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The association between 1,3-dichloropropene and asthma emergency department visits in California, USA from 2005 to 2011: a bidirectional-symmetric case crossover study

Hamed Gharibi, PhD^a, Marcela R. Entwistle, MD^a, Donald Schweizer, PhD^{a,b}, Pooya Tavallali, PhD^c, and Ricardo Cisneros, PhD, MPH^{a,d}

^aHealth Sciences Research Institute, University of California, Merced, California, USA; ^bUSDA Forest Service, Pacific Southwest Region, California, USA; ^cElectrical Engineering and Computer Science, University of California, Merced, USA; ^dPublic Health, University of California, Merced, California, USA

ABSTRACT

Objective: The ever-increasing rate of pesticide use in California farmlands is of great concern due to its potential toxicity on human health. In this study, the association between short term exposure to 1,3-dichloropropene (1,3-D) and asthma emergency department (ED) visits in central and southern California from 2005 to 2011 is investigated.

Methods: 3878 ED visits were identified from 2005 to 2011 (1064 days). Conditional logistic regression models were used to obtain the odds ratio (OR) associated with 0.01 ppb increase in 1,3-D. Potential effect modification by sex, race/ethnicity (Non-Hispanic White, Non-Hispanic Black, or Hispanic), and age (2–5, 6–18, 19–40, 41–64 or ≥ 65) are investigated.

Results: It was found that a 0.01 ppb increase in 1,3-D at the event day is associated with 13.5% [OR = 1.135, 95% CI: 1.123, 1.149] increase in the odds of having asthma ED visits in central and southern California during October to February of 2005 to 2011. Race had a positive association between 1,3-D and asthma ED visits among Non-Hispanic Black [OR = 1.095 95% CI: 1.035, 1.155] and Hispanic [OR = 1.121 95% CI: 1.064, 1.179]; while Non-Hispanic Whites had no association. Positive association for age was found between 1,3-D and asthma ED visits among patients 2 to 5 [OR = 1.065 95% CI: 1.020, 1.133], 6 to 18 [OR = 1.142 95% CI: 1.086, 1.196], and 19 to 40 [OR = 1.023 95% CI: 1.015, 1.073] years old.

Conclusion: These findings suggest a 0.01 ppb increase in 1,3-D concentration increases the odds of having asthma ED visits.

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1,3-dichloropropene; pesticide air toxicants; central and southern California; asthma ED visits

Introduction

California is a leader in American agricultural production because of the abundance and diversity of crops grown in the state [1]. However, the ever-increasing rate of pesticide use in its farmlands is of great concern due to its potential toxicity for human health [2]. 1,3-Dichloropropene (1,3-D) is widely used as a substitute for methyl bromide as a soil fumigant to control parasitic fungi and nematodes. Commercial formulations of 1,3-D include Telone II (The DOW Chemical Company). 1,3-D is among the most used pesticides in California and has been linked to harmful effects in humans [3–5]. It is included on California's Proposition 65 list of chemicals "known to the state to cause cancer" and was classified in 2007 by the U.S. Environmental Protection Agency as a likely carcinogen [2] (CDPR 2018).

1,3-D is a fumigant pesticide that has been used in the United States since 1954 and in California, primarily in the San Joaquin Valley and Central Coast regions, since 1970 [2,6]. Application includes injection into the soil to sterilize it before the crop is planted or during post-plant drip irrigation primarily as a nematicide for crops including sweet potatoes, almonds, strawberries, grapes, and carrots [2]. Runoff rates are low for 1,3-D, however, within 2 weeks, 25–56% will be volatilize [6]. After application, a significant proportion of this compound in soil or surface waters volatilizes into the atmosphere, becoming an ambient air toxicant [6–7].

Farm workers are the population at highest risk of illness and injuries due to occupationally exposure to pesticides [8–11]. However, people living close to agricultural areas are also exposed to pesticide emissions through atmospheric transport moving these pollutants

long distances from where they are applied [12–13]. Previous studies on children [4], non-farm worker women [14] and minority populations [13] living in agricultural areas have shown positive association between 1,3-D exposure and respiratory diseases. Research on animals has shown that the lungs are one of the primary target organs of 1,3-D where acute inhalation of this pesticide causes mucous membrane irritation and breathing difficulties [15–17].

