_2014WSP_Fellows_Report.pdf

**Criteria Air Pollutants**

Belanger, K., Holford, T.R., Gent, J.F., Hill, M.E., Kezik, J.M., Leaderer, B.P. (2013). Household levels of nitrogen dioxide and pediatric asthma severity *Epidemiology* 24: 320-30.

# 1 References

Border Environmental Corporation Commission (BECC). (2016). Air Quality. Retrieved from http://www.becc.org/certification-process/environmental-sectors/air-quality#/tab1

Center for Disease Control (CDC). (2015). What is carbon monoxide? Retrieved from http://www.cdc.gov/co/faqs.htm

Center for Disease Control (CDC). (2015). Carbon monoxide poisoning. Retrieved from https://www.cdc.gov/co/faqs.htm

Delfino, R.J., Coate, B.D., Zeiger, R.S.,Seltzer, J.M, Street, D.H., Koutrakis, Daily, P. (1996). Asthma severity in relation to personal ozone exposures and outdoor fungal spores. *Am. J. Respir. Crit. Care Med.*, *154*: 633–641

Gorai, A.K., Tuluri, F., Tchounwou, P.B. (2014). A GIS based approach for assessing the Association between Air Pollution and Asthma in New York State, USA. *Int. J. Environ. Res. Publ. Health, 11*: 4845–4869

Hansel, N.N., McCormack, M.C., Kim, V. (2016). The Effects of Air Pollution and Temperature on COPD.*COPD, 13*(3):372-9.

McBride, D. E., Koenig, J. Q., Lutchel, D.L, Williams, P.Y., Henderson, W. R. (1994). Inflammatory effects of ozone in the upper airways of subjects with asthma. *Am J Respir. Crit. Care Med., 149* (5), 1192-1997.

Samet, J. M., Bell, M. L. (2004). Commentary: Nitrogen dioxide and asthma redux. *International Journal of Epidemiology, 33*:215-216.

U.S Environmental Protection Agency (U.S EPA). (2016). Clean Air Act (CAA). Retrieved from https://www.epa.gov/clean-air-act-overview

U.S Environmental Protection Agency (U.S EPA). (2016). Carbon monoxide pollution. Retrieved from https://www.epa.gov/co-pollution

U.S Environmental Protection Agency (U.S EPA). (2016). Ozone pollution. Retrieved from https://www.epa.gov/ozone-pollution

U.S Environmental Protection Agency (U.S EPA). (2016). Lead pollution. Retrieved from https://www.epa.gov/lead-air-pollution

U.S Environmental Protection Agency (U.S EPA). (2016). Sulfur oxide pollution. Retrieved from https://www.epa.gov/so2-pollution
U.S Environmental Protection Agency (U.S EPA). (2016). Nitrogen oxide pollution. Retrieved from https://www.epa.gov/no2-pollution

U.S Environmental Protection Agency (U.S EPA). (2016). Particulate matter pollution. Retrieved from https://www.epa.gov/pm-pollution

U.S Environmental Protection Agency (U.S EPA). (2016). National Ambient Air Quality Standard (NAAQS) Table. Retrieved from https://www.epa.gov/criteria-air-pollutants/naaqs-table#3

U.S Environmental Protection Agency (U.S EPA). (2016). Air Quality Index (AQI) basics. Retrieved from https://airnow.gov/index.cfm?action=aqibasics.aqi

U.S Environmental Protection Agency (U.S EPA). (2016). Air Quality Index (AQI) breakpoints. Retrieved from https://aqs.epa.gov/aqsweb/documents/codetables/aqi_breakpoints.html

U.S Environmental Protection Agency (U.S EPA). (2010). Office of Air Planning and Standards: final revision to the Primary National Air Quality Standards (NAAQS) for nitrogen dioxide ($NO_2$). Retrieved from https://aqs.epa.gov/aqsweb/documents/codetables/aqi_breakpoints.html

**Hazardous Air Pollutants**

Caldwell, J.C., Woodruff, T.J., Morello-Frosch, R., Axelrad, D, A. (1998). Application of health information to hazardous air pollutants modeled in EPA's Cumulative Exposure Project. *Toxicol Ind Health*, I (3), 429-454.

Collins, J. (2008). Children are not little adults. *Seminars in Roentgenology, 43*(1), 1-2. doi:10.1053/j.ro.2007.08.010

Franklin, P. J. (2007). Indoor air quality and respiratory health of children. *Paediatric Respiratory Reviews*, *8*(4), 281-286.

Homann, N., Tillonen, J., Rintamäki, H., Salaspuro, M., Lindqvist, C., & Meurman, J. H. (2001). Poor dental status increases acetaldehyde production from ethanol in saliva: a possible link to increased oral cancer risk among heavy drinkers. *Oral oncology*, *37*(2), 153-158.

Hubal, E. C., Sheldon, L. S., Burke, J. M., McCurdy, T. R., Berry, M. R., Rigas, M. L., ... & Freeman, N. C. (2000). Children's exposure assessment: a review of factors influencing Children's exposure, and the data available to characterize and assess that exposure. *Environmental health perspectives*, *108*(6), 475.

Jones, A.P., (1999). Indoor Air Quality and Health. *Atmospheric Environment*, *33*(28), 4535-4564.

Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. *Environmental pollution*, *151*(2), 362-367.

Mueller, M., & Borland, C. (1997). Delayed cyanide poisoning following acetonitrile ingestion. *Postgraduate medical journal*, *73*(859), 299-300.

# 1 References


Nilsson, R. I., Nordlinder, R. G., Tagesson, C., Walles, S., & Järvholm, B. G. (1996). Genotoxic effects in workers exposed to low levels of benzene from gasoline. *American journal of industrial medicine*, *30*(3), 317-324.

Nordlinder, R., & Järvholm, B. (1997). Environmental exposure to gasoline and leukemia in children and young adults–an ecology study. *International archives of occupational and environmental health*, *70*(1), 57-60.

Salaspuro, M. P. (2003). Acetaldehyde, microbes, and cancer of the digestive tract. *Critical reviews in clinical laboratory sciences*, *40*(2), 183-208.

Seitz, H. K., & Stickel, F. (2010). Acetaldehyde as an underestimated risk factor for cancer development: role of genetics in ethanol metabolism. *Genes & nutrition*, *5*(2), 121-128.
Spengler, J. D., & Sexton, K. (1983). Indoor air pollution: a public health perspective. *Science*, *221*(4605), 9-7.

U.S. Environmental Protection Agency (2013). America's Children and the Environment (ACE), Third Edition. U.S. Environmental Protection Agency, Washington, D.C., 2013.

U.S. Environmental Protection Agency (U.S EPA). (2011). Summary of Results for the 2005 National-Scale Assessment. Retrieved at https://www.epa.gov/sites/production/files/2015-10/documents/2005-nata-results-summary.pdf

U.S. Environmental Protection Agency (U.S EPA). (n.d.). National-Scale Air Toxics Assessment for 2005 Fact Sheet. Retrieved at https://www.epa.gov/sites/production/files/2015-10/documents/2005-nata-factsheet.pdf.

U.S. Environmental Protection Agency (U.S EPA). (n.d.). Overview of EPA's 2011 National Air Toxics Assessment. Retrieved at https://www.epa.gov/sites/production/files/2015-12/documents/2011-nata-fact-sheet.pdf,

U.S. Environmental Protection Agency (U.S EPA).  (2015). Technical Support Document EPA's 2011 National-scale Air Toxics Assessment. Office of Air Quality, Planning, and Standards. Retrieved at https://www.epa.gov/sites/production/files/2015-12/documents/2011-nata-tsd.pdf

Windham, G. C., Zhang, L., Gunier, R., Croen, L. A., & Grether, J. K. (2006). Autism spectrum disorders in relation to distribution of hazardous air pollutants in the San Francisco Bay area. *Environmental health perspectives*, 1438-1444.

Wiwanitkit, V. (2008). Estimating cancer risk due to benzene exposure in some urban areas in Bangkok. *Stochastic Environmental Research and Risk Assessment*, *22*(1), 135-137.

# 1 References

## Pesticides in Food

Abdel-Shafy, H. I., & Mansour, M. S. (2016). A review of polycyclic aromatic hydrocarbon: source, environmental impacts, effects on human health and remediation. *Egyptian Journal of Petroleum*, 25(1), 107-123.

Aigueperse, J., Mollard, P., Devilliers, D., Chemla, M., Faron, R., Romano, R., & Cuer, J. P. (2005). Ullmann's encyclopedia of industrial chemistry.

Alavanja, M. C., Dosemeci, M., Samanic, C., Lubin, J., Lynch, C. F., Knott, C., ... & Thomas, K. (2004). Pesticides and lung cancer risk in the agricultural health study cohort. *American Journal of Epidemiology*, *160*(9), 876-885.

Aldana-Madrid M.L., Valdez-Hurtado, S., Vargas-Valdez, N, D., Salazar-Lopez, N.J., Silveira-Gramont, M.I., Loarca-Piña, F.G....& Burgos-Hernández, A. (2008). Insecticides residue in stored grains in Sonora, Mexico: quantification and toxicity testing. *Bull Environ Contam Toxicol*, 80(2),93-96.

Badreshia, S., & Marks Jr, J. G. (2002). Iodopropynyl butylcarbamate. *Dermatitis*, *13*(2), 77-79.

Boström, C. E., Gerde, P., Hanberg, A., Jernström, B., Johansson, C., Kyrklund, T., ... & Westerholm, R. (2002). Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons in the ambient air. *Environmental health perspectives*, *110* (Suppl 3), 451.

Bradbury, S. P., & Coats, J. R. (1989). Comparative toxicology of the pyrethroid insecticides. *Reviews of environmental contamination and toxicology* (pp. 133-177). Springer New York.

Brusick, D. J. (1994). An assessment of the genetic toxicity of atrazine: relevance to human health and environmental effects. *Mutation Research/Reviews in Genetic Toxicology*, *317*(2), 133-144.

Cooper, R. L., Stoker, T. E., Tyrey, L., Goldman, J. M., & McElroy, W. K. (2000). Atrazine disrupts the hypothalamic control of pituitary-ovarian function. *Toxicological Sciences*, *53*(2), 297-307.

Dost, K., & İdeli, C. (2012). Determination of polycyclic aromatic hydrocarbons in edible oils and barbecued food by HPLC/UV–Vis detection. *Food chemistry*, *133*(1), 193-199.

Eason, T. H., & Scanlon, P. F. (2002). Effects of atrazine and glyphosate ingestion on body weight and nutritional well-being of Coturnix quail. *Zeitschrift für Jagdwissenschaft*, *48*(1), 281-285.

Eskanazi, B.E., Bradman, A., Castorina, R (1999) Exposure of children to organophosphate pesticides and their potential adverse health effects. *Environ Health Perspect*, 107 (3), 409-419.

# 1 References

Flowers, T. J (2004). Improving crop salt tolerance. *Journal of Experimental Botany,* 55.396, 307-319.

Gordon, S. M., Callahan, P. J., Nishioka M. G., Brinkman, M.C., O'Rourke, M.K., Lebowitz, M. D., Moschandreas DJ (1999). Residential environmental measurements in the national human exposure assessment survey (NHEXAS) pilot study in Arizona: preliminary results for pesticides and VOCs. J Expo Anal Environ Epidemiology, *9*(5),456-470.

Jaeger, J. W., Carlson, I. H., & Porter, W. P. (1999). Endocrine, immune, and behavioral effects of aldicarb (carbamate), atrazine (triazine) and nitrate (fertilizer) mixtures at groundwater concentrations. *Toxicology and Industrial health*, *15*(1-2), 133-151.

Hamburg, M., (n. d). Food Safety Modernization Act: Putting the Focus on Prevention. Retrieved from https://www.foodsafety.gov/news/fsma.html

Karami-Mohajeri, S., & Abdollahi, M. (2010). Toxic effects of organophosphate, carbamate, and organochlorine pesticides on cellular metabolism of lipids, proteins, and carbohydrates: A comprehensive review. *Human & experimental toxicology*, 0960327110388959.

Katz, F. S., Pecic, S., Tran, T. H., Trakht, I., Schneider, L., Zhu, Z.… Stojanovic, M. N. (2015). Discovery of new classes of compounds that reactivate acetylcholinesterase inhibited by organophosphates. *Chembiochem : A European Journal of Chemical Biology, 16*(15), 2205.

Korashy, H. M., & El-Kadi, A. O. (2006). The role of aryl hydrocarbon receptor in the pathogenesis of cardiovascular diseases. *Drug metabolism reviews*, *38*(3), 411-450.

Lim, S., Anh, S.Y., Song, I. C., Chung, M. H., Jang, H.C., Park, K. S., …..& Lee, H. K. (2009). Chronic exposure to the herbicide atrazine, causes mitochondrial dysfunction and insulin resistance. PLOS ONE, 4(4) e5186. doi:10.1371/journal.pone.0005186.

Morrissette, N. S., Mitra, A., Sept, D., & Sibley, L. D. (2004). Dinitroanilines bind alpha-tubulin to disrupt microtubules. *Molecular Biology of the Cell, 15*(4), 1960-1968.

Muntean, N., Muntean, E., & Marcel, D. U. D. A. (2013). Contamination of some plant origin food products with polycyclic aromatic hydrocarbons. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture*, *70*(2), 383-386.

Narra, M. R., Begum, G., Rajender, K., & Rao, J. V. (2012). Toxic impact of two organophosphate insecticides on biochemical parameters of a food fish and assessment of recovery response. *Toxicology and Industrial Health, 28*(4), 343-352.

National Research Council (1993). Pesticides in the Diets of Infants and Children. Washington: National Academy Press, 1993. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK236275/

## 1 References

Nieva-Cano, M. J., Rubio-Barroso, S., & Santos-Delgado, M. J. (2001). Determination of PAH in food samples by HPLC with fluorimetric detection following sonication extraction without sample clean-up. *Analyst*, *126*(8), 1326-1331.

Pérez-Olvera, A., Navarro-Garza, H., & E. Miranda-Cruz. (2011). Use of Pesticides for Vegetable Crops in Mexico, Pesticides in the Modern World - Pesticides Use and Management. Retrieved from http://cdn.intechopen.com/pdfs-wm/21981.pdf

Purdue, M. P., Hoppin, J. A., Blair, A., Dosemeci, M., & Alavanja, M. C. R. (2007). Occupational exposure to organochlorine insecticides and cancer incidence in the agricultural health study. *International Journal of Cancer*, *120*(3), 642-649.

Quintanar, A. I. V. (2014). Residuos de plaguicidas organoclorados en suelos agrícolas. *Revista Terra Latinoamericana*, *32*(1), 1-12.

Samanta, S. K., Singh, O. V., & Jain, R. K. (2002). Polycyclic aromatic hydrocarbons: environmental pollution and bioremediation. *TRENDS in Biotechnology*, *20*(6), 243-248.

Sueda, Y., Koumura, S., Hirabayashi, K., Kenmochi, H., Terao, H., & Mori, Y. (1977). *U.S. Patent No. 4,038,267*. Washington, DC: U.S. Patent and Trademark Office.

Suzuki, H., Tomizawa, M., Ito, Y., Abe, K., Noro, Y., & Kamijima, M. (2013). A potential target for organophosphate insecticides leading to spermatotoxicity. *Journal of Agricultural and Food Chemistry*, *61*(41), 9961.

Tester, M., & Langridge, P. (2010). Breeding technologies to increase crop production in a changing world. *Science*, *327*(5967), 818-822.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., ... & Swackhamer, D. (2001). Forecasting agriculturally driven global environmental change. *Science*, *292*(5515), 281-284.

