PESTICIDE EXPOSURE TO DOGS AND THEIR OWNERS LIVING IN THE CITY OF BOULDER

By

DULCE F. GONZALEZ-BELTRAN

B.S., University of Colorado Boulder, 2022

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirement for the degree of

Master of Science

Department of Paul M. Rady Mechanical Engineering

2024

Committee Members:

Shelly Miller

Carmen Pacheco

Krystal Pollitt

Gonzalez-Beltran, Dulce F. (M.S., Mechanical Engineering)

Pesticide Exposure to Dogs and Their Owners Living in the City of Boulder

Thesis directed by Professor Shelly Miller

ABSTRACT

Pesticides are used widely in agriculture and urban settings to mitigate the impact of pests and unwanted weeds. The application of pesticides has the potential to drift landing on nontargeted areas such as other lawns, people, and pets. This exposure can be inhaled or absorbed through the skin. Using passive monitoring devices like the Fresh Air sampler wristband and tag, 39 City of Boulder residents and their dogs participated in a seven-day study where they were instructed to record their daily dog walks with the phone application STRAVA, record daily activities, and take a one-time survey about home characteristics and habits. It was hypothesized that dogs were exposed to hazardous pesticides and their human owners were exposed to the same pesticides at similar quantities. It was also hypothesized that the relationship between exposure concentration and home habits, daily dog walk locations, and time spent outdoors during the study were also explored with spearmen's rank correlation coefficients test and generalized linear models. Piperonyl butoxide exposure concentrations were found to be correlated in both human and dog. In addition to spending more time outdoors, piperonyl butoxide exposure concentration in dogs and humans was increased when they walked their daily dog walk in the southern region of the City of Boulder. In this study, six out of eight pesticides that could be calculated with conservative assumption for cancer risk factor resulted in a cancer risk factor above the EPA acceptable 10^{-6}. DDD was detected in one human-dog pair participants and DDT was detected in five human and five dog pairs above the limit of detection.

ACKNOWLEDGEMENTS

Thank you to the City of Boulder residents -- both human and dog. Thank you to Rella and the City of Boulder team for their support throughout the project process. Thank you to Yale University for collaborating on this project. Thank you to my advisor, Shelly Miller. Thank you to my family and friends.

CONTENTS

TABLES

FIGURES

Figure

CHAPTER 1

INTRODUCTION

1.1 Introduction

Pesticides are used widely in agriculture settings to mitigate the impact of pests and unwanted weeds. In more urban areas, pesticides are used in a variety of landscapes like lawns, greenhouses, and as general pest control around urban homes *(Cole, 2022)*. The most frequent time pesticides are used are during the Spring and Summertime when the lawns are growing, and the number of pests has increased. However, this is also the time when both humans and dogs are spending more time outdoors. The application of pesticides includes insecticides, fungicides, organochlorine, etc. which are applied unintentionally at higher concentrations in these urban areas *(Meftaul, Venkateswarlu, Dharmarajan, Annamalai, & Megharaj, 2020)*.

Exposure to pesticides can be immediate outdoor exposure which may include local pesticide applications from neighbors or nearby spaces in the form of pesticide drift *(Wise, et al., 2022)*. Pesticide drift can land on other lawns or drift indoors. It can even land on clothing, shoes, and skin that can lead to further exposure via take-home *(López-Gálvez, et al., 2019)*. Pesticides can accumulate on fur and paws -which are another form of take-home exposure after a pet has spent time outdoors on chemical sprayed lawns or near an area being sprayed with pesticide chemicals. Take-home exposure can also occur from foot traffic with shoes on from spending time outdoor and shedding from clothing or human bodies, causing resuspension of chemicals *(Goebes, Boehm, & Hildemann, 2010)*. Similar chemical exposure occurrences in dogs and humans living under the same household provided an insight into exposure-related diseases *(Wise, et al., 2022)*. Adverse health effects after pesticide exposure can range from acute symptoms like dizziness, irritation of the eyes, skin, or respiratory tract to long-term effects like cancer, asthma, and birth defects *(Meftaul, Venkateswarlu, Dharmarajan, Annamalai, & Megharaj, 2020).*