To the best of our knowledge, this is the first epidemiological population-based study on the effect of 1,3-D on Emergency Department (ED) visits due to asthmatic exacerbations. It is hypothesized in this study that there is an association between short term exposure to 1,3-D and asthma ED visits. In order to test the hypothesize, the association between short term exposure to 1,3-D and asthma ED visits in California from 2005 to 2011 is investigated applying a bidirectional-symmetric case-crossover design. The potential effect modifications from sex (female or male), races/ethnicities (Non-Hispanic Whites, Non-Hispanic Blacks, and Hispanics), and age (i.e., 2–5, 6–18, 19–40, 41–64, and ≥ 65) were analyzed.

Material and methods

Data and participants

There is a potential for misclassification of asthma cases when only using the first diagnosis code, rather than the first 2–3. In previous studies, it has been shown that other conditions (e.g. infection) may exacerbate asthma and using the primary billing code would exclude such visits [18]. However, using the other diagnosing codes (i.e. second and third diagnosing codes for asthma) may sacrifice specificity in capturing asthma ED visits.

The asthma ED visit data were obtained from the California Office of Statewide Health Planning and Development (OSHPD). The dataset, submitted every 3 months by EDs to OSHPD, contains information on individual patient records including patient ZIP code, sex, and birthdate; and service date, diagnosis, cause of injury, treatment/procedure, and expected source of payment. The International Classification of Diseases, 9th Revision (ICD-9) code 493 for asthma related visits as a primary diagnosis was used to determine asthma ED visit cases. Multiple visits by a single person cannot be identified because the data is not linked by person longitudinally due to the lack of records of personally identifiable material such as social security number; therefore, each valid observation was taken as an independent observation.

Study design

A bidirectional-symmetric case cross-over study was applied to compare exposure of patients on the day of the ED visit to four referent days, two occurring before, and two after each visit. This design is an adaptation of the matched case-control study and limits the effects of potential confounding caused by individual characteristics, such as age, sex, and race [19]. Using this design, time trends were controlled for through the selection of control periods in both directions from the event day. The air samples were one day samples taken every two weeks. In this study, four control days were applied in the model. For example, if an individual visited the ED at November 30th, there are two control days before (i.e. November 2nd and 16th) and two control days after (i.e. December 14th and 28th) to control for seasonal trends [20].

Exposure assessment

Air quality data were collected from the Environmental Protection Agency Outdoor Air Exposure database for 14 sampling stations located in 10 counties throughout California (Table 1). In this work, 5 km radius around the sampling stations was applied for assigning the patients to their corresponding pesticide exposure. This encompassed 69 ZIP codes.

Every two weeks, daily-average values were collected for 1,3-D, NO_2 , and $\text{PM}_{2.5}$. Temperature and relative humidity were also collected and were controlled via restricted cubic spline (RCS) with 3 degrees of freedom (3 d.f.). Geographical assignment was performed using QGIS V. 2.14.20.

Statistical analysis

Conditional Logistic Regression was used to estimate the association between 1,3-D (daily average; continuous) and the outcome (case) in California, USA. The bidirectional symmetric case-crossover analysis using conditional logistic regression can be written as follows:

$$l_c(\beta) = \sum_{k=1}^n Y_k \times \left\{ \beta \cdot \left((1, 3_D(k)_{ED}), (PM_{2.5(k)_{ED}}), (NO_{2(k)_{ED}}), (Spline(T(k)_{ED})), (Spline(RH(k)_{ED})) - \log \left[\sum_{j=-2, j \neq 0}^2 \exp \left(\beta \cdot \left((1, 3_D(k)_{ED+(14 \times j)}), (PM_{2.5(k)_{ED+(14 \times j)}}, (NO_{2(k)_{ED+(14 \times j)}}), (Spline(T(k)_{ED+(14 \times j)})), (Spline(RH(k)_{ED+(14 \times j)})) \right) \right] \right\} \right.$$

Table 1. The information of the 1,3-D sampling stations and the race/ethnicity diversity in 5 km radius around the stations in California, USA between 2005 and 2011.