Todd, E. C. (1985). Economic loss from foodborne disease and non-illness related recalls because of mishandling by food processors. *Journal of Food Protection®*, *48*(7), 621-633.

U. S Environmental Protection Agency (U.S EPA) (2016). What is a pesticide? Retrieved from https://www.epa.gov/minimum-risk-pesticides/what-pesticide

U.S Food and Drug Administration (FDA). (2013). Pesticide monitoring program fiscal year 2013 pesticide report. Retrieved from http://www.fda.gov/downloads/Food/FoodborneIllnessContaminants/Pesticides/UCM508084.pdf

U.S Department of Agriculture (USDA). (2014). Pesticide use in the U.S Agriculture: 21 selected crops, 1960-2008. A report summary from the economic research service.

# 1 References

U.S Department of Agriculture (USDA). (2014). Pesticide data program: annual summary, calendar year 2014.

U.S Government Accountability Office (GAO). (1992). Pesticides: Comparison of U.S and Mexican Pesticides Standards and Enforcement. Retrieved from http://www.gao.gov/products/RCED-92-140

West, S. D., & Day Jr, E. W. (1979). Determination of volatile nitrosamines in crops and soils treated with dinitroaniline herbicides. *Journal of agricultural and food chemistry*, *27*(5), 1075-1080.

World Health Organization (WHO). (2016). Pesticide Residues in Foods?. Retrieved from http://www.who.int/features/qa/87/en/

World Health Organization (WHO). (1990). Public health impact of pesticide used in agriculture. Retrieved from http://apps.who.int/iris/bitstream/10665/39772/1/9241561394.pdf

## Blood Lead

A biomonitoring indicator is the measurement of a specific item (e.g., chemical, protein) in a human biological matrix (e.g., blood, urine, breast milk, hair) (U.S Environmental Protection Agency (U.S EPA), 2013). Monitoring of these indicators in children provides information on their level of internal exposure and potential for adverse health outcomes. Monitoring of these indicators in pregnant women may also provide information on the potential risks to fetal development complications during pregnancy and to a child's development (Centers for Disease Control and Prevention (CDC), 2010; World Health Organization (WHO, 2016)). Biomonitoring indicators can include the measurement of lead in blood.

## Lead Exposure

Lead is a naturally occurring element and is found in small amounts in the earth's crust. High amounts of lead may be toxic to human health (U.S EPA, n.d.). Lead affects multiple body systems including the brain, kidney, liver, and bones (Shonkoff et al., 2009, WHO, 2016). Lead is especially harmful to children, even at low levels. Lead has been shown to affect IQ, ability to pay attention, and academic achievement in children (CDC, n.d.). Worldwide, lead exposure is estimated to contribute to 600,000 new cases of children developing intellectual disability every year, and accounts for 143,000 deaths annually (WHO, 2010). Anthropogenic sources of lead in the environment include industrial contaminated sites, such as older lead smelters. In the U.S., the historic and most important sources of lead exposure are dust from lead-based paint (Committee of Environmental Health, 2005). Prior to the U.S. phase out of leaded gasoline in the early 1970s, leaded gasoline was a major source of environmental lead exposure. By the end of 1996 under the Clean Air Act, there was a total ban to sell leaded gasoline fuel (U.S. EPA, 2016).

In Mexico, the phase out of leaded gasoline started in the early 1990 and was completely phased out by 1997 (Caravanos et. al, 2014). Lead based paint is still widely used in Mexico. Mexico is among 40 countries where lead-based paint is still sold (Environmental Health Perspectives, 2014). A study conducted in 2008 by the International Persistent Organic Pollutants Elimination Network (IPEN) found that enamel paint samples in Mexico contained concentrations of lead greater than the regulatory limit for China and the United States of 90 ppm (Caravanos et al., 2014; IPEN, 2009).

Social economic factors are important determinants of health that can predict potential for lead exposure (Adler & Newman, 2012). Poorer families tend to live near industrial plants such as those that recycle lead batteries. Poorer families also tend to live in older homes that may potentially contain lead-based paint (CDC, 2014; National Center for Healthy Housing (NCHH), 2008). All these conditions are characteristics of the population that live along Arizona-Sonora Border. It is estimated that 38 million older homes still contain lead-based paint in the United States, and 24 million homes still contain significant amount of lead hazards as of 2000 (Housing and Urban Development (HUD) n.d.; Jacobs et al., 2002). Based on a 2005-2006 survey, 23.2 million homes, or 21.9% of the housing stock in the U.S., had lead paint, with 93% of these homes built before 1978 (HUD, 2011). In Arizona, approximately 50% of the homes in the border regions were built prior to 1979 compared to approximately 46% for the entire state

(Appendix E: Table 4). There is a correlation between age of housing and occupants' income. Low income households tend to have higher prevalence of lead-based paint (29%) than higher income (18%) (HUD, 2011). The household median income in Arizona ($49,774) is lower than the national average ($53,889). Median income along the Arizona border counties is even lower, and poverty rate is much higher than the national average. For instance, in Santa Cruz the median income is as low as $37,745 with a poverty rate of 26.3%, compared to the national median income of $53,889 and poverty rate of 15.5% (Appendix E: Table 4).

### Lead Exposure along the Arizona-Sonora Border

Lead-based paint is a main concern of lead exposure. However, the border region is unique in the sense that these communities from two countries influence and share a similar culture. Part of this cultural influence involves the exchange of goods and services between the communities along the border. Ceramics are one among many cultural articles that are brought into the U.S through the border. A study conducted in U.S.-Mexico Border cities in 2014 found that 90% of clay pots used as food containers contained lead (Valles-Medina et al., 2014) and they were also an important source of lead exposure in Mexico (Rojas-Lopez et al., 1994). The 2014 Arizona Department of Health Services (ADHS) report highlights candy and makeup, in addition to ceramics as being important sources of lead exposure brought across the U.S border. This same report also sheds light on exposure of non-lead paint sources identified for children with elevated blood lead levels. Of phone and home investigations conducted in 2014 with children with elevated blood lead levels where a potential source could be identified, 70% of sources identified were sources other than lead-based paint. Some of these sources were sampled and analyzed and confirmed positive. The majority of these articles were from Mexico and Asian countries. ADHS tested for lead in cultural medicinal products and spices such as *azarcon* and *greta* from Mexico, which are used to treat stomach illnesses and teething, and were found to contain very high levels of lead (ADHS, 2014). Some of the tested spices that contained high concentrations of lead were turmeric and thyme, with lead concentrations as high as 600-890 ppm. The same study also identified another import with very high concentration of lead, a red powder used in Hindu culture, known as hanuman sindoor. This powder contained lead concentrations as high as 920,000 ppm (ADHS, 2014). Even though lead poisoning from sources such as cooking spices and the hanuman sindoor may seem to be isolated incidences, these incidences shed light on other potential sources of lead poisoning in addition to ceramics from the Mexico.

### Blood Lead Level (BLLs) and Health Benchmark

Nationally, about 4 million households have children living in them that are being exposed to high levels of lead (CDC, n.d.), and over half a million children between the ages of 1-5 years old have BLL higher than 5 µg/dL, the CDC reference level that requires public health action. This is approximately 23% of the total children population ages 0-5 years (Federal Interagency Forum on Child and Family Statistics, n. d). It is important to note that there is no safe blood lead level for children. In the early 1990's, the CDC set the standard to screen for BLLs in children, and required that those identified with BLLs ≥10 µg/dL must receive a public health action and follow up. By 2012, the Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) recommended a reference range for blood lead of 5 µg/dL. This recommendation was based on $97.5^{th}$ percentile of the BLL distribution among 1-5 years olds in the U.S. (CDC, 2015).

Even though the screening rate in Arizona is low, with only 20% of Arizona children accounted for (ADHS, 2014), data available shows 1%-2% of the screened children have BLLs > 5 µg/dL, the reference level that requires public health initiation. Currently, ADHS has a Targeted Lead Screening Plan for the Prevention of Childhood Lead Poisoning, which is based on the targeted high risk ZIP codes. The plan requires that all children living in high risk ZIP codes be tested at 12 and 24 months (ADHS, 2014).

**Data presented in the Indicator**

Data presented in Figure 1, Percentage of children along the U.S. side of the Border with BLL > 5 µg/dL, was provided by ADHS. The percentage of the children with BLL > 5 µg/dL along the border counties was calculated. This percentage may underestimate the true percentage of children with BLL > 5 µg/dL, as only 20% of the target population received the blood lead screening. Figure 2 represents the percentage of children under six years of age and below poverty, with BLL> 5 µg/dL for the 2011-2015 period. Data for Figure 2 were obtained from the Centers for Disease Control and Prevention (CDC), Arizona Data, Statistics and Surveillance, 2011-2015 (CDC, 2016). State Surveillance systems are based on reports of blood lead tests from laboratory reports and results of all blood lead tests. Data are collected for program management purposes and methods of data collections vary by state and even by counties (CDC, 2016). Data for housing built in 1979 and prior was also included for comparison between BLL, poverty, and age of the house.

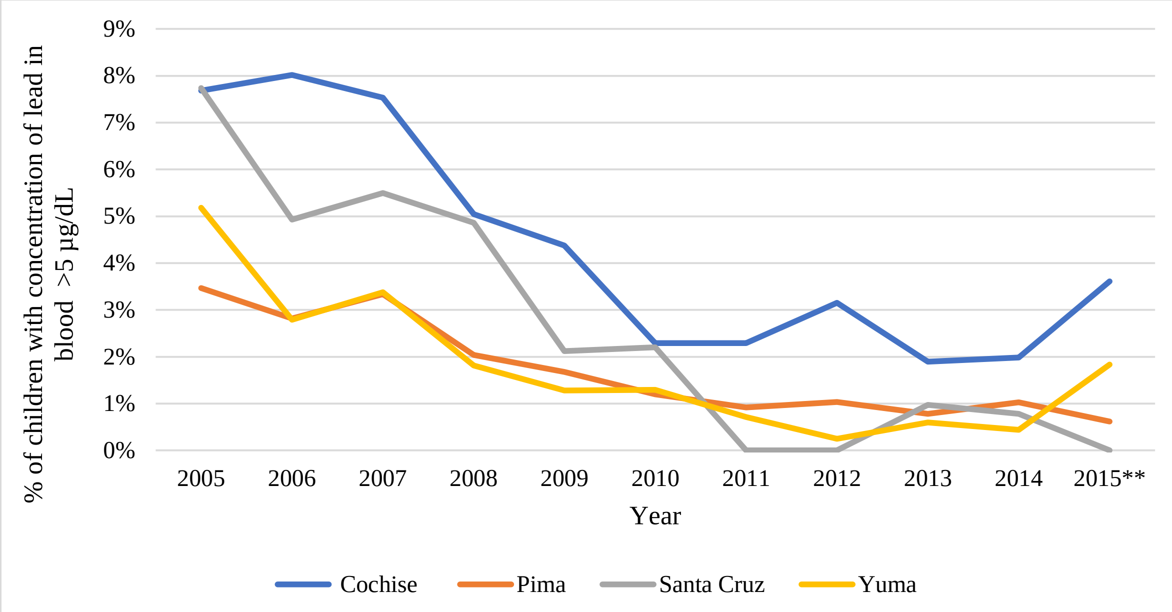
No data were found on routine monitoring for BLLs in Mexico. However, data presented in Figure 3 have been compiled from different sources to provide an overview and historic trend for established geometric mean over 40 years. The first study presented in Figure 3 is a meta-analysis study done in Mexico to establish the BLL in Mexico. This study looked at 83 published journal articles from 1978-2010, and from approximately 50,000 participants (Caravanos et al., 2014). The meta-analysis concluded that the Mexican national average was estimated to be between 8.85 and 22.24 µg/dL for rural and urban communities, respectively. Some cities in Sonora may be considered urban (i.e. Nogales) while others may be considered rural. The second study was done to evaluate lead exposure among children living in border communities by collecting blood samples. This study was conducted in 1998, where Cowan et al. (2006) collected blood samples from 1,210 children along the Arizona-Sonora border, Agua Prieta, San Luis Colorado, and Yuma to measure lead levels. This study found that the geometric mean BLL along the Arizona-Sonora Border was 4.3 µg/dL (Cowan et al., 2006).

It should be noted that data from Mexico analyzed by Caravanos et al. (2014) was collected between 1978-2010 while the binational study conducted by Cowan et al. (2006), data were collected during 1997-1998. Both data were collected and analyzed using different methods and covered different time periods. Hence, the established national geometric means were also different for those time periods (Figure 3). Between 1976-1980, the estimated national geometric mean BLL was 15 µg/dL. This decreased sharply between 1988-1991 to 3.6 µg/dL. The BLL decreased even further during 1999-2002 to 1.9 µg/dL (Morbidity and Mortality Weekly Report (MMWR), 2013). The most current BLL is 1.2 µg/dL (EPA, 2013). The historic BLL data included in Figure 3 are meant to provide a close reference of the BLL during the time periods data were collected or analyzed.

**About the indicators:** Figure 1 illustrates percentage of children in counties located along the border with BLLs > 5 µg/dL. This data is based on 20% of screened at-risk children[1]. Figure 2 shows the percentage of children in counties located along the border with BLL > 5 µg/dL, living under poverty, and residing in homes built in 1979 or earlier. Figure 3 shows the BLL along the Sonora-Arizona border region, in Mexico, and the historic established BLL over the past forty years.

[1] ADHS uses a targeted screening plan which includes identification of high risk areas based on ZIP codes and individual risk assessment questionnaire (ADHS, 2014)

**Figure 1: Percentage of children ages 1-5 years with Blood Lead Levels (BLLs) > 5 µg/dL, along the Arizona Border.**




Data Source: Arizona Department of Health Services (ADHS)

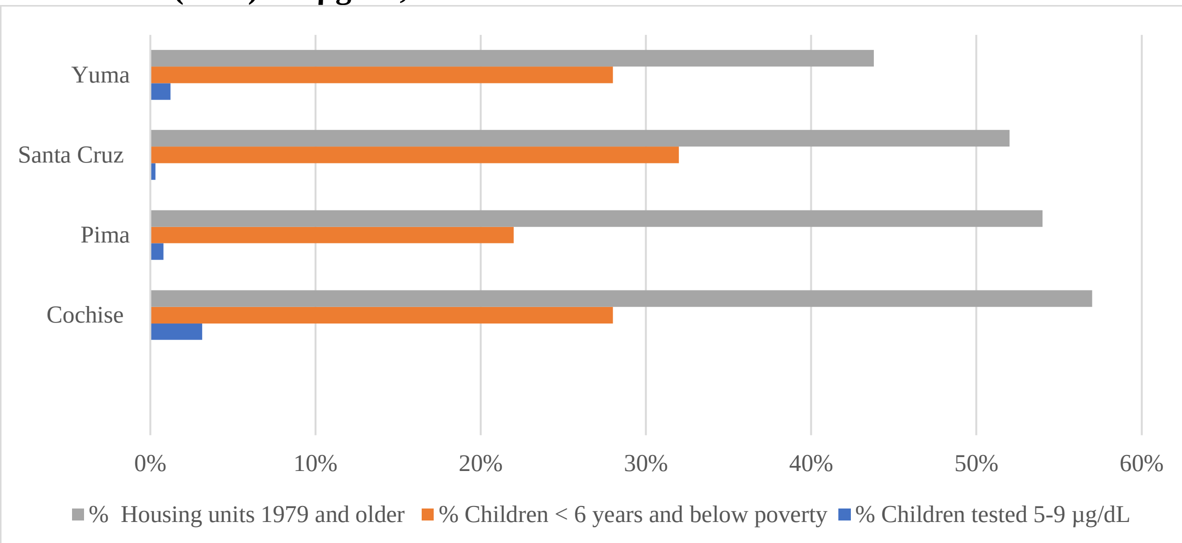
**Data Characterization**

- Data were obtained from ADHS as percentage of screened children with concentration of lead in blood > 5 µg/dL for all four border counties on the U.S. side.
- Data based on approximately 20% of screened children
- ** data from months Jan-Jun 2015 only

**Key Findings**

- ❖ Overall decrease in the percentage of children with BLL > 5 µg/dL between 2005 to 2014.
- ❖ The percentage of children screened with BLL > 5 µg/dL remained 2% between 2009 to 2015 except for Cochise county, compared to the national average of 2.8-6% (CDC, 2016) during the same period.
- ❖ There is a slight increasing trend in the percentage of screened children with BLL > 5 µg/dL beginning in 2015 for Cochise and Yuma counties. We speculate this may well be due to the initiatives to increase screening rates

**Figure 2: Percentage of screened children living in Arizona border counties with Blood Lead Levels (BLL) > 5 µg/dL, 2011-2015**




Data source: Center for Disease Control and Prevention (CDC), Arizona Data, Statistics and Surveillance, 2011-2015. United States Census Bureau; Profile of Selected Housing Characteristics:2000 Census 2000 Summary File 3 (SF3).