Pesticide exposures come from inhaling airborne chemicals, ingesting chemicals, or absorption through the skin. Documenting the concentration inhaled is typically accomplished by either using an active sampling method with a sampling pump and a filter collection device or using passive sampler. Because passive samplers are simpler and less bulky and noisy, the use of passive monitoring devices like the Fresh Air sampler wristband and tag have launched an effect way of quantifying inhalation exposures to toxic chemicals including pesticides *(Wise, et al., 2022) (Lin, Esenther, Mascelloni, Irfan, & Pollitt, 2020).*

1.2 Purpose of the study

The purpose of the study was to measure airborne pesticide exposure concentration that were experienced by thirty-nine City of Boulder residents and their dogs from daily activities such as taking their dogs for a walk. Measurements were conducted in the springtime when pesticide application typically occurred. Fresh Air passive wristband and dog tag samplers were used in the study. The obtained results estimated the chemical exposure concentrations and informed the influences that activities, location, and home characteristics could have on both human and dog. The hypothesis is that dogs are exposed to hazardous pesticides and their human owners are exposed to the same pesticides at similar quantities.

1.3 Arrangement of the Thesis

This thesis is arranged in three separate chapters. The first chapter is the introduction to the study with background information on the importance of pesticide chemical exposure. Chapter two provides the study design, materials used to collect chemical, survey, and activity log data, and methods used to analyze the data collected. The third chapter presents the overall results and discussion to connect the relationship between chemical exposure and the participants activities documented through survey responses and personal activity logs. The fourth chapter contains the overall conclusion and recommendations for future work.

CHAPTER 2

STUDY DESIGN, MATERIALS AND METHODS

2.1. Study Design

Recruitment

Thirty-nine City of Boulder residents and their dogs were recruited to participate in the study using the City of Boulder advertising connections and flyers at local City of Boulder dog parks and local businesses. Interested participants filled out a google survey providing information on their residence location and answering questions about their availability to participate for seven consecutive days from June 26th to July 10th of 2023. Participant selection was based on availability, geographic location in the City of Boulder, willingness to wear a Fresh Air wristband for seven consecutive days and record their daily dog walks using the phone application STRAVA. The study protocols were approved by the University of Colorado Boulder Institutional Review Board (Protocol 21-0284).

Participant Involvement

Participants were instructed to pick up their kits at the University of Colorado (CU) Boulder Sustainability, Energy and Environment Laboratory (SEEL). Kits were prepared at Yale University with Fresh Air samplers for the dog and owner in separate containers, labeled Dog, Human, and Control. A silicon tag for the dog and an adjustable silicon wristband for the human to hold the Fresh Air samplers were provided in the box. A paper activity log was included in the kit to keep track of daily activities. Lastly, two ice packs were also given for kit return. A set of instructions for both sampler preparation and activity log instructions were included in the kit, and sent by email, for participants to follow. Additional instructions of STRAVA download and use to record daily dog walks were distributed during kit pick up.

After the seventh day of the participants' chosen study participation dates, the kits were dropped off at the CU Boulder SEEL location with samplers, activity logs, and two cold ice packs to keep the entire kit cool. The jars from the kits were stored at 4 °C until all 39 kits were returned. All kits were packed with ice packs and mailed overnight to Yale or chemical analysis.

2.2. Materials and Methods

Fresh Air Samplers

The Fresh Air samplers were used to assess personal exposure of dogs and their owners to air borne contaminants. Contaminants are passively collected by the polydimethylsiloxane (PDMS) sorbent bars within the plastic case of the sampler, shown in Figure 1.