Site Name	Latitude	Longitude	Race/Ethnicity diversity in 5 km radius around the sampling stations		
			Non-Hispanic White	Non-Hispanic Black	Hispanic
Stockton-Hazelton Street	37.95167	−121.269	20240	11082	76006
Chico-Manzanita Avenue	39.7575	−121.842	62551	1565	13073
El Cajon-Redwood Avenue	32.79083	−116.943	100582	8737	39991
North Long Beach	33.82417	−118.189	49330	48234	146752
Azusa	34.1364	−117.924	28743	4385	91128
Burbank-W Palm Avenue	34.1758	−118.317	103732	5242	58291
Chula Vista	32.6314	−117.059	44288	10175	151601
Riverside-Rubidoux	34.00056	−117.415	29617	5116	63813
Simi Valley-Cochran Street	34.2761	−118.684	31185	639	11270
Los Angeles-North Main Street	34.0664	−118.227	42338	19411	291450
Roseville-N Sunrise Blvd	38.74611	−121.265	70923	1679	16102
Fresno-1st Street	36.7819	−119.773	51670	12593	108118
Calexico-Ethel Street	32.6761	−115.483	729	51	37909
Bakersfield-5558 California Avenue	35.35667	−119.063	52140	12236	55311

Table 2. Characteristics of asthma ED visits from 2005 to 2011 in Central and Southern California, USA ($n = 3878$).

Characteristics	N (%)
Sex	
Female	2094 (54.0)
Male	1784 (46.0)
Race/ethnicity	
Non-Hispanic White	1094 (28.2)
Non-Hispanic Black	884 (22.8)
Hispanic	1507 (38.8)
Age	
2–5	450 (11.6)
6–18	881 (22.7)
19–40	1214 (31.3)
41–64	930 (23.9)
≥65	259 (6.6)
Total Population	3878 (100%)

Where, Y_k is the daily count of asthma events on k -th day;

$\beta = \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$, and β_7 refers to the coefficient for each covariate. In addition, $1, 3_D(k-l)_{ED}, PM_{2.5}(k-l)_{ED}, NO_2(k-l)_{ED}, spline(T_{(k-l)_{ED}}), spline(RH_{(k-l)_{ED}})$ stand for the covariates for the case; and, $1, 3_D(k-l)_{ED+(14 \times j)}, PM_{2.5}(k-l)_{ED+(14 \times j)}, NO_2(k-l)_{ED+(14 \times j)}, spline(T_{(k-l)_{ED+(14 \times j)}}), spline(RH_{(k-l)_{ED+(14 \times j)}})$ are covariates for the four matched controls.

Also, the coefficient β corresponding to spline temperature and relative humidity is a vector of the spline variables where k -knots (i.e. 3 knots in our study) provide $k - 1$ variables (i.e. the linear variable itself and $k - 2$ cubic variables).

Results are based on a 0.01 ppb increase in the concentration of 1,3-D October to February of 2005–2011. This period was selected based on the time of application and high concentrations of this pesticide. October to February experienced the highest ambient concentrations of 1,3-D in Fresno during the years 2005 to 2011 (Figure B(0).1 in Appendix B). Application of 1,3-D primarily occurred during October through February of each year (Table A(0).1 in Appendix A).

Potential effect modifications were evaluated by stratifying for age (2–5, 6–18, 19–40, 41–64, or >65), race/ethnicity (Non-Hispanic White, Non-Hispanic Black, or Hispanic), and sex (female or male). Two pollutant models were developed: a single pollutant model without controlling for other possible co-present pollutants; and a multi-pollutant model to control for the concomitant presence of other aforementioned pollutants. All analyses were performed using STATA V. 14 (College Station, TX).

Results

Descriptive analysis of the hospital data

There was a total of 35876 visits to the ED in the study area from 2005 to 2011. However, only 3878 visits corresponded to days with ambient pesticide concentrations. Of these visits, a total of 46% were males and 54% were females. In addition, 28.2, 22.8, and 38.8% were found to be Non-Hispanic White, Non-Hispanic Black, and Hispanic, respectively. Furthermore, 11.6, 22.7, 31.3, 23.9, and 6.6% of the population were found to be between the age of 2 and 5, 6 and 18, 19 and 40, 41 and 64, and 65 years old or older, respectively (Table 2).