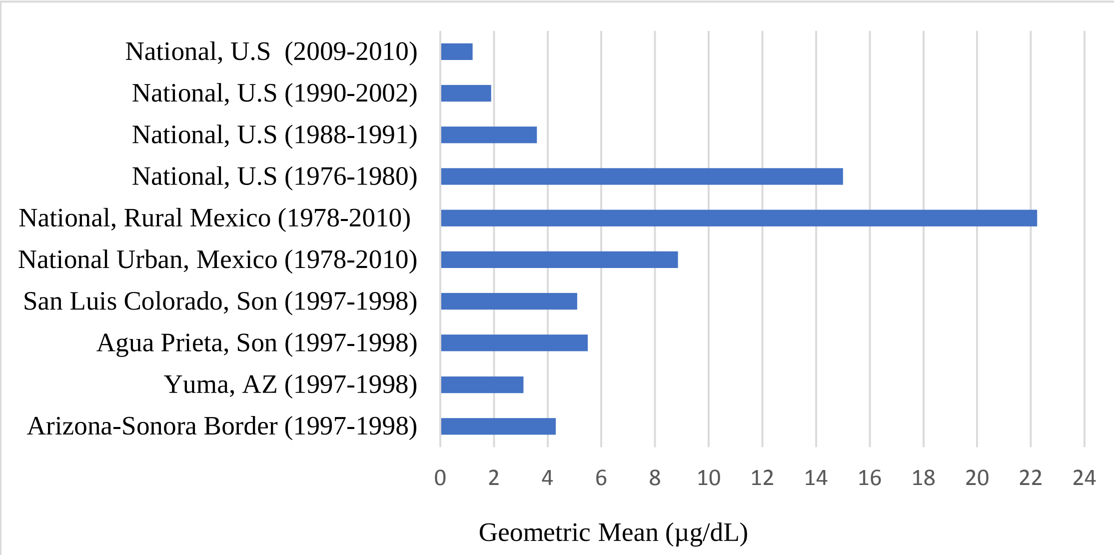
## Data Characterization

- Percentage BLL and poverty rates for children 6 years of age and below for the four border counties were obtained from CDC state surveillance systems. Data reported to the CDC surveillance system are collected from reports of blood lead tests from laboratories and results of all other blood lead tests.
- Percentage for housing units for 1979 and older were obtained from Census 2000 and percetage was calculated based on each county total housing stock.

## Key Findings

- ❖ Average poverty rate for children < 6 years along the four Border counties is 28%, with Santa Cruz county having the highest at 32%, and Pima County having the lowest at 22%.
- ❖ There is no specific trend or difference observed between percentage of children under poverty, who live in older home and those with BLL > 5µg/dL along the border counties. One of the reasons may be the low screening rate in Arizona, at approximately 20%. However, the data confirms that children living in older homes are at higher risk for lead exposure.

**Figure 3. Geometric Mean BLLs in the U.S., Mexico and along the Arizona-Sonora Border**




Data source: Caravano et al., (2014); Cowan et al., (2006); the Environmental Protection Agency (U.S EPA), (2013); and CDC, Morbidity and Mortality Weekly Report (MMWR), 2013)

## Data Characterization

- Data for geometric mean BLL in Arizona-Sonora Border including San Luis Colorado, Agua Prieta, and Yuma were obtained from a study conducted by Cowan et al. (2006). Data were collected from schools, daycare centers and health centers between 1997-1998.
- Data for geometric mean BLL in Mexico were obtained from a meta-analysis study of 83 published articles between 1978-2010 with blood lead levels measured in 50,000 study participants conducted by Caravanos et al. (2014).
- Data for geometric mean BLL in U.S. were obtained from the third report of the Americas Child and the Environment (ACE3) (U.S EPA, 2013)
- Historic data for national geometric mean BLL beginning 1976-2002 were obtained from the CDC MMWR (2013).
- No calculations were done for any of the data above. Data from the sources were directly plotted to provide the historic trend of BLLs overtime.

## Key Findings

❖ The BLLs in Arizona-Sonora Border region were 4.3 µg/dL between 1997 and 1998 compared to the national geometric mean BLLs of 3.6 µg/dL and 1.9 µg/dL during a similar period in 1988-1991 and 1999-2002 respectively. When looking at each side of the border, the BLLs for Sonora was higher at 5µg/dL.

❖ Rural and urban cities in Mexico are estimated to have higher BLLs ranging from of 8-22 µg/dl. The Sonora border regions has some cities that are considered rural and others urban.

### Data Gaps

- In Arizona, the screening rate is very low and therefore number of children with elevated BLL may be underestimated.
- There is a need to establish a current geometric mean BLL for Arizona and along the border counties to measure progress of current health initiatives to address blood lead in children.
- Even though data for BLL may be available in the State of Sonora, data were not accessible. The available data conducted by Cowan et al. (2006) were old. This limits the ability to better understand the current status of BLLs along the Arizona-Sonora Border as a whole.
- The screening is based on at risk index, mostly the Latino population. However, it is important to note that Yuma and Santa Cruz counties are made up of 80 and 60% Hispanic populations, respectively. Conversely, approximately 30% of Pima and Cochise counties' populations are Hispanic. Targeting Hispanic population in Santa Cruz may yield representative data for the population while the same approach may not be ideal for Pima.

### Recommendations

- Even though less than 15% of the homes along the border are pre-1978; shared cultural practices especially those related to food including ceramic imports for food preparation, may all increase the potential risks for elevated BLLs for children along the border, especially of Hispanic origin. More recent data, such as a follow-up study by Cowan et al. (2006) will provide a snapshot of the current status of BLL for children along the Arizona-Sonora Border.
- Continue to target older homes with campaign to emphasize on repairing old paint and other lead mitigations.

## 2 References

### Blood Lead

Arizona Department of Health Services (ADHS) (2014). Arizona Lead Screening Score Card. Retrieved from http://azdhs.gov/documents/preparedness/epidemiology-disease-control/childhood-lead/2014-lead-scorecard.pdf

Arizona Department of Health Services (ADHS) (2014). Targeted Lead Screening Plan for the Prevention of Childhood Lead Poisoning. Retrieved from http://www.azdhs.gov/documents/preparedness/epidemiology-disease-control/childhood-lead/targeted-lead-screening-plan.pdf

Caravanos, J., Dowling, R., Téllez-Rojo, M.M., Cantoral, A., Kobrosly, R., Estrada, D., Orjuela, M., Gualtero, S., Ericson, B., Rivera, A., Fuller, R. (2014). Blood Lead Levels in Mexico and Pediatric Burden of Disease Implications. *Ann Glob Health*, *80*(4):269-77.

Center for Disease Control (CDC). (n. d): Blood Lead Levels in Children. Retrieved from http://www.cdc.gov/nceh/lead/ACCLPP/Lead_Levels_in_Children_Fact_Sheet.pdf

Center for Disease Control (CDC). (2005). Morbidity and Mortality Weekly Report (MMWR): Childhood Blood Lead Levels – United States, 2007-2012. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6254a5.htm

Center of Diseases Control (CDC). (2014). Lead. Retrieved from https://www.cdc.gov/nceh/lead/tips.htm

Center for Disease Control (CDC). (2015). Morbidity and Mortality Weekly Report: Childhood Blood Lead Levels – United States 2007-2012. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6254a5.htm

Centers for Disease Control (CDC). (2015). Morbidity and Mortality Weekly Report (MMWR) Blood lead levels in children ages 1-5 years -United States, 1999-2010. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6213a3.htm?s_cid=mm6213a3_e

Center for Disease Control ( CDC). (2016). Arizona Data, Statistics, and Surveillance. Retrieved from https://www.cdc.gov/nceh/lead/data/state/azdata.htm

Center for Disease Control (CDC). (2016). Total blood lead surveillance, 1997-2015. Retrieved from https://www.cdc.gov/nceh/lead/data/Chart_Website_StateConfirmedByYear_1997_2015.pdf

Committee on Environmental Health. (2005). Lead Exposure in Children: Prevention, Detection, and Management. *Pediatrics Oct 2005*, *116*(4): 1036-1046.

Cowan, L., Esteban, E., McElroy-Hart, R., Kieszak, S., Meyer P., Rosales, C., Applegate, M., Mada Vélez, G., Arias-Ortiz, J., Rubin, C. (2006). Binational study of pediatric blood lead levels along the United States/Mexico border. *Int J Hyg Environ Health*, *209*(3):235-240.

Federal Interagency Forum on Child and Family Statistics (n. d). POP1 Child Population: Number of Children Ages 0-17 in the United States by age, 1950-2015 and Projected 2016-2050. Retrieved from https://www.childstats.gov/americaschildren/tables/pop1.asp

Flores-Ramírez, R., Rico-Escobar, E., Núñez-Monreal, J.E., García-Nieto, E., Carrizales, L., Ilizaliturri-Hernández, C., Díaz-Barriga, F. (2012). Children exposure to lead in contaminated sites. *Salud Publica Mex, 54*(4):383-92.

International Persistent Organic Pollutants Elimination Network (IPEN). (2009). Global study to determine lead in decorative paints in 10 countries. Retrieved from http://ipen.org/sites/default/files/documents/global_paintstudy-en.pdf

Jacobs, D. E., Clickner, R. P., Zhou, J. Y., Viet, S.M., Marker, D.A., & Rogers, J.W. (2002). The prevalence of lead-based paint hazards in U.S. housing. *Environ Health Perspect, 110*: A599–A600.

Kessler, R. (2014). Lead-Base Decorative Paints: Where are they still being sold? – and why? *Environmental Health Perspectives*. Retrieved from http://ehp.niehs.nih.gov/wpcontent/uploads/122/4/ehp.122-A96.pdf

Medina-Valles, A. M., Osuna-Leal, A. I., Martinez-Cervantes, M. E., Castillo-Gregoso, M. C., Vazquez-Erlbeck, M. and Rodriguez-Lainz, A. (2014). Do Glazed Ceramic Pots in a Mexico-US Border City Still Contain Lead? *International Scholarly Research Notices 2014.*

National Center for Healthy Housing (NCHH). (2008). What we do: Lead. Retrieved from http://www.nchh.org/What-We-Do/Health-Hazards--Prevention--and-Solutions/Lead.aspx

Rojas-López, M. (1994). Use of lead-glazed ceramics is the main factor associated to high lead in blood levels in two Mexican rural communities. *Journal of Toxicology and Environmental Health*, *42*(1):45–52.

Romieu, I., Palazuelos, E., Hernandez, A. M., Rios, C., Muñoz, I., Jimenez, C., Cahero, G. (1994). Sources of lead exposure in Mexico. *Environ Health Perspect, 102*(4):384-9.

Shonkoff, J. P., Boyce, W. T. and McEwen, B. S. (2009). Neuroscience, Molecular Biology, and the Childhood Roots of Health Disparities Building a New Framework for Health Promotion and Disease Prevention. *JAMA, 301*(21):2252-9

U.S Department of Housing and Urban Development (HUD). (n.d). Office of Healthy Homes and Lead Hazard Control. Lead. Retrieved from http://portal.hud.gov/hudportal/documents/huddoc?id=DOC_11875.pdf

U.S Environmental Protection Agency (U.S EPA). (n. d). Learn about Lead. Retrieved from https://www.epa.gov/lead/learn-about-lead#lead

## 2 References

U.S Environmental Protection Agency (U.S EPA). (2016). EPA takes final steps in phaseout of leaded gasoline. Retrieved from http://www.epa.gov/aboutepa/epa-takes-final-step-phaseout-leaded-gasoline

U.S. Environmental Protection Agency (U.S EPA). (2016). EPA History: Lead Retrieved from https://www.epa.gov/aboutepa/epa-history-lead

U.S Census Bureau. (n.d.) Profile of Selected Housing Characteristics: 2000 Census 2000 Summary File 3 (SF 3) Sample Data. Retrieved from https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

World Health Organization (WHO). (2010). Childhood Lead Poisoning Report. Retrieved from http://www.who.int/ceh/publications/leadguidance.pdf.

World Health Organization (WHO). (2016). Lead poisoning and Health. Retrieved from http://www.who.int/mediacentre/factsheets/fs379/en/.

## Childhood Cancer

Cancer is a conglomeration of diseases that are all caused by the uncontrollable division of cells that can quickly spread to surrounding tissues due to changes in genes that aid in controlling cell function, including their growth and their division. In a healthy individual, cells normally grow and divide to form new cells, replacing older ones or those that have been damaged. However, when this normal process is disrupted, old, abnormal or damaged cells can survive longer at the same time that newly formed cells are accumulating in the body (O'Brien et al., 2009). This uncontrollable increase in cells could then lead to growths called tumors that can either be malignant (cancerous) or benign. Malignant tumors or cancerous tumors can invade nearby tissues and can even break off and travel and spread to other parts of the body through the circulatory or lymph system. Benign tumors, on the other hand, do not spread to other nearby tissues or grow again after removal and are generally considered non-threatening. New technology, better prevention, and enhanced treatment options have led to improved survival rates in cancer patients, including children (Allemani et al., 2015).

Despite major improvements in survival rates in childhood cancer in the United States (U.S.) with a death rate decline of 2.1% per year from 1975 to 2009, childhood cancer incidence rate has increased at approximately an annual rate of 0.6% nationally since 1975 (Ward et al., 2014). Cancer remains the leading cause of death in children from disease in the United States and the second leading cause of death in children overall, following accidents (Ward et al., 2014; Linet et al., 1999; Jemal et al., 2008). Although very little is known of the causes of childhood cancer, the predominant cancer types diagnosed in children in the U.S. have been: leukemia, brain and other nervous system tumors, and bone- and joints-related cancers (Siegel et al., 2013). About 1 in 285 children in the U.S. will be diagnosed with cancer before the age of 20 (Howlander et al., 2013). In Arizona, approximately 86% of all Arizona residents diagnosed with cancer are age 50 or older (Arizona Department of Health Services (ADHS), 2013). Out of the remaining 14%, about 1.1% are children under 19 (ADHS, 2013). Similar to U.S. national trends, childhood cancer in Arizona is also the leading cause of death due to disease (ADHS, 2013).