Figure 1. Fresh air sampler, wristband, and dog collar clip *(Pollitt, 2023)*

Participants were instructed to wear the Fresh Air sampler tag and wristband outside of their clothing consistently for seven consecutive days except during sleep and water activities like showering, swimming, washing dishes, etc.

Data Collection from Fresh Air Samplers via Chemical Analysis

The Yale School of Public Health chemically analyzed the samplers. The PDMS sorbent bars were spiked with an internal standard mixture followed by thermal extraction and analyzed using gas chromatography coupled with the high-resolution mass spectrometer *(Lin, Esenther, Mascelloni, Irfan, & Pollitt, 2020)*. All human-dog pairs were provided with an additional Fresh Air sampler as the control sampler to evaluate potential contamination during transport.

Data Analyses Method

Of interest to this study were two types of data: measurements that could be used to understand exposures for the sample population and measurements for individual dogs and humans to better understand individual risk. The limit of detection (LOD) for each pesticides detected was used to determine which pesticides had a median above the LODx0.5 for sample population statistical analyses ensuring that the inhalation exposure concentration was quantified for more than 50% of the sample population. Measurements that were either zero or below the LOD were replaced with LODx0.5, see Table S2 and S3 in the appendix.

An initial look at the histograms and Shapiro test was applied to each pesticide to explore if the data followed a normal distribution. If the p-value was greater than 0.05, then it could be assumed that the distribution for that pesticide followed a normal distribution with a null hypothesis of non-normally distributed.

A non-parametric spearmen's rank correlation coefficient test and two tailed Wilcoxon signed-rank test were applied to each of the pesticides in three different ways. The first was to apply the spearmen's rank correlation coefficient to the paired human-dog exposure levels followed by the Wilcoxon signed-rank test to explore whether the paired exposure levels followed the same distribution. The null hypothesis for the Wilcoxon signed-rank test was that the difference in medians is zero. If the p-value of the Wilcoxon signed-rank test was less than or equal to 0.05 the null hypothesis was rejected, and the two distributions were assumed to be different. The second use of the spearmen's rank correlation coefficient test was to explore the human exposure relationship with the survey response to four activities: wearing shoes inside the home (question six of the survey), turning on stove hood/ opening windows when cooking (question seven of the survey), frequency of cleaning/vacuuming floor and carpets (question 10 of the survey), and the number of hours spent at home during a workday(question 11 of the survey). The response values were changed to ranked number values to allow analysis through R-Studio. For questions six (Q6) and seven (Q7), the answer yes was changed to the numerical value one and the answer no was changed to the numerical value zero. For question 10 (Q10), the answer never was changed to the numerical value zero and the answer daily was changed to the numerical value of six. Answers in between never through daily for frequency of cleaning their floors was incremented by one. Similar for question 11 (Q11), the answer none was changed to the numerical value zero, more than 12 hours was changed to the numerical value of four, and all other answers in between were changed to a value incremented by one to show the increasing number of hours spent at home during the workday. The third use of the spearmen's rank correlation coefficient test was used for exposure levels in relation to the location of the daily dog walk for both human and dog and the fraction of time spent outdoors based on the human daily activity logs. The location of the participant daily dog walk was divided into seven regions of the City of Boulder: northwest, northeast, west, east, southwest, southeast, and south as labeled in Figure 2. These labels were also assigned numerical values between one through seven to allow analysis in R-Studio.