Unadjusted and adjusted pollutant model

As shown in Table 3 for the unadjusted model, a 0.01 ppb increase in the concentration of 1,3-D at the event day is associated with 14.8% [OR= 1.148 95% CI: 1.123, 1.173] increase in the odds of having an asthma ED visit. Adjusting for concomitantly present pollutants, a 0.01 ppb increase in the concentration of 1,3-D at the event day is associated with 13.5% [OR= 1.135 95% CI: 1.123, 1.149] increase in the odds of having an asthma ED visit in central and southern

Table 3. The association between the 1,3-D and asthma ED visits in Central and Southern California between 2005 and 2011.

Unadjusted and Adjusted Models	1,3-D (ppb) OR (95% CI)
Unadjusted event day	1.091 (1.009, 1.175)
Adjusted for temperature (RCS) and Relative humidity (RCS)	1.148 (1.123, 1.173)
Adjusted for PM _{2.5} , temperature (RCS) and Relative humidity (RCS)	1.153 (1.134, 1.172)
Adjusted for NO ₂ , temperature (RCS) and Relative humidity (RCS)	1.155 (1.129, 1.180)
Adjusted for PM _{2.5} , NO ₂ , temperature (RCS) and Relative humidity (RCS)	1.135 (1.123, 1.149)

Abbreviations: CI: confidence interval; OR: odds ratio; RCS: restricted cubic spline.

Table 4. The association between 1,3-D ambient air concentration and asthma ED visits in Central and Southern California between 2005 and 2011 by stratifying for sex, race, and age.

Strata	1,3-D (ppb) OR (95% CI)
^a Stratification for Sex	
Female	1.069 (1.035, 1.103)
Male	1.081 (1.042, 1.123)
^a Stratification for Race/ethnicity	
Non-Hispanic White	1.003 (0.921, 1.079)
Non-Hispanic Black	1.095 (1.035, 1.155)
Hispanic	1.121 (1.064, 1.179)
^a Stratification for Age	
2–5	1.065 (1.020, 1.113)
6–18	1.142 (1.086, 1.196)
19–40	1.044 (1.015, 1.073)
41–64	0.991 (0.977, 1.012)
≥65	1.081 (0.991, 1.162)

Abbreviations: CI: confidence interval; OR: odds ratio.

^aStratification analysis was conducted by adjusting for PM_{2.5}, NO₂, temperature (RCS) and relative humidity (RCS).

California during October to February of 2005 to 2011.

Stratification for sex, race/ethnicity, and age

As can be seen from Table 4, the association between 1,3-D and the odds of having an asthma ED visit were nearly similar among females and males; a 0.01 ppb increase in the concentration of 1,3-D at the event day is associated with a 6.9% [OR= 1.069 95% CI: 1.035, 1.103] and 8.1% [OR= 1.081 95% CI: 1.042, 1.123] increase in the odds of having an asthma ED visit among females and males respectively.

Positive association between 1,3-D concentrations and asthma ED visits among Non-Hispanic Whites was not found (Table 4). However, the association between both Blacks and Hispanics and 1,3-D concentrations were positive. A 0.01 ppb increase in the concentration of 1,3-D at the event day was found to be associated with a 9.5% [OR= 1.095 95% CI: 1.035, 1.155] and 12.1% [OR= 1.121 95% CI: 1.064, 1.179] increase in the odds of having an asthma ED visit among Blacks and Hispanics, respectively.

A positive association was found for patients 2 to 5, 6 to 18 and 19 to 40 years of age (Table 4). A

0.01 ppb increase in the concentration of 1,3-D at the event day was associated with a 6.5% [OR= 1.065 95% CI: 1.020, 1.133], 14.2% [OR= 1.142 95% CI: 1.086, 1.196], and 4.4% [OR= 1.023 95% CI: 1.015, 1.073] increase in the odds of having an asthma ED visit among patients 2 to 5, 6 to 18, and 19 to 40 years old, respectively.

Discussion

Our findings agree with the hypothesis that short term exposure to 1,3-D is associated with asthma ED visits in the study area, suggesting that a 0.01 ppb increase in the concentration of 1,3-D increases the odds of having an asthma ED visit and it varied depending on race, sex, and age. To the best of our knowledge, this is the first epidemiological population-based study showing the association between 1,3-D and asthma ED visits. Although studies have shown the effect of criteria air pollutants on human health in terms of asthma attacks [21–28], none have investigated the effect of ambient air concentrations of the pesticide 1,3-D and asthma. It has been previously suggested that 1,3-D, had the potential to trigger respiratory responses in people; and long exposure to this pesticide air toxicant might result in developing more serious health effects [29].