Unlike the U.S., in Mexico, the childhood cancer incidence rate has decreased from 1996 to 2001 with an annual percentage of change of about 6.6% (Fajardo-Gutierrez et al., 2016). The primary cancer types in Mexico between 1996 and 2013 were similar to those of U.S.: leukemia, central nervous system tumors, and lymphomas in children (0-14 year olds), in addition to bone and joint related cancers in adolescents (15-19 year olds) (Fajardo-Gutierrez et al., 2016; Escamilla-Santiago et al., 2012). Compared to the U.S., Mexico also has observed a decline in mortality rates in childhood cancer of about 2.8% per year from 1996 to 2013 (Fajardo-Gutierrez et al., 2016). In Sonora, according to the Director of the Oncology Department in the Children's Hospital of the State of Sonora (HIES), for every 100 million children under the age of 18, about 11,500 are diagnosed with cancer – primarily leukemia, lymphomas and brain, and central nervous system tumors (Porras, 2016). At 11.5%, the childhood cancer rate in the State of Sonora exceeds the national rate in Mexico of 8% (Porras, 2016).

## The Arizona Cancer Registry Database (ACR)

The Arizona Cancer Registry (ACR) Database from the Arizona Department of Health Services (ADHS) Indicator Based Information System for Public Health (IBIS-PB) was queried for mortality and cancer incidence rates for the state of Arizona, including the four counties along the Arizona-Sonora border region. Data obtained by the ACR are derived from a population-based surveillance system with the primary goal of administering, collecting and analyzing the data to determine incidence, mortality, and survival of individuals diagnosed with cancer in the state of Arizona each year (ADHS, 2016). These data only reflect information provided by physicians, pathology laboratories, Arizona hospitals and case data exchanges from other state registries in the United States (ADHS, 2016). American Indian information is received from the Indian Health Service (IHS).

Some cancer cases have been excluded from the 2013 data in the ACR database results due to incomplete processing. Thus, all counties in Arizona may be under-representing the total number of cancer cases. For instance, if a physician does not return the required paperwork for further information, that may lead to incomplete cases and may not be included in the ACR database (ADHS, 2016). Based on ADHS, cancer case counts in Arizona have been affected by incomplete reporting from Veterans hospitals between 2006-2013, and also from small rural hospitals in Cochise and Santa Cruz counties (ADHS, 2016). Incomplete reporting may have underestimated the true number of cancer cases.

Cancer mortality cases in the registry are obtained from the ADHS Office of Vital Records Death Certificate Database. They are reported under the International Classification of Diseases $10^{th}$ revision (ICD-10). Funeral directors are responsible for filing all death certificates in the state. Certification of the cause of death of an individual is done by a decedent's physician, the physician that was present at the time of death, or the Medical Examiner (ADHS, 2016).

## Data Presented in the Indicators

The cancer incidence rate is the number of new cancer cases for a specific period of time. Figures 1 and 2 represent the number of new childhood cancer cases and are expressed per million children per year. The rate is age-adjusted, using the 2000 U.S. children population distributions for each age bracket: 0-4 years, 5-9 years, 10-14 years and 15-19 years as appropriate weights for standardization. For example, the U.S. children distribution between the ages of 0-4 in the year 2000 was 23.83%. That percentage was used to determine the cancer incidence rate for all other years between 2000-2013 for that age bracket. This helps reduce the possibility of confounding due to age (Kalmijn et al., 1995). Figure 2 represents cancer incidence based on the cancer site for each individual Arizona border county. Figure 3 represents cancer mortality as the number of deaths per million children per year.

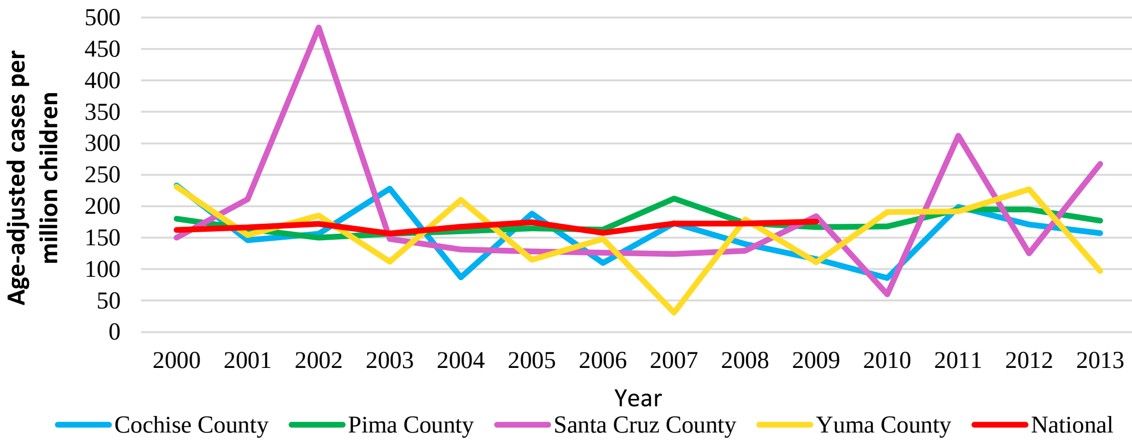
Queries through the ACR for **cancer incidence** are broken down into five different categories: single years, cancer sites, age groups, race and county. The years selected were from 2000-2013, for all cancer sites and races ages 0-19 years for the four Arizona border counties.

**Cancer mortality** indicators analyzed in this report are for the entire Arizona border, and not just for the four border counties. The ACR does allow query for cancer mortality by county. In addition, only 0-14 years' age groups are shown on the graph. The ACR breaks down the age categories between 0-14 age groups, and 15-24 age groups, which falls outside the children age groups. Queries through the ACR database for cancer mortality are broken down into four different categories: single years, cause of death (based on cancer site), age groups, and gender. The years selected for the indicator were from 2000-2013. All cancer death sites were included and only ages 0-14 years for both genders were part of the query. Arizona county populations used to determine age-adjusted cancer incidence rates and mortality rates for each year and county were estimates obtained from the National Cancer Institute (NCI) and the Surveillance Epidemiology and End Results (SEER) Program in the ACR database.

Figures 1 and 3 both compare the respective national average for cancer incidence rates and cancer mortality per year as that of the America's Children and the Environment (ACE3) report, and the National Vital Statistics System's 15 leading causes of death reports, respectively. Due to the rarity of some cancer types, each bar in the graphs in Figure 2 represents the cancer incidence for a specific cancer site for every three-year period mirroring the ACE3 report, except the bars representing 2012-2013. Graph bars for 2012-2013 account for only two years due to lack of data for the year 2014. The bars represent the average number of cancer cases divided by the average children population per million for each individual three-year period.

**About the indicators:** Figure 1 and Figure 2 represent the number of new childhood cancer cases in the Arizona Border Region between 2000-2013. The cancer incidence for children ages 0 to 19 years was obtained from the Arizona Cancer Registry (ACR) for the U.S. border region (Cochise, Pima, Santa Cruz and Yuma). Data for national trends were obtained from the ACE3. Figure 2 represents the childhood cancer incidence by cancer type. Data for all four Border counties were obtained from the ACR. Figure 3 presents childhood cancer mortality in the state of Arizona and in the United States. The childhood cancer death data were obtained from the ACR and from the Center for Disease Control and Prevention (CDC) National Vital Statistics System (NVSS), by year. Figures 1, 2 and 3 mirror the ACE3 report health indicators H4 and H5, with a minor exception; data presented in Figure 3 are for age group 0-14 years of age instead of 0-19 years of age. Figure 4 presents the childhood cancer incidence and mortality for the State of Sonora and Mexico. Data presented in Figure 4 is between the ages of 0 to 17 years and were obtained from the Mexican Secretariat of Health 2008-2014 Epidemiologic Cancer Behavior report for children below 18 years.

**Figure 1: Cancer incidence for children ages 0 to 19 years in Arizona Border Region, 2000-2013**




Data source: Arizona Department of Health Services (ADHS) Cancer Registry, The 3rd America's Child and the Environment Report (ACE3) (U.S EPA, 2013)

**Data Characterization**

- Childhood cancer incidence data for Figure 1 were obtained from the Arizona Cancer Registry Database maintained by ADHS.
- Population estimates for the years 2000-2013 were obtained from the National Cancer Institute (NCI) Surveillance Epidemiology and End Results (SEER) Program in the ACR
- Data were queried by year, county, and age group from 0-4, 5-9, 10-14, 15-19 years in ACR years in ACR.
- National data for comparison were obtained from ACE3 Report.

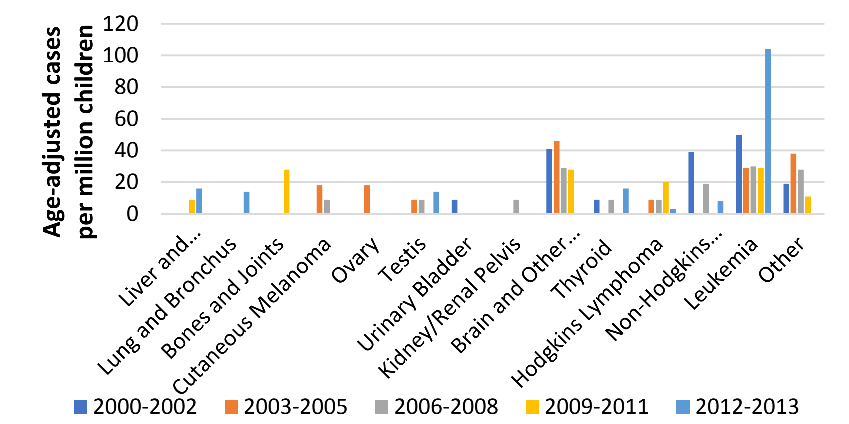
**Key findings**

❖ The age-adjusted cancer incidence in children between the years 2000 and 2013 for each county ranged from 31 to 484 cases per million. For the most part, all four counties were below the national average with exceptions of some peak years. The national average ranged from 157 to 175 cases per million children

❖ Santa Cruz County had the highest cancer incidence peaks from 2001-2002 and 2010-2011 than any other Arizona border county, with 484 and 312 cases per million children respectively. Due to the small population size in the county, a difference of one cancer case for both 2002 and 2011 in each standardized age group made a significant difference in the childhood cancer incidence.

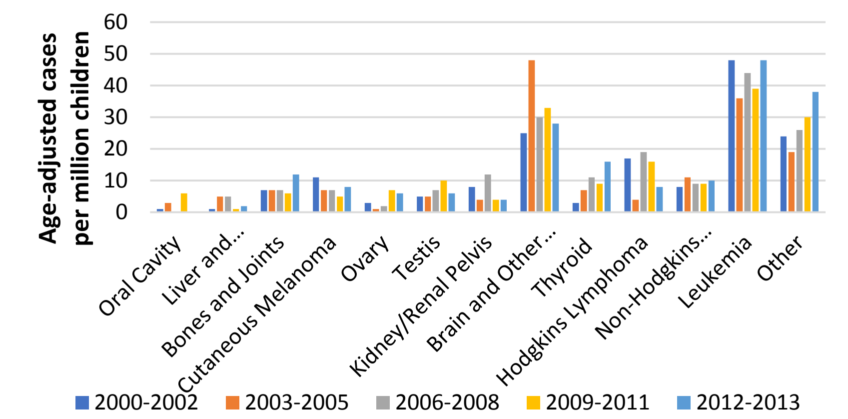
❖ Cochise County and Yuma County both had an average childhood cancer incidence of about 156 cases per million between 2000-2013. Pima County had an average cancer incidence of about 173 cases per million and Santa Cruz County had an average cancer incidence of about 184 cases per million. Conversely, the national average childhood cancer for the same years was about 168 cases per million.

**Figure 2: Cochise county cancer incidence for children ages 0 to 19 years, by cancer type, 2000-2013**



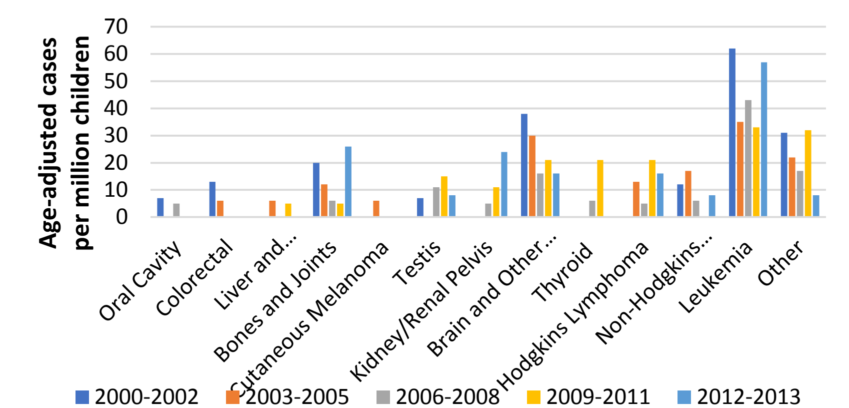

Data source: Arizona Department of Health Services (ADHS)

**Figure 2: Pima county cancer incidence for children ages 0 to 19 years, by cancer type, 2000-2013**



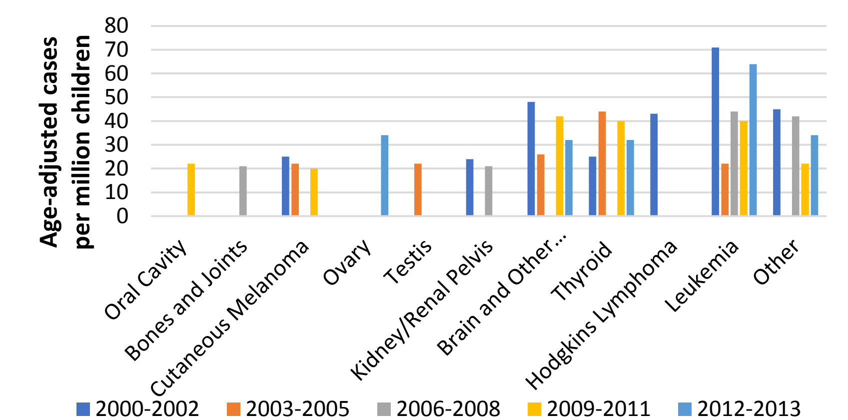

Data source: Arizona Department of Health Services (ADHS)

**Figure 2: Yuma cancer incidence for children ages 0 to 19 years by cancer type, 2000-2013**




Data source: Arizona Department of Health Services (ADHS)

**Figure 2: Santa Cruz cancer incidence for children ages 0 to 19 years, by cancer type, 2000-2013**




Data source: Arizona Department of Health Services (ADHS)

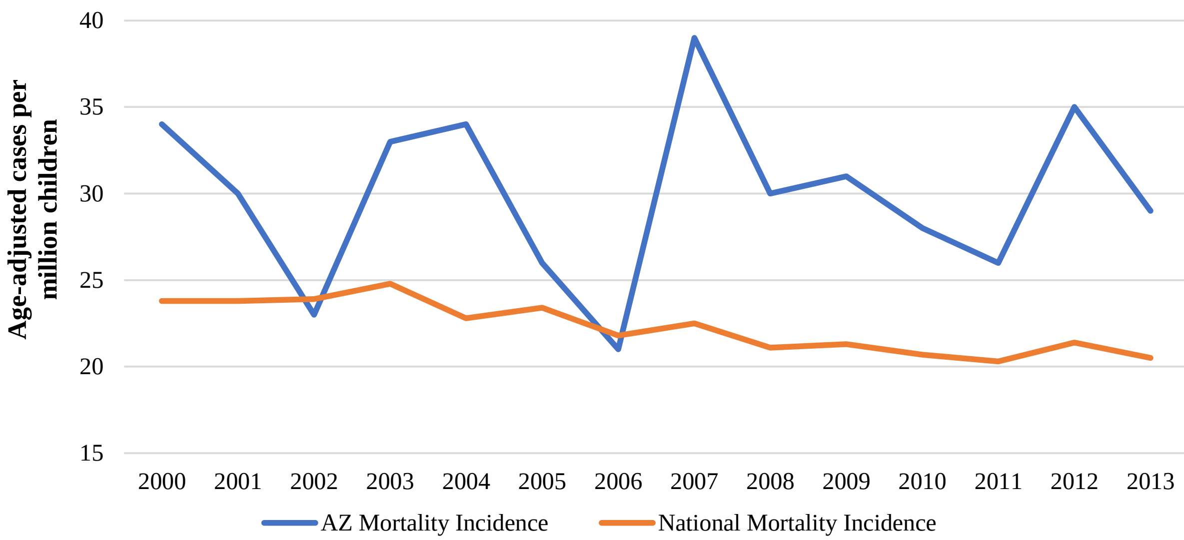
**Data Characterization**

- Childhood cancer incidence data for Figure 2, for all counties were obtained from the Arizona Department of Health Services (ADHS) Arizona Cancer Registry Database (ACR).
- Population estimates for the years 2000-2013 were obtained from the National Cancer Institute (NCI) Surveillance Epidemiology and End Results (SEER) Program in the ACR.
- Data were queried in the ACR by year, county, cancer type and age groups from 0-4, 5-9, 10-14, 15-19 years.