In this work, the results showed that 1,3-D had a nearly similar effect among females and males. The effect of toxic damage on respiratory tissues from 1,3-D is due to mucous membrane irritation and inflammation [30]; a common mechanism of tissue damage for both men and women. Studies on animals exposed to 1,3-D via inhalation show a toxic effect when the pesticide molecules are in direct contact with the mucous membrane of the respiratory system [15,16,31]. Although the results were on animals, they support the epidemiological evidence of our study and provide a possible causal mechanism that warrants further study.

A positive association was found between 1,3-D and asthma ED visits among Hispanics and Blacks, while an association was not found for Non-Hispanic

Whites. The findings suggest that Hispanics and Blacks who are exposed to the 1,3-D have high odds of having asthma ED visits. A study by Schwartz et al. [13] on pesticide exposure, childhood asthma and environmental justice among Mexican-American farmworkers in San Joaquin Valley reported that Hispanics and other minority groups living nearby agricultural areas resulted in more asthmatic events among these populations. In this study, it was found that Hispanics have a larger population in the areas with higher air concentrations of 1,3-D. Socioeconomic status (i.e. differences in exposures related to places of residence, types of employment, and social behaviors), social inequalities in racial minorities, differing vulnerability from preexisting medical conditions, health-related behaviors, and higher stress are possible explanations of the positive association among the minorities [32]. Our results suggest these factors, that increase minority exposure to 1,3-D, has a role in the differences between race and health outcomes as measured by asthma ED visits. Although, previous research suggests human biologic variation has an influence in asthmatics and supports the differences encountered between races [32–33]. Further research is needed to understand this complex topic.

Our results also showed that 1,3-D had a positive association with asthma ED visits among patients 2 to 5, 6 to 18, and 19 to 40 years old; with the highest OR among those 6 to 18 years of age. These findings agree with Schwartz et al. [13] who found the rate of asthma was high among Mexican-American children who live near agricultural lands in the San Joaquin Valley of California, USA. Research elucidated the factors contributing to higher rates of asthma in children and younger populations compared to other age groups. Immune system immaturity, structural and functional differences in the respiratory system have been associated with higher susceptibility to asthmatic events [34–35]. The inhalation-to body weight ratio of toxic compounds has shown to play an important role in the greater toxicity to children [36].

The health effects of residues from 1,3-D are not well understood. Consequently, an understanding of the toxicity of inhaled 1,3-D along with its mode of action and environmental fate after injection into the soil is required. More extensive monitoring of ambient air concentrations of 1,3-D, particularly nearest to the application, is needed to better evaluate the risk of exposure and would be beneficial to protect the health of residents. Considering 1,3-D as an air toxicant and preventing future exposure can help prevent

life-threatening health outcomes, including severe asthmatic exacerbations. For asthmatic patients, knowing what triggers their symptoms is fundamental. Identifying pesticides in air as a possible trigger of asthmatic exacerbations may help physicians to instruct asthmatic patients in taking preventive measurements before exposure (i.e. starting medication earlier, remaining indoors during the farming operations). Having an asthma management plan is the best way to control and prevent asthmatic episodes [37]. More transparency and outreach by applicators would allow health professionals and the public to better avoid exposure. Examining the health effects of pesticides as air contaminants can enhance policies and regulations for pesticide use through improved understanding of consequences from exposure.

Strengths and limitations

This study has two main strengths. The ability to limit the effects of invariant subject confounders (i.e. sex, smoking, occupational history, and genetics) due to their consistency over the case and control days is one of the strengths of this work. In addition, the possibility of confounding effects of concomitantly present pollutants in the ambient air during the study period was taken into account by including NO₂, and PM_{2.5} in the regression. The concentration of these two air pollutants during the October to February is quite high in California, USA.