**Key Findings**

- ❖ Leukemia was the most common diagnosis in all four counties between 2000-2013, accounting for approximately 28% of all cancer cases for those years respectively (national average was 28% from 2004-2006, U.S EPA, 2013).
- ❖ While the general trend shows that the incidence rate for leukemia and other cancers has been decreasing or remained relatively the same along the Border Region, Cochise shows that the incidence rate for leukemia has almost quadrupled from 29 cases per million in 2009-2011 to 104 cases per million in 2012-2013. The increase could be due to an aging children leukemia cancer cluster back in 2005 in Cochise Count (Roberts, 2005). (National incidence rate was about 33 cases per million in 2001-2003 and about 35 cases per million in 2004-2006, U.S. EPA, 2013).
- ❖ Brain and other nervous system cancer cases accounted for about 17% of total cancer cases along the Border Region (national average 18% from 2004-2006, U.S EPA, 2013).
- ❖ Lymphomas including non-Hodgkin's and Hodgkin's lymphoma, accounted for about 11% of childhood cancer cases between 2000-2013 (National average was 14% from 2004-2006, U.S EPA, 2013).

**Figure 3: Cancer mortality for children ages 0 to 14 years in Arizona and the U.S , 2000-2013**




Data source: Arizona Department of Health Services (ADHS) Cancer Registry & Center for Disease Control and Prevention (CDC) National Vital Statistics System

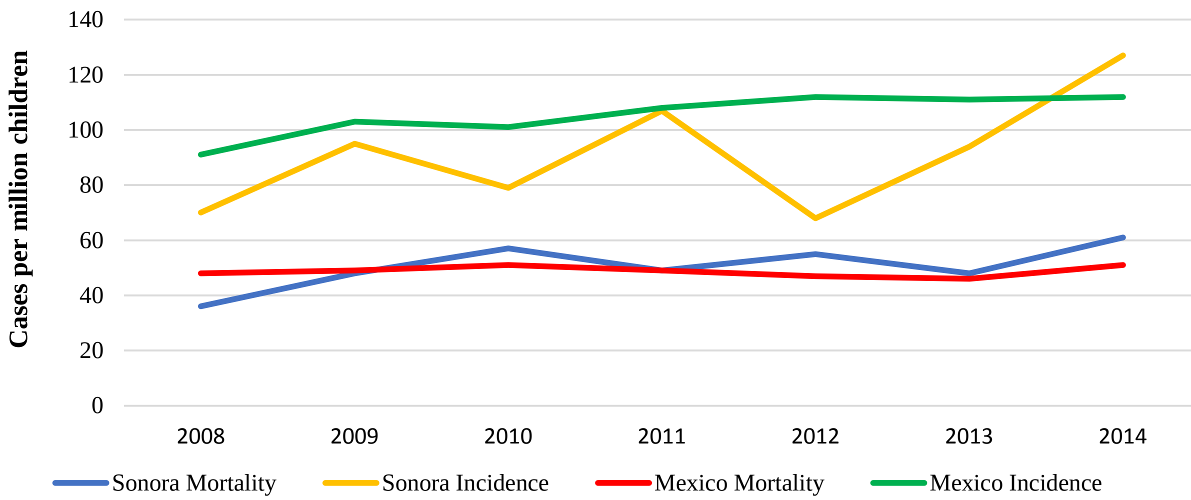
**Data Characterization**

- National childhood cancer mortality data for Figure 3 were obtained from the ADHS Office of Vital Records Death Certificate Database through the Arizona Cancer Registry Database for Arizona and the National Vital Statistics System (NVSS), the Center for Disease Control and Prevention (CDC) for the years 2000-2013.
- Population estimates for the years 2000-2013 were obtained from the National Cancer Institute (NCI) Surveillance Epidemiology and End Results (SEER) Program through the ACR.
- Data were queried in the ACR by year and age groups from 0-4, 5-9, 10-14 years.
- Data were acquired by year and age groups from 0-4, 5-9, 10-14 years in NVSS only for malignant neoplasm cases.

**Key Findings**

- ❖ The age-adjusted childhood cancer mortality in children between the years 2000 and 2013 for the entire state of Arizona ranged from 21 to 39 cases per million children compared to the national rates of 20.5 to 24.8 cases per million.
- ❖ The highest Arizona childhood cancer mortality rate of 39 cases per million children was 14 cases above the highest childhood cancer mortality rate in the nation of 24.8 cases per million children.
- ❖ Arizona had a higher childhood cancer mortality incidence in 12 out of the 14 years observed (excluding 2002 and 2006) with an average of 7.6 cases per million higher than the national mortality rates. From 2010-2013, the range of childhood cancer mortality cases ranged
- ❖ between 26-35 cases per million in Arizona compared to 20.3-21.4 cases per million children nationally.

**Figure 4: Cancer mortality and incidence for children ages 0 to 17 years in Sonora and Mexico, 2008-2014**




Data source: Secretaría de Salud, *Comportamiento Epidemiológico del Cáncer en menores de 18 años. México 2008-2014*

**Data Characterization**

- Cancer mortality and incidence data were obtained from the Mexican report on Epidemiologic Cancer Behavior for children below 18 years for 2008-2014 compiled by the Secretariat of Health in Mexico.
- Data for Sonora were provided by state health services and the Children's Hospital for the State of Sonora.
- Data for Mexico were provided by the Secretariat of Health.
- Childhood mortality in Sonora for the year 2014 is a projected rate.

**Key Findings**

❖ The childhood cancer incidence for Mexico has slowly increased from 2008 to 2014 from 91 to 112 cases per million children.
❖ The childhood cancer incidence for Sonora has been below the national average from 2008 to 2013 ranging from 70 to 94 cases per million children. In 2014, the cancer incidence for the state surpassed the national childhood cancer incidence by 15 cases to 127 cases per million children.
❖ The childhood cancer mortality in children in Mexico has remained relatively the same ranging from 47 to 51 between 2008 and 2014.
❖ The childhood cancer mortality in children in Sonora has remained above or at the same level as the national level for 5 out of the 7 years illustrated in Figure 4 ranging from 36 to 61 cancer cases per million children between 2008 to 2014.

### Data Gaps

- ACE3 cancer incidence data only runs to 2009, thus years 2010-2013 were unable to be compared between the Arizona border region and the national levels.
- Some data in the ACR are not complete and thus cancer cases may be underreported or underestimated.
- ACE3 data could not be compared to national data because cancer types and year brackets were not similar.
- Statewide childhood cancer mortality case data were available in the ACR for analysis but not for the individual Arizona border region counties of interest.
- Queries in the ACR for age could only be done from 0-4 years, 5-14 years and 15-24 years. The latter age group had to be excluded from analysis due to a mixture of adult and children data. Thus, relevant data for this indicator for children between the ages of 15-19 is missing.
- Childhood cancer incidence and mortality are not comparable between the United States and Mexico due to different age groups analyzed in this report.

### Recommendations

- Work collaboratively to develop a system for sharing cancer information binationally, that also allows comparison within similar age groups by cancer types.
- Improve the Arizona Cancer Registry to allow greater flexibility to query data by different age groups, by counties and ethnicities.

## Adverse Birth Outcomes

The quality of an infant's gestation can be measured by the weight at birth and by the length of the pregnancy. A normal pregnancy lasts between 37 and 41 weeks, which allows for adequate development of the infant's tissue, organs, and systems (Center for Disease Control and Prevention (CDC), 2016; National Institute of Health (NIH), 2017). According to the University of Rochester Medical Center Health Encyclopedia, a pregnancy that does not reach the 37$^{th}$ week is considered preterm. An infant that is born weighing less than 2,500 grams, or about 5 pounds and 8 ounces, is considered to be low birth weight (LBW). For reference, an average newborn weighs approximately 8 pounds. An infant may be born with a LBW because they did not develop fully in utero, because they were born earlier than 37 weeks, or in some cases, both (United States Institute of Medicine (U. S IOM), 2007). Infants that are born preterm and/or LBW are at risk for complications during infancy that may last for years.

In 2013, approximately one-third of infant deaths in the United States were caused by preterm-related complications (CDC, 2016). In a retrospective cohort study in the United States, it was found that teenage pregnancy leads to increased risk of adverse birth outcomes independent of confounders that are well known (Chen et al., 2007). In addition to the health complications associated with, preterm births, it should be noted that families of preterm infants often suffer a financial and emotional toll (CDC, 2016). In the United States, black women have consistently had higher rates of preterm and LBW babies, even when controlling for differences in social economic status (Goldenberg et al., 1996; CDC, 2002; U.S IOM, 2007; CDC, 2016;). In Arizona, the cost of hospitalization due to preterm and low birth in infants currently accounts for half of the total infant hospitalization costs in the state as well as the United States (Russell et al., 2007).

In Mexico, national studies have found the percentage of children born preterm to be about 4.1% and 6.73% (Miranda et al., 2003; Morales et al., 2005). A more recent study found the percentage of children born preterm from 2007 to 2012 to be 7.7% (Hernandez-Valencia et al., 2014). This shows percentage of children born preterm from 2003-2007 has not changed much. Primary reasons for adverse birth outcomes in Mexico include: premature rupture of membranes, preeclampsia-eclampsia, twin births, intrauterine growth restriction and congenital defects (Cruz et al., 2007). In Sonora, the percentage of children born preterm recently was at 7.8%- barely above the national average of 7.7% (Hernandez-Valencia et al., 2014). The U.S. border region has higher prevalence of low birth weight, premature births and before term births compared to the Mexican border region (McDonald et al., 2013). Furthermore, prevalence of adverse birth outcomes in the Mexican border region is lower than national levels, but higher in the U.S. border region compared to national levels (McDonald et al., 2013).

## Data Presented in the Indicators

### *United States Data*

The National Vital Statistics System (NVSS), which is operated by the National Center for Health Statistics, publishes national data on births, deaths, marriages, divorces, and fetal deaths. The information is shared by each state and is mandated by federal law. The most recent information available for birth outcomes is for 2014. Each year, the NVSS publishes a report detailing birth outcomes, including the percentage of LBW infants born in each state and the percentage of babies born preterm in each state. Tables 1 and 3 in the appendix detail the NVSS report number with the corresponding birth data. The LBW and preterm data are further divided by race and ethnicity for each state and include the following categories: all races, white non-Hispanic, black or African American non-Hispanic, and Hispanic. For the years 1997-2003, the reports on LBW infants included Hispanic white and black as separate race and ethnicity categories; these were omitted to match more recent data. Race and Hispanic origin are reported separately on birth certificates; persons of Hispanic origin can be any race. The category "all races" includes races other than white and black and origin not stated. Figure 1 displays the trend in the percentage of infants delivered in Arizona that weighed less than 2,500 grams, or 5 pounds 8 ounces, with a separate line for each maternal race and ethnicity group and a single line for all maternal races and ethnicities combined for the years 2000 to 2014. A dashed line for each corresponding U.S. figure is included for comparison. Figure 3 displays the percentage of Arizona infants born preterm, with a separate line for with a separate line for each maternal race/ethnicity group and a single line for all maternal races and ethnicities combined for the years 2002 to 2014. A dashed line for each corresponding U.S. figure is included for comparison. All information in figures 1 and 3 was collected from the NVSS.

The Arizona Department of Health Services (AZDHS) compiles information from Arizona birth certificates in annual reports and assembles information from birth certificates to publish statistical trends over periods of time (e.g. 10 years). This information is found online under *Population Health and Vital Statistics* from the AZDHS website. The number of LBW infants and total number of infants born are divided by mother's county of residence. The number of LBW infants born was divided by the total number of infants to get a percentage, as this information was not available. Beginning in 2013, AZDHS began omitting cells with counts less than 6, and left resultant rates blank if counts were less than 6. Population Health and Vital Statistics data from 1990 to 2014 are currently available. Figure 2 displays the percentage of infants delivered to mothers listing residence in Arizona, the U.S., and the four Arizona-Mexico border counties weighing less than 2,500 grams, with separate lines for all of Arizona, Cochise, Pima, Santa Cruz, and Yuma counties for the years 1990 to 2014. Each annual AZDHS *Arizona Health Status and Vital Statistics* report includes the percentage of births delivered preterm, by Arizona county and year. Reports from 2000 to 2014 are currently available online. It is important to note that in the year 2000, the AZDHS included births that were 37 weeks long in the percentages of infants born preterm and in later years did not. The data from 2000 were therefore omitted from this analysis. The percentage of births delivered preterm from 2001 to 2014 in all of Arizona, the U.S., and each of the four Arizona-Mexico border counties is displayed in Figure 4 for the years 2001 to 2014.