One of the limitations of this study is the issue of exposure misclassification (i.e. poor correlation between the 1,3-D levels measured at fixed sites and personal exposure). The exposure to 1,3-D was assigned to the patient's zip-code of residence given that the center of the zip-code of residence is within 5 km of the sampling station. Hence, the zip-codes which were at the edge of the 5 km radius were not fully covered and it could result in having ED visits from the patients who are not exactly within the 5 km radius. The second limitation of the study is the potential for misclassification of asthma cases. In this work, the first diagnosis code for asthma was used, rather than the first 2 to 3. There is a possibility that other conditions, which would be present at the time of ED visit (e.g. infection), could exacerbate asthma; by using the first diagnosis code, these types of ED visits would be excluded [18]. It should be however noted that, the use of second or third diagnosis codes for asthma lowers specificity in capturing asthma ED visits.

Conclusion

In this study, the association between short term exposure to 1,3-D and asthma ED visits in California during 2005 to 2011 was investigated. It was found that increase in 1,3-D exposure increases the odds of having asthma ED visits in central and southern California, USA during the October to February of 2005 to 2011. Sex was not a significant modifier. There was a positive association between 1,3-D and asthma ED visits among Non-Hispanic Black and Hispanic, and not Non-Hispanic Whites. 1,3-D had positive association with asthma ED visits among patients 2 to 5, 6 to 18, and 19 to 40 years old.

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Compliance with ethical standards

Ethics approval and consent to participate

The study was approved by the State of California Committee for the Protection of Human Subjects. The data used in this analysis does not contain any personal identifiable information. Informed consent was not required because data were anonymous. Additional safeguards included physical and electronic barriers to data access and encryption.

Consent for publication

Not Applicable

Disclosure Statement

The authors declare that they have no conflict of interest.

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Appendix A

Table A.1. Sum of the applied 1,3-D (10^3 kg) per month and year in 10 California, USA counties^a.

1,3-Dichloropropene (10^3 kg)	2005	2006	2007	2008	2009	2010	2011	Total/month (10^3 kg)
January	112.0	155.3	190.4	189.0	127.3	83.3	105.6	962.8
February	107.6	126.7	172.4	115.2	41.5	154.5	176.4	894.4
March	85.3	45.5	122.7	184.5	91.8	149.5	208.7	887.9
April	109.8	34.6	51.9	121.2	49.5	83.6	239.6	690.1
May	31.7	60.1	107.6	52.8	16.8	27.2	42.5	338.7
June	147.5	122.2	103.6	48.7	31.5	45.2	22.7	521.4
July	115.4	78.9	116.5	93.0	56.7	47.8	76.1	584.3
August	146.4	184.7	160.2	188.2	116.0	200.2	201.5	1197.1
September	332.1	334.6	373.9	280.6	138.7	319.4	263.3	2042.6
October	303.3	221.4	185.9	212.9	135.1	161.2	400.1	1619.8
November	346.1	284.9	352.6	395.9	122.7	296.3	317.3	2115.6
December	214.4	176.5	193.9	180.1	144.1	144.0	181.0	1233.9
Total/year (10^3 kg)	2051.4	1825.3	2131.5	2061.9	1071.7	1712.1	2234.6	

Counties ^a: Butte; Fresno; Imperial; Kern; Los Angeles; Placer; Riverside; San Diego; San Joaquin; Ventura.

Source: California Environmental Health Tracking Program, California Department of Public Health. Agricultural Pesticide Mapping Tool. Data from California Department of Pesticide Regulation Pesticide Use Report Database, 1991–2015. 2017. Online at www.cehtp.org/pesticidetool.

Sensitivity analysis

Table A.2 indicates the ORs obtained from conducting the analysis by using bidirectional symmetric and semi-

symmetrical bidirectional models for adjusted pollutant and stratification by race.

Table A.2. The association between the 1,3-D and asthma ED visits in Central and Southern California between 2005 and 2011: a sensitivity analysis by comparing the results of bidirectional symmetric model and semi-symmetrical bidirectional.

Strata	Bidirectional Symmetric model OR (95% CI)	semi-symmetrical bidirectional model OR (95% CI)
^a Adjusted model for all	1.135 (1.123, 1.149)	1.089 (1.048, 1.142)
^a Stratification for Race		
Non-Hispanic White	1.003 (0.921, 1.079)	0.991 (0.905, 1.088)
Non-Hispanic Black	1.095 (1.035, 1.155)	1.075 (1.001, 1.154)
Hispanic	1.121 (1.064, 1.179)	1.101 (1.041, 1.158)

^aStratification analysis was conducted by adjusting for PM_{2.5}, NO₂, temperature (RCS) and relative humidity (RCS).