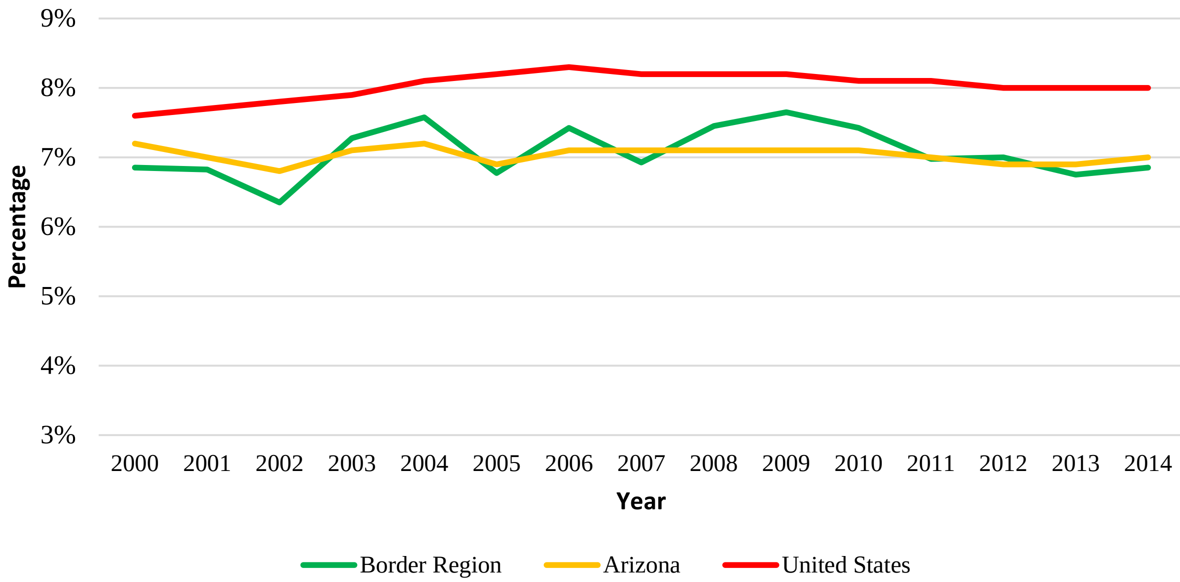
*Mexico Data*

The Mexican Health Ministry compiles and grants access to non-identifiable health information in order to aid with transparency and access of government information under the Norma Oficial Mexicana Law. The Subsystem of Information for Births (SINAC) under the National System of Health Information (SNIS) contains a database on yearly births for the entire country, Mexican states and municipalities within those states. Figure 5 represents the percentage of infants delivered at term weighing less than 2,500 grams at term between 2008-2014 for Mexico, the

State of Sonora and the Border Region. This includes all types of births such as singletons or multiples. Due to unknown weights of certain entries in the database, not all newborns are represented in the indicator. Figure 6 represents the percentage of infants born preterm, which is characterized by a gestation period less than 37 weeks, between 2008-2014 for Mexico, the State of Sonora and the Border Region.

**About the indicators:** Figure 1 displays the percentage of infants delivered along the Arizona border at term, weighed less than 2,500 grams, or 5 pounds 8 ounces, compared to the Arizona and the U.S national percentages for the years 2000 to 2014. Figure 2 displays the percentage of infants delivered at term with low birth weight along Sonora Border Region, compared to the state of Sonora and the Mexico national percentages between 2008 and 2014. Figure 3 displays the percentage of Arizona infants born preterm, along the Arizona-Sonora Border Region, also compared to Arizona and the state of Sonora, as well as the national data for both countries.

**Figure 1: Percentage of infants delivered at term with low birth weight in Arizona Border Region, 2000-2014**




Data source: Arizona Department of Health Services (ADHS), *Population Health and Vital Statistics*

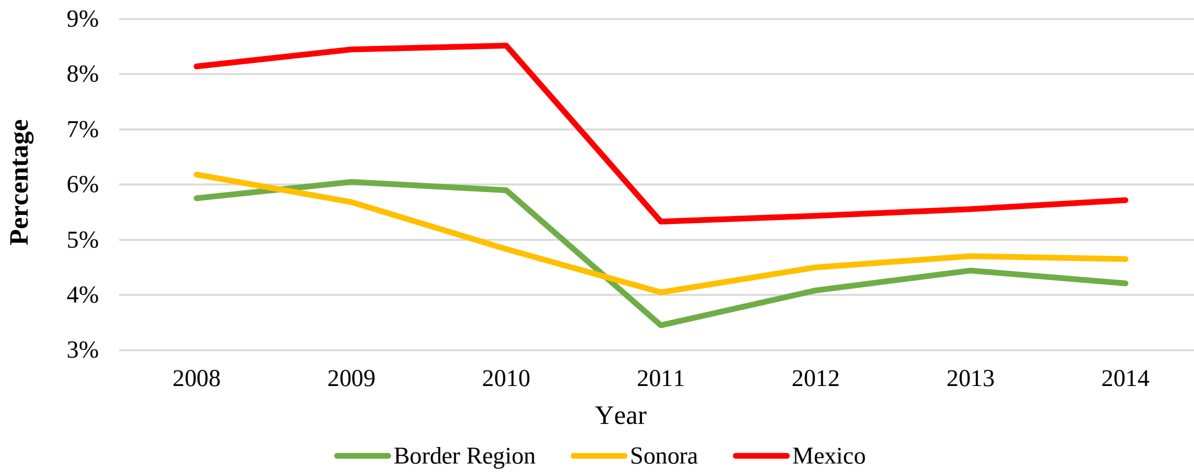
## Data Characterization

- Data obtained from Arizona Department of Health Service, Population Health and Vital Statistics database that collects information from birth certificates which includes birth weight and length of gestation, and mother’s residency.

### Key Findings

- ❖ Percentage of infants delivered at term with low birth weight has remained relatively the same between 2000-2014 for the Arizona Border region, the state of Arizona and nationally.
- ❖ The percentage of infants delivered at term with low birth weight in both, the Arizona Border region and the state of Arizona are relatively similar and below the national percentage.

**Figure 2: Percentage of infants delivered at term with low birth weight in Sonora Border Region, 2008-2014**




Data Source: Mexican Health Ministry (MHM) Live Newborn Database (LND)

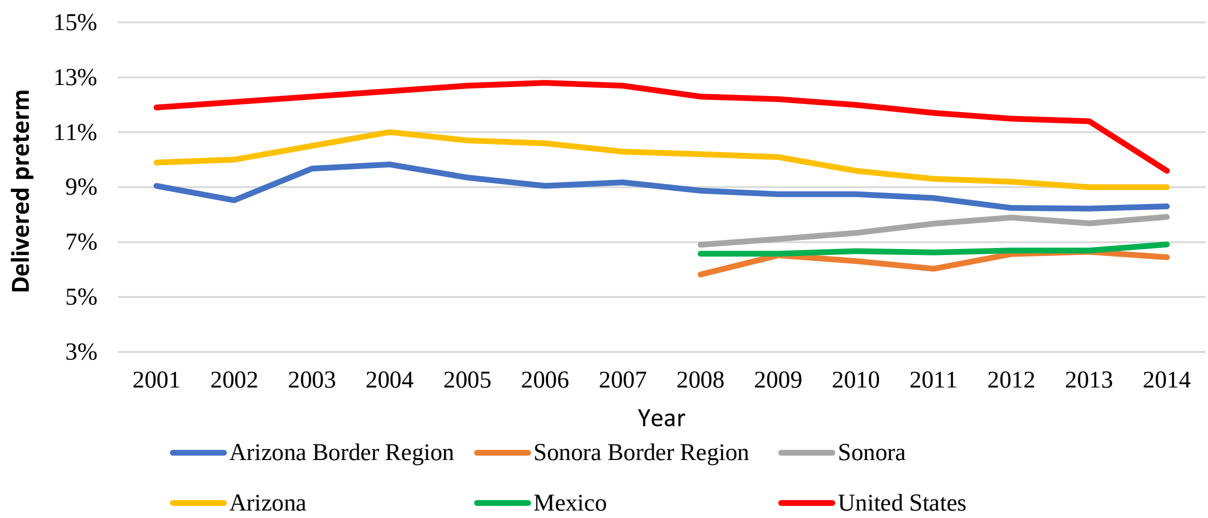
### Data Characterization

- Data was obtained from the Mexican Health Ministry through the Live Newborn Database for the years 2008-2014
- Data for infants delivered at term with low birth weight for Border Region and the state of Sonora are based on where the mother resides

### Key Findings

- ❖ The percentage of infants delivered at term with low birth weight along the Sonora border region, and the state of Sonora are relatively similar at 3-6% (2008-2014), which is below the Mexico national average of 5-8% (2008-2014)
- ❖ There is a sharp decrease of percentage of infants delivered at term with low birth weight for the Sonora border region, the state of Sonora and Mexico. This indicate a major change in either how data is collected or a national health policy change.

**Figure 3: Percentage of births delivered preterm in the Arizona-Sonora Border Region, 2001-2014**




Data source: Arizona Department of Health Services (ADHS), Arizona Health Status and Vital Statistics Report & Mexican Health Ministry (MHM) Live Newborn Database (LND)

## Data Characterization

- Data for Mexico, the state of Sonora and along the Sonora Border region were obtained from the Mexican Health Ministry through the Live Newborn Database.
- Data for infants delivered at term with low birth weight for Border Region and the state of Sonora are based on where the mother resides

## Key Findings

- ❖ The U.S, Arizona and along the Arizona side of the border have higher percentages of birth delivered pre-term (9-11%) compared to Mexico, the state of Sonora and the Sonora side of the border (5-7%).
- ❖ The percentage have remained relatively the same for the U.S, Mexico and along both sides of the border.

## Data Gaps

- ❖ Arizona county data for preterm and LBW births are not available by race to allow comparisons of these adverse birth outcomes by county and by race.
- ❖ The percentage of mothers in rural municipalities who have birth in their homes due to lack of access to transportation of health facilities is unknown and is not reflected in the data for Mexico.
- ❖ It is unknown why there was a sharp decrease from 2010 to 2011 in the percentage of infants delivered at term with low birth weight for Mexico and the Sonora Border Region.

**Recommendations**

- Even though health agencies may collect data by race, income and age by county, most of the time data were not easily available on their websites. Being able to analyze data for preterm and low birth weight by race/ethnicity would allow comparisons of these adverse birth outcomes by county and race/ethnicity. This will shed light on where to focus efforts to further lower cases of preterm and low birth weight and to improve overall children's health. Preterm and low birth weight can cause long-term health problems for babies and have long-lasting effects into adulthood.

# 3 References

## Childhood Cancer

Allemani, C., Weir, H. K., Carreira, H., Harewood, R., Spika, D., Wang, X. S., ... & Marcos-Gragera, R. (2015). Global surveillance of cancer survival 1995–2009: analysis of individual data for 25 676 887 patients from 279 population-based registries in 67 countries (CONCORD-2). *The Lancet*, *385*(9972), 977-1010.

Arizona Department of Health Services (ADHS) (2013). Cancer in Arizona: Cancer incidence and mortality 2008-2009. Phoenix, AZ: The Arizona Cancer Registry, Bureau of Public Health Statistics.

Arizona Department of Health Services (ADHS): Arizona Cancer Registry Database Query Module (ACRDQM) (n.d). Retrieved from http://healthdata.az.gov/query/module/AzCR/AzCRCntyICDO2/count.html

Arizona Department of Health Services (ADHS): Arizona Mortality Module(AMM) (n.d). Retrieved from http://healthdata.az.gov/query/module/mortality/MortCntyICD10/crudeRate.html

Arizona Department of Health Services (ADHS): Population Query Module for Arizona's General Population (n.d). Retrieved from http://healthdata.az.gov/query/module/pop/PopMain/count.html

Centers for Disease Control and Prevention: National Vital Statistics System (2017). Death, percent of total deaths, and death rates for the 15 leading causes of death in 5-year age groups, by race and sex: United States. Retrieved from https://www.cdc.gov/nchs/nvss/mortality/lcwk1.htm

Escamilla-Santiago, R., Narro-Robles, J., Fajardo-Gutierrez, A., Rascon-Pacheco, R., & Lopez-Cervantes, M. (2012). Trends of cancer mortality rates in children and adolescents by level of marginalization in Mexico (1990-2009). *Salud Publica De Mexico, 54*(6), 587-594.

Fajardo-Gutierrez, A., Gonzalez-Miranda, G., Pachuca-Vazquez, A., Allende-Lopez, A., Fajardo-Yamamoto, L., & Rendon-Macias, M. (2016). Cancer incidence and mortality in children in the mexican social security institute (1996-2013). *Salud Publica De Mexico, 58*(2), 162-170. doi:10.21149/spm.v58i2.7785

Howlader, N., Noone, A. M., Krapcho, M., Garshell, J., Miller, D., Altekruse, S. F., ... & Mariotto, A. (2013). SEER Cancer Statistics Review, 1975-2010, National Cancer Institute. Bethesda, MD.

Jemal, A., Siegel, R., Ward, E., Hao, Y., Xu, J., Murray, T., & Thun, M. J. (2008). Cancer statistics, 2008. *CA: a cancer journal for clinicians, 58*(2), 71-96.

Kalmijn, S., Feskens, E. J. M., Launer, L. J., Stijnen, T., & Kromhout, D. (1995). Glucose intolerance, hyperinsulinaemia and cognitive function in a general population of elderly men. *Diabetologia*, *38*(9), 1096-1102.

Linet, M. S., Ries, L. A., Smith, M. A., Tarone, R. E., & Devesa, S. S. (1999). Cancer surveillance series: recent trends in childhood cancer incidence and mortality in the United States. *Journal of the National Cancer Institute*, *91*(12), 1051-1058.

Roberts, Michelle. (2005). Children in Arizona Town Touched by Cancer Cluster. Los Angeles Times. Retrieved from http://articles.latimes.com/2005/jan/16/news/adna-ccluster16

National Cancer Institute (NCI): Surveillance, Epidemiology and End Results Programs (SEER) (2013). Retrieved from https://seer.cancer.gov/mortality/

O'Brien, C. A., Kreso, A., & Dick, J. E. (2009, April). Cancer stem cells in solid tumors: an overview. In *Seminars in radiation oncology* (Vol. 19, No. 2, pp. 71-77). WB Saunders.

Porras, Bárbara (2016). Sonora por encima de media nacional en Cáncer Infantil. *UniradioNoticias.* Retrieved from http://www.uniradionoticias.com/noticias/hermosillo/321551/sonora-por-encima-de-media-nacional-en-cancer-infantil.html

Secretaría de Salud. (2014). Comportamiento Epidemiológico del Cáncer en menores de 18 años México 2008-2014. CenSIA.

Siegel, R., Naishadham, D., & Jemal, A. (2013). Cancer statistics, 2013. *CA: a cancer journal for clinicians*, *63*(1), 11-30.

U.S. Census Bureau (2017). Age and Sex Composition in the United States: 2000-2013. Retrieved from https://www.census.gov/population/age/data/2003comp.html

U.S. Environmental Protection Agency (U.S EPA) (2013). America's Children and the Environment, 3rd edition (ACE3). Retrieved from https://www.epa.gov/ace

Ward, E., DeSantis, C., Robbins, A., Kohler, B., & Jemal, A. (2014). Childhood and adolescent cancer statistics, 2014. *CA: a cancer journal for clinicians*, *64*(2), 83-103.

**Adverse Birth Outcomes**

Centers for Disease Control and Prevention (CDC). 2002. Infant mortality and low birth weight among black and white infants--United States, 1980-2000. *MMWR. Morbidity and mortality weekly report*, *51*(27): 589.

Centers for Disease Control and Prevention (CDC). (2016). *Preterm Birth*. Retrieved from https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pretermbirth.htm on 26 January 2017.

Centers for Disease Control National Environmental Public Health Tracking (CDC NEPHT). (2016). *Reproductive and Birth Outcomes*. Retrieved from https://ephtracking.cdc.gov/showRbLBWGrowthRetardationEnv on 26 January 2017.

# 3 References

Chen, X. K., Wen, S. W., Fleming, N., Demissie, K., Rhoads, G. G., & Walker, M. (2007). Teenage pregnancy and adverse birth outcomes: a large population based retrospective cohort study. *International journal of epidemiology*, *36*(2), 368-373.

Cruz, H. O., Plascencia, J. L., Nakashimada, A. I., & Espinoza, J. M. G. (2007). Causas de nacimiento pretérmino entre madres adolescentes. *Ginecol Obstet Mex*, *75*, 17-23.

Hernández-Valencia, M. (2014). Incidencia de nacimientos pretérmino en el IMSS (2007-2012). *Ginecol Obstet Mex*, *82*, 465-471.

McDonald, J. A., Mojarro, O., Sutton, P. D., & Ventura, S. J. (2013). Panorama binacional de salud reproductiva entre las mujeres mexicanas y las hispanas en los EE. UU. de la región fronteriza.

Miranda-Del Olmo, H., Cardiel-Marmolejo, L., Reynoso, E., Oslas, L. P., & Acosta-Gómez, Y. (2003). Morbilidad y mortalidad en el recién nacido prematuro del Hospital General de México. *Rev Med Hosp Gen Mex*, *66*(1), 22-28.

Morales, R., & Vega, A. J. (2005). Factores de riesgo materno asociados al parto pretérmino. *Rev Med IMSS*, *43*(4), 339-342.

National Institutes of Health, Eunice Kennedy Shriver National Institute of Child Health and Human Development. (2017). *Preterm Labor and Birth: Condition Information*. Retrieved from https://www.nichd.nih.gov/health/topics/preterm/conditioninfo/Pages/default.aspx on 26 January 2017.

Russell, R. B., Green, N. S., Steiner, C. A., Meikle, S., Howse, J. L., Poschman, K., ... & Petrini, J. R. (2007). Cost of hospitalization for preterm and low birth weight infants in the United States. *Pediatrics*, *120*(1), e1-e9.

United States Institute of Medicine (US IOM) Committee on Understanding Premature Birth and Assuring Healthy Outcomes. (2007). *Preterm Birth: Causes, Consequences, and Prevention*. Washington, DC: National Academics

## Data Tables: Water and Contaminants

### Table 1: Estimated percentage of the total Arizona border population served by water systems that did not meet all applicable health-based drinking water standards, 2006-2014

| Type of standard violated | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|
| Chemical and Radionuclide | NA* | 2.11 | 3.28 | 1.40 | 1.49 | 2.73 | 1.98 | 0.31 | 0.22 |
| Disinfectants and Disinfectant Byproducts | NA* | NA* | NA* | NA* | 3.43 | NA* | NA* | NA* | NA* |
| Total Coliforms | 9.74 | 6.41 | 7.75 | 3.52 | 0.41 | 3.45 | 2.77 | 3.15 | 2.14 |
| Any health-based standard | 9.74 | 8.53 | 11.03 | 4.92 | 5.33 | 6.18 | 4.75 | 3.46 | 2.37 |

Data Source: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System https://iaspub.epa.gov/enviro/sdw_form_v3.create_page?state_abbr=AZ
*No violations were reported to EPA by any community water system in the Arizona border counties

### Table 2: Estimated percentage of the total Arizona border population served by water systems with violations of drinking water monitoring and reporting violations, 2000-2014

| Type of standard violated | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| Total Coliforms | NA* | NA* | NA* | NA* | NA* | 0.17 | 17.53 | 14.69 |
| Surface Water Treatment | NA* | NA* | NA* | NA* | NA* | NA* | NA* | NA* |
| Lead and Copper | 0.31 | 0.31 | 1.94 | 3.41 | 7.21 | 4.21 | 7.40 | 2.71 |
| Chemical and Radionuclide | NA* | NA* | NA* | NA* | 9.84 | NA* | NA* | 0.46 |
| Nitrate/Nitrite | NA* | NA* | NA* | NA* | NA* | 1.40 | 8.26 | 5.69 |
| Disinfectants and disinfection byproducts | NA* | NA* | NA* | NA* | 0.55 | 0.83 | 10.15 | 17.91 |
| Any Violation | 0.31 | 0.31 | 1.94 | 3.41 | 17.60 | 6.60 | 43.34 | 41.46 |

| Type of standard violated | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|
| Total Coliforms | 11.94 | 4.48 | 5.74 | 5.81 | 6.81 | 3.47 | 8.76 |
| Surface Water Treatment | 0.02 | 0.02 | NA* | 0.02 | 0.02 | 0.02 | 2.37 |
| Lead and Copper | 1.49 | 0.60 | 2.36 | 0.16 | 0.15 | 0.65 | 2.02 |
| Chemical and Radionuclide | NA* | 0.33 | 0.31 | 0.01 | 0.01 | 0.02 | 0.01 |
| Nitrate/Nitrite | 4.47 | 0.91 | 0.43 | 0.79 | 0.38 | 3.46 | 1.47 |
| Disinfectants and disinfection byproducts | 9.56 | 9.42 | 5.35 | 10.53 | 5.87 | 8.55 | 5.65 |
| Any Violation | 27.48 | 15.75 | 14.19 | 17.33 | 13.24 | 16.17 | 20.27 |

Data Source: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System https://iaspub.epa.gov/enviro/sdw_form_v3.create_page?state_abbr=AZ
*No violations were reported to EPA by any community water system in the Arizona border counties

**Table 3: U.S. Census data on all four Arizona border counties, 2009-2014**

| Arizona Border Counties' Census Data | Pima | Cochise | Santa Cruz | Yuma |
|---|---|---|---|---|
| Total population estimate, 2014 | 1,004,516 | 127,448 | 46,695 | 203,247 |
| Persons under 5 years, 2014 | 5.9% | 6.5% | 7.3% | 7.5% |
| Persons under 18 years, 2014 | 21.9% | 22.4% | 28.3% | 26.2% |
| Persons 65 years and over, 2014 | 17.7% | 19.9% | 15.8% | 17.4% |
| Female persons, 2014 | 50.8% | 49.2% | 52.0% | 48.8% |
| Hispanic or Latino, 2014 | 36.1% | 34.6% | 82.8% | 61.7% |
| White alone, not Hispanic or Latino, 2014 | 53.3% | 56.1% | 15.6% | 32.9% |
| Language other than English spoken at home, percent age 5+, 2009-2013 | 28.5% | 27.4% | 76.9% | 51.2% |
| High school graduate or higher, percent of persons age 25+, 2009-2013 | 87.2% | 85.8% | 72.5% | 71.9% |
| Median household income, 2009-2013 | $45,841 | $45,755 | $37,745 | $41,595 |
| Persons below poverty level, 2009-2013 | 19.2% | 17.1% | 26.3% | 20.2% |

Data Source: US Census Bureau, Quick Facts (Census, 2011)

## Data Tables: Criteria Air Pollutants

**Table 1: Percentage of children ages 0 to 17 years living in counties with pollutant concentrations above the levels of air quality standards, 2005–2015**

| Year | % Population living in counties with ozone (4th Max 8-hr > 0.075 ppm) | % Population living in counties with $PM_{10}$ (2nd Max 24-hr > 150 μg/m³) | $PM_{2.5}$ (24-hr Percentile > 35 μg/m³) |
|---|---|---|---|
| 2005 | 4 | 28 | 0 |
| 2006 | 22 | 55 | 28 |
| 2007 | 0 | 55 | 0 |
| 2008 | 26 | 77 | 28 |
| 2009 | 0 | 55 | 28 |
| 2010 | 26 | 76 | 0 |
| 2011 | 48 | 76 | 0 |
| 2012 | 26 | 76 | 0 |
| 2013 | 0 | 99 | 0 |
| 2014 | 26 | 77 | 0 |
| 2015 | 26 | 26 | 0 |

Data source: U.S EPA outdoor air quality data, air quality statistics report, https://www.epa.gov/outdoor-air-quality-data/air-quality-statistics-report

**Table 2: Ozone concentrations along the Arizona Border counties, 2005-2015**

| Year | Pima (ppm) | Yuma (ppm) | Cochise (ppm) |
|---|---|---|---|
| 2005 | 0.079 | 0.08 | 0.072 |
| 2006 | 0.076 | 0.07 | 0.074 |
| 2007 | 0.073 | 0.07 | 0.067 |
| 2008 | 0.074 | 0.08 | 0.068 |
| 2009 | 0.068 | 0.07 | 0.065 |
| 2010 | 0.069 | 0.08 | 0.071 |
| 2011 | 0.075 | 0.08 | 0.075 |
| 2012 | 0.071 | 0.08 | 0.074 |
| 2013 | 0.074 | 0.07 | 0.072 |
| 2014 | 0.069 | 0.08 | 0.068 |
| 2015 | 0.066 | 0.08 | 0.065 |

Data source: U.S EPA outdoor air quality data, air quality statistics report, https://www.epa.gov/outdoor-air-quality-data/air-quality-statistics-report

**Table 3: $PM_{10}$ concentrations along the Arizona Border counties, 2005-2015**

| Year | Pima (µg/m³) | Cochise (µg/m³) | Santa Cruz (µg/m³) | Yuma (µg/m³) |
|---|---|---|---|---|
| 2005 | 88 | 82 | 327 | 116 |
| 2006 | 95 | 83 | 256 | 230 |
| 2007 | 123 | 72 | 211 | 320 |
| 2008 | 121 | 156 | 217 | 252 |
| 2009 | 128 | 83 | 204 | 218 |
| 2010 | 186 | 83 | 177 | 113 |
| 2011 | 226 | 98 | 159 | 178 |
| 2012 | 228 | 94 | 153 | 240 |
| 2013 | 363 | 218 | 174 | 228 |
| 2014 | 143 | 175 | 180 | 375 |
| 2015 | 98 | 84 | 100 | 182 |

Data source: U.S EPA outdoor air quality data, air quality statistics report, https://www.epa.gov/outdoor-air-quality-data/air-quality-statistics-report

**Table 4: $PM_{2.5}$ along the Arizona Border counties, 2005-2015**

| Year | Pima (µg/m³) | Cochise (µg/m³) | Santa Cruz (µg/m³) | Yuma (µg/m³) |
|---|---|---|---|---|
| 2005 | 12 | 16 | 33 | . |
| 2006 | 12 | 14 | 56 | . |
| 2007 | 14 | 11 | 29 | . |
| 2008 | 12 | 14 | 37 | 21 |
| 2009 | 12 | 14 | 118 | 15 |
| 2010 | 12 | 14 | 33 | 14 |
| 2011 | 14 | 13 | 27 | 16 |
| 2012 | 13 | 12 | 26 | 16 |
| 2013 | 16 | 18 | 28 | 27 |
| 2014 | 19 | 16 | 29 | 23 |
| 2015 | 11 | 11 | 27 | 15 |

Data source: U.S EPA outdoor air quality data, air quality statistics report, https://www.epa.gov/outdoor-air-quality-data/air-quality-statistics-report

**Table 5: $PM_{10}$ concentrations along the Nogales Sonora Border 1995-2009**

| Year | $PM_{10}$ (2nd Max 24-hr > 150 µg/$m^3$) |
|---|---|
| 1995 | 0 |
| 1996 | 0 |
| 1997 | 207 |
| 1998 | 190 |
| 1999 | 152 |
| 2000 | 160 |
| 2001 | 156 |
| 2002 | 198 |
| 2003 | 0 |
| 2004 | 50 |
| 2005 | 240 |
| 2006 | 188 |
| 2007 | 170 |
| 2008 | 0 |
| 2009 | 0 |

Data source: Arizona Department of Environmental Quality (ADEQ), Office of Border Health.

**Table 6: Percentage of days with good, moderate, or unhealthy air quality along the Arizona Border Region, 2005-2015**

| Year | Days with AQI | Percentage days with good air quality | Percentage days with moderate air quality | Percentage days with unhealthy air quality |
|---|---|---|---|---|
| 2005 | 336 | 56 | 38 | 1 |
| 2006 | 357 | 53 | 41 | 0 |
| 2007 | 363 | 55 | 41 | 0 |
| 2008 | 362 | 56 | 40 | 0 |
| 2009 | 360 | 62 | 36 | 0 |
| 2010 | 313 | 63 | 33 | 0 |
| 2011 | 359 | 60 | 36 | 0 |
| 2012 | 357 | 59 | 37 | 0 |
| 2013 | 360 | 62 | 35 | 0 |
| 2014 | 365 | 61 | 36 | 0 |
| 2015 | 365 | 69 | 28 | 0 |

Data source: U. S EPA Outdoor Air Quality data, https://www.epa.gov/outdoor-air-quality-data/air-quality-index-report

## Data Tables: Hazardous Air Pollutants

**Table 1: Percentage of children ages 0 to 17 years living in census tracts where estimated hazardous air pollutant concentrations were greater than health benchmarks in 2005 and 2011 in the Arizona-Sonora Border region**

| Health Benchmark | 2005 | 2011 |
|---|---|---|
| Cancer, 1 in 100,000 | 99.3 | 100 |
| Cancer, 1 in 10,000 | 0 | 0 |
| Non-Cancer Adverse Health Effects | 0 | 0 |

Data: U.S. Environmental Protection Agency, National Air Toxics Assessment 2005-2011

## Data Tables: Pesticides in Food

**Table 1: Percentage of sampled meals in Arizona border county households with detectable residues of a given pesticide**

| Pesticide in Food | Cochise (%) | Santa Cruz (%) | Yuma (%) |
|---|---|---|---|
| Chlorpyrifos | 65.5 | 44 | 65.6 |
| Diazinon | 6.9 | 16 | 18.8 |
| Malathion | 51.7 | 40 | 59.4 |
| g-Chlordane | 3.4 | 4 | 9.4 |
| p,p- DDD | 3.4 | 16 | 18.8 |
| p,p- DDE | 41.4 | 48 | 50 |
| p,p- DDT | 0* | 16 | 0* |
| Dieldrin | 6.9 | 0* | 9.4 |
| Heptachlor | 75.9 | 52 | 90.6 |
| a-Chlordane | 0* | 4 | 0* |
| Carbaryl | 0* | 0* | 0* |
| Pendimethalin | 6.9 | 8 | 0* |
| Methomyl | 20.7 | 16 | 3.1 |
| Atrazine | 96.6 | 96 | 100 |
| Trifluralin | 3.4 | 0* | 3.1 |
| Propoxur | 17.2 | 16 | 12.5 |
| Acephate | 0* | 0* | 0* |
| Fluorene-D10 | 72.4 | 72 | 87.5 |
| y-hexachlorocyclohexane | 24.1 | 36 | 18.8 |
| Methyl Parathion | 0* | 4 | 3.1 |

Data: NHEXAS U.S. Border 2012 Program

***** No detectable residues were found for the specific pesticides in any household in the Arizona Border county.

## Data Tables: Blood Lead

**Table 1: Percentage of children ages 1-5 years with Blood Lead Level (BLL) > 5 µg/dL along the Arizona Border.**

| Year | % Children with BLL >5µg/dL | | | |
|---|---|---|---|---|
| | Cochise | Pima | Santa Cruz | Yuma |
| *2003 | 100 | 100 | 100 | 100 |
| *2004 | 70 | 100 | 83 | 100 |
| 2005 | 8 | 3 | 8 | 5 |
| 2006 | 8 | 3 | 5 | 3 |
| 2007 | 8 | 3 | 5 | 3 |
| 2008 | 5 | 2 | 5 | 2 |
| 2009 | 4 | 2 | 2 | 1 |
| 2010 | 2 | 1 | 2 | 1 |
| 2011 | 2 | 1 | 0 | 1 |
| 2012 | 3 | 1 | 0 | 0 |
| 2013 | 2 | 1 | 1 | 1 |
| 2014 | 2 | 1 | 1 | 0 |
| 2015** | 4 | 1 | 0 | 2 |

Data source: ADHS
Data based on 20% of screened at risk children ages 1-5 years
* Data provided by ADHS for years prior to 2008 does not include all non-elevated results
**data only from Jan-Jun 2015

**Table 2. Percentage of Children under 6 years of age with Blood Lead Levels (BLL) > 5µg/dL and under poverty, 2011-2015**

| County | % of Children tested 5-9 µg/dL | % Children < 6 years and below poverty | % of Housing units 1979 and older |
|---|---|---|---|
| Cochise | 3 | 28 | 57 |
| Pima | 1 | 22 | 54 |
| Santa Cruz | 0 | 32 | 52 |
| Yuma | 1 | 28 | 43.8 |

Data source: Center for Disease Control and Prevention (CDC), Arizona Data, Statistics and Surveillance, 2011-2015, and United States Census Bureau; Profile of Selected Housing Characteristics: 2000 Census 2000Summary File 3 (SF 3) Sample Data.