"The ORs obtained from comparing the results of bidirectional symmetric model with semi-symmetrical bidirectional model indicated that the effect of 1,3-D on the asthma ED visits is still significant. However, the ORs obtained from semi-symmetrical bidirectional model had larger confidence intervals, which could be due to the randomness of assigning either the 2 occurring before or 2 after each ED visit to the model. In other words, the model has less control days to compare their exposure with the relative event day."

Appendix B

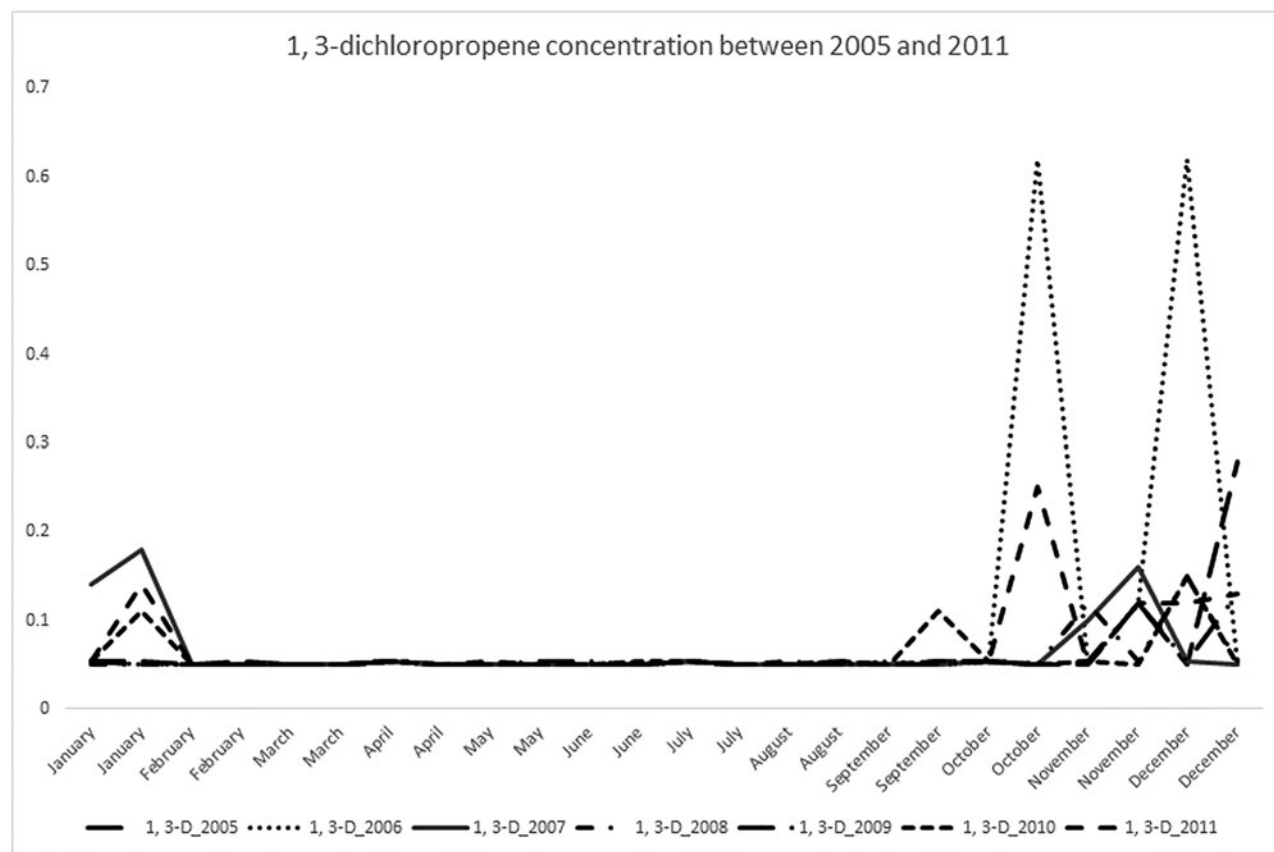


Figure B.1. Daily mean concentration of 1,3-Dichloropropene between 2005 and 2011 in San Joaquin Valley (Fresno-1st Street, Site: 3009).