**Table 3. National Geometric Mean in the U.S., Mexico and along the Arizona-Sonora Border**

| Area (year) | Geometric Mean (µg/dL) |
|---|---|
| Arizona-Sonora Border (1997-1998) | 4.3 |
| Yuma, AZ (1997-1998) | 3.1 |
| Agua Prieta, Son (1997-1998) | 5.5 |
| San Luis Colorado, Son (1997-1998) | 5.1 |
| National Urban, Mexico (1978-2010) | 8.85 |
| National, Rural Mexico (1978-2010) | 22.24 |
| National, U.S (1976-1980) | 15 |
| National, U.S (1988-1991) | 3.6 |
| National, U.S (1990-2002) | 1.9 |
| National, U.S (2009-2010) | 1.2 |

Data source: Caravano et al., (2014); Cowan et al., (2006); ACE3 (U.S EPA, 2013); and WMMR, 2013.

**Table 4: Housing Characteristics in Arizona Border Counties**

| Subject | National (US) | | Arizona | | Cochise County | | Pima County | | Santa Cruz County | | Yuma County | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| **Total housing units** | 115,904,641 | 100 | 2,189,189 | 100 | 51,126 | 100 | 366,737 | 100 | 13,036 | 100 | 74,140 | 100 |
| **Year Structure Built** | | | | | | | | | | | | |
| 1970 to 1979 | 21,438,863 | 18.5 | 517,059 | 23.6 | 12,551 | 24.5 | 93,996 | 25.6 | 3,030 | 23.2 | 16,168 | 21.8 |
| 1960 to 1969 | 15,911,903 | 13.7 | 231,071 | 10.6 | 5,706 | 11.2 | 42,803 | 11.7 | 1,510 | 11.6 | 7,596 | 10.2 |
| 1940 to 1959 | 23,145,917 | 20 | 210,845 | 9.6 | 6,413 | 12.5 | 51,713 | 14.1 | 1,211 | 9.3 | 7,450 | 10 |
| 1939 or earlier | 17,380,053 | 15 | 48,794 | 2.2 | 4,539 | 8.9 | 11,094 | 3 | 1,039 | 8 | 1,353 | 1.8 |
| **Household median income 2009-2013** | $53,889 | | $49,774 | | $45,755 | | $45,841 | | $37,745 | | $41,595 | |
| **Persons living in poverty, percent 2009-2013** | 15.5 | | 17.9 | | 17.1 | | 19.2 | | 26.3 | | 20.2 | |

Data source: United States Census Bureau; Profile of Selected Housing Characteristics: 2000 Census 2000Summary File 3 (SF 3) Sample Data

## Data Tables: Childhood Cancer

**Table 1: Cancer incidence for children ages 0 to 19 in Arizona-Sonora Border Counties vs National Level, 2000-2013**

| | Age-adjusted rate per million children | | | | |
|---|---|---|---|---|---|
| **Year** | **Cochise County** | **Pima County** | **Santa Cruz County** | **Yuma County** | **Nationa l** |
| 2000 | 233 | 180 | 150 | 231 | 162 |
| 2001 | 146 | 164 | 211 | 154 | 167 |
| 2002 | 156 | 150 | 484 | 185 | 172 |
| 2003 | 228 | 156 | 148 | 112 | 157 |
| 2004 | 87 | 160 | 131 | 210 | 167 |
| 2005 | 188 | 165 | 128 | 115 | 175 |
| 2006 | 110 | 163 | 126 | 148 | 158 |
| 2007 | 173 | 212 | 124 | 31 | 172 |
| 2008 | 140 | 173 | 129 | 179 | 173 |
| 2009 | 116 | 167 | 184 | 111 | 175 |
| 2010 | 86 | 168 | 60 | 191 | NA |
| 2011 | 199 | 195 | 312 | 192 | NA |
| 2012 | 171 | 195 | 125 | 227 | NA |
| 2013 | 157 | 177 | 267 | 97 | NA |

Data source: Arizona Department of Health Services (ADHS) Cancer Registry & ACE3 (U.S EPA, 2013)

**Table 2: Cochise County cancer incidence for children ages 0 to 19 years, by cancer type, 2000-2013**

| | Age-adjusted rate per million children | | | | |
|---|---|---|---|---|---|
| | 2000-2002 | 2003-2005 | 2006-2008 | 2009-2011 | 2012-2013 |
| Liver and Intrahepatic Bile Duct | 0 | 0 | 0 | 9 | 16 |
| Lung and Bronchus | 0 | 0 | 0 | 0 | 14 |
| Bones and Joints | 0 | 0 | 0 | 28 | 0 |
| Cutaneous Melanoma | 0 | 18 | 9 | 0 | 0 |
| Ovary | 0 | 18 | 0 | 0 | 0 |
| Testis | 0 | 9 | 9 | 0 | 14 |
| Urinary Bladder | 9 | 0 | 0 | 0 | 0 |
| Kidney/Renal Pelvis | 0 | 0 | 0 | 9 | 0 |
| Brain and Other Nervous System | 41 | 46 | 29 | 28 | 0 |
| Thyroid | 9 | 0 | 9 | 0 | 16 |
| Hodgkins Lymphoma | 0 | 9 | 9 | 20 | 0 |
| Non-Hodgkins Lymphoma | 39 | 0 | 19 | 0 | 0 |
| Leukemia | 50 | 29 | 30 | 29 | 104 |
| Other | 19 | 38 | 28 | 11 | 0 |

Data source: Arizona Department of Health Services (ADHS) Cancer Registry

**Table 2: Pima County cancer incidence for children ages 0 to 19 years, by cancer type, 2000-2013**

| | Age-adjusted rate per million children | | | | |
|---|---|---|---|---|---|
| | 2000-2002 | 2003-2005 | 2006-2008 | 2009-2011 | 2012-2013 |
| Oral Cavity | 1 | 3 | 0 | 6 | 0 |
| Liver and Intrahepatic Bile Duct | 1 | 5 | 5 | 1 | 2 |
| Bones and Joints | 7 | 7 | 7 | 6 | 12 |
| Cutaneous Melanoma | 11 | 7 | 7 | 5 | 8 |
| Ovary | 3 | 1 | 2 | 7 | 6 |
| Testis | 5 | 5 | 7 | 10 | 6 |
| Kidney/Renal Pelvis | 8 | 4 | 12 | 4 | 4 |
| Brain and Other Nervous System | 25 | 48 | 30 | 33 | 28 |
| Thyroid | 3 | 7 | 11 | 9 | 16 |
| Hodgkins Lymphoma | 17 | 4 | 19 | 16 | 8 |
| Non-Hodgkins Lymphoma | 8 | 11 | 9 | 9 | 10 |
| Leukemia | 48 | 36 | 44 | 39 | 48 |
| Other | 24 | 19 | 26 | 30 | 38 |

Data source: Arizona Department of Health Services (ADHS) Cancer Registry

**Table 2: Santa Cruz County cancer incidence for children ages 0 to 19 years, by cancer type, 2000-2013**

| | Age-adjusted rate per million children | | | | |
|---|---|---|---|---|---|
| | 2000-2002 | 2003-2005 | 2006-2008 | 2009-2011 | 2012-2013 |
| Oral Cavity | 0 | 0 | 0 | 22 | 0 |
| Bones and Joints | 0 | 0 | 21 | 0 | 0 |
| Cutaneous Melanoma | 25 | 22 | 0 | 20 | 0 |
| Ovary | 0 | 0 | 0 | 0 | 34 |
| Testis | 0 | 22 | 0 | 0 | 0 |
| Kidney/Renal Pelvis | 24 | 0 | 21 | 0 | 0 |
| Brain and Other Nervous System | 48 | 26 | 0 | 42 | 32 |
| Thyroid | 25 | 44 | 0 | 40 | 32 |
| Hodgkins Lymphoma | 43 | 0 | 0 | 0 | 0 |
| Leukemia | 71 | 22 | 44 | 40 | 64 |
| Other | 45 | 0 | 42 | 22 | 34 |

Data source: Arizona Department of Health Services (ADHS) Cancer Registry

**Table 2: Yuma County cancer incidence for children ages 0 to 19 years, by cancer type, 2000-2013**

| | Age-adjusted rate per million children | | | | |
|---|---|---|---|---|---|
| | 2000-2002 | 2003-2005 | 2006-2008 | 2009-2011 | 2012-2013 |
| Oral Cavity | 7 | 0 | 5 | 0 | 0 |
| Colorectal | 13 | 6 | 0 | 0 | 0 |
| Liver and Intrahepatic Bile Duct | 0 | 6 | 0 | 5 | 0 |
| Bones and Joints | 20 | 12 | 6 | 5 | 26 |
| Cutaneous Melanoma | 0 | 6 | 0 | 0 | 0 |
| Testis | 7 | 0 | 11 | 15 | 8 |
| Kidney/Renal Pelvis | 0 | 0 | 5 | 11 | 24 |
| Brain and Other Nervous System | 38 | 30 | 16 | 21 | 16 |
| Thyroid | 0 | 0 | 6 | 21 | 0 |
| Hodgkins Lymphoma | 0 | 13 | 5 | 21 | 16 |
| Non-Hodgkins Lymphoma | 12 | 17 | 6 | 0 | 8 |
| Leukemia | 62 | 35 | 43 | 33 | 57 |
| Other | 31 | 22 | 17 | 32 | 8 |

Data source: Arizona Department of Health Services (ADHS) Cancer Registry

**Table 3: Cancer mortality for children ages 0 to 14 years in Arizona vs National levels, 2000-2013**

| Year | AZ Mortality Incidence (per million) | National Mortality Incidence (per million) |
|---|---|---|
| 2000 | 34 | 24 |
| 2001 | 30 | 24 |
| 2002 | 23 | 24 |
| 2003 | 33 | 25 |
| 2004 | 34 | 23 |
| 2005 | 26 | 23 |
| 2006 | 21 | 22 |
| 2007 | 39 | 23 |
| 2008 | 30 | 21 |
| 2009 | 31 | 21 |
| 2010 | 28 | 21 |
| 2011 | 26 | 20 |
| 2012 | 35 | 21 |
| 2013 | 29 | 21 |

Data source: Arizona Department of Health Services (ADHS) Cancer Registry, ACE3 (U.S EPA, 2013) & NCI SEER

**Table 4: Cancer mortality and incidence for children ages 0 to 17 years in Sonora vs National levels, 2008-2014**

| Year | Sonora Mortality | Sonora Incidence | Mexico Mortality | Mexico Incidence |
|---|---|---|---|---|
| 2008 | 36 | 70 | 48 | 91 |
| 2009 | 48 | 95 | 49 | 103 |
| 2010 | 57 | 79 | 51 | 101 |
| 2011 | 49 | 107 | 49 | 108 |
| 2012 | 55 | 68 | 47 | 112 |
| 2013 | 48 | 94 | 46 | 111 |
| 2014 | 61 | 127 | 51 | 112 |

Data source: Secretaría de Salud, Comportamiento Epidemiológico del Cáncer en menores de 18 años. México 2008-2014.

## Data Tables: Adverse Birth Outcomes

**Table 1: Percentage of infants delivered at term with low birth weight in Arizona Border Region, 2000-2014**

| Year | Arizona Border Region | Arizona | United States |
|---|---|---|---|
| 2000 | 6.85% | 7.20% | 7.60% |
| 2001 | 6.83% | 7.00% | 7.70% |
| 2002 | 6.35% | 6.80% | 7.80% |
| 2003 | 7.28% | 7.10% | 7.90% |
| 2004 | 7.58% | 7.20% | 8.10% |
| 2005 | 6.78% | 6.90% | 8.20% |
| 2006 | 7.43% | 7.10% | 8.30% |
| 2007 | 6.93% | 7.10% | 8.20% |
| 2008 | 7.45% | 7.10% | 8.20% |
| 2009 | 7.65% | 7.10% | 8.20% |
| 2010 | 7.43% | 7.10% | 8.10% |
| 2011 | 6.98% | 7.00% | 8.10% |
| 2012 | 7.00% | 6.90% | 8.00% |
| 2013 | 6.75% | 6.90% | 8.00% |
| 2014 | 6.85% | 7.00% | 8.00% |

Data Source: Arizona Department of Health Services (ADHS), *Population Health and Vital Statistics*

**Table 2: Percentage of infants delivered at term with low birth weight in Sonora Border Region, 2008-2014**

| Year | Sonora Border Region | Sonora | Mexico |
|---|---|---|---|
| 2008 | 5.75% | 6.18% | 8.14% |
| 2009 | 6.05% | 5.68% | 8.45% |
| 2010 | 5.90% | 4.83% | 8.52% |
| 2011 | 3.45% | 4.05% | 5.33% |
| 2012 | 4.08% | 4.50% | 5.43% |
| 2013 | 4.44% | 4.70% | 5.56% |
| 2014 | 4.21% | 4.65% | 5.72% |

Data Source: Mexican Health Ministry (MHM) Live Newborn Database (LND)

**Table 3: Percentage of births delivered preterm in the Arizona-Sonora Border Region, 2001-2014**

| Year | Arizona Border Region | Sonora Border Region | Sonora | Arizona | Mexico | United States |
|---|---|---|---|---|---|---|
| 2001 | 9.05% | NA | NA | 9.90% | NA | 11.90% |
| 2002 | 8.53% | NA | NA | 10.00% | NA | 12.10% |
| 2003 | 9.68% | NA | NA | 10.50% | NA | 12.30% |
| 2004 | 9.83% | NA | NA | 11.00% | NA | 12.50% |
| 2005 | 9.35% | NA | NA | 10.70% | NA | 12.70% |
| 2006 | 9.05% | NA | NA | 10.60% | NA | 12.80% |
| 2007 | 9.18% | NA | NA | 10.30% | NA | 12.70% |
| 2008 | 8.88% | 5.82% | 6.90% | 10.20% | 6.58% | 12.30% |
| 2009 | 8.75% | 6.52% | 7.11% | 10.10% | 6.58% | 12.20% |
| 2010 | 8.75% | 6.31% | 7.34% | 9.60% | 6.68% | 12.00% |
| 2011 | 8.60% | 6.03% | 7.67% | 9.30% | 6.62% | 11.70% |
| 2012 | 8.25% | 6.57% | 7.89% | 9.20% | 6.70% | 11.50% |
| 2013 | 8.23% | 6.65% | 7.68% | 9.00% | 6.70% | 11.40% |
| 2014 | 8.30% | 6.45% | 7.92% | 9.00% | 6.91% | 9.60% |

Data Source: Arizona Department of Health Services (ADHS), Arizona Health Status and Vital Statistics Report & Mexican Health Ministry (MHM) Live Newborn Database (LND)