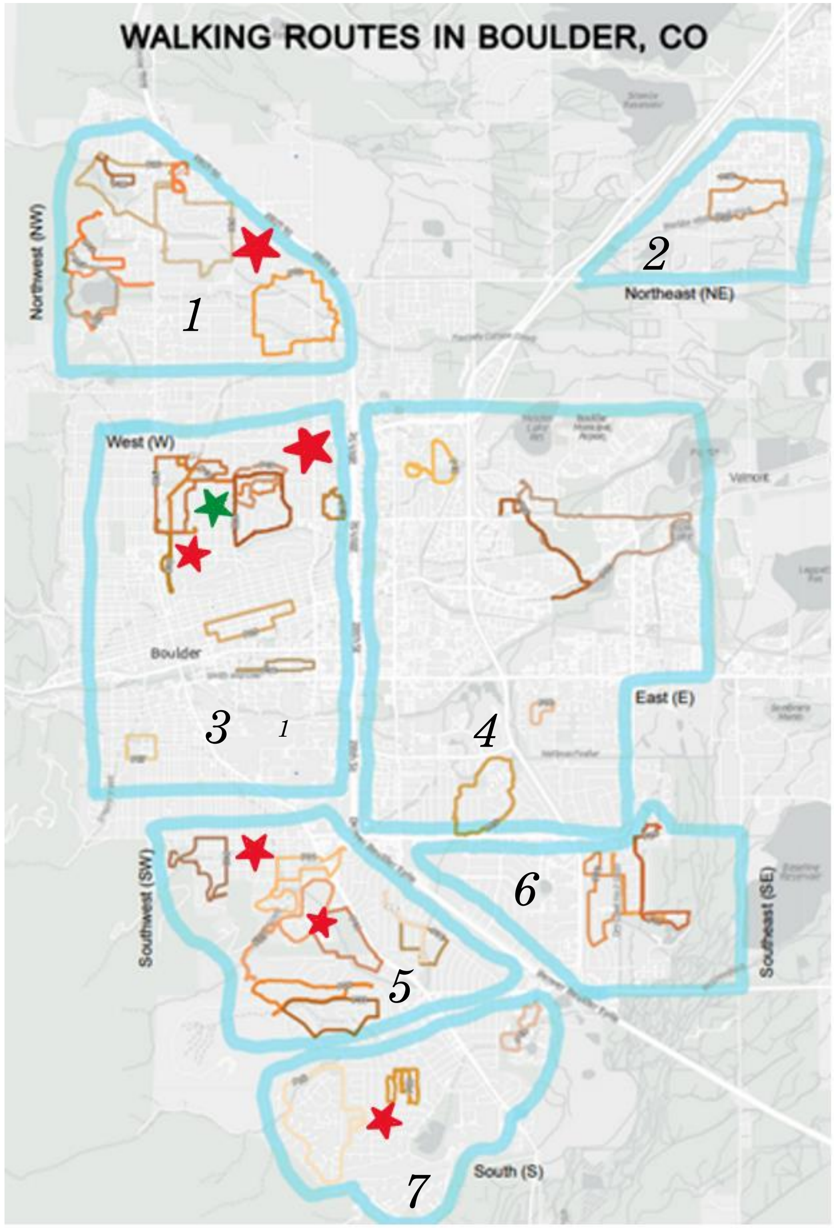


Figure 2. Map of City of Boulder participants' daily dog walks. Light blue lines denote the split regions where the daily dog walks occurred. The red stars are the general locations where participants exposed to DDT lived, and green stars are the general locations where participants exposed to DDD lived.

A high rho spearmen correlation indicates that observations have similar ranks, while a low correlation suggested dissimilarities. The significance of the observed correlation was denoted by the accompanying p-value. P-values less than 0.05 suggested the observed correlation is unlikely due to random chance.

Generalized linear models (GLMs) were used to explore the relationship between pesticide exposure concentrations and our study variables. A GLM is a generalized linear regression that consists of response variables, predictor variables, and the error. The response variables in this study are the pesticide exposure concentrations. Two different GLMs were explored, each with different sets of predictor variables. The first predictor variables were the home characteristics gleaned from the survey responses to the four survey questions of interest as shown in Equation 1. The second predictor variables were from the location that the daily dog walk location and fraction of time spent outdoors during the study based on human daily activity log.

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \epsilon, \qquad \text{Eq. 1}$$

The predictor variables x_1 through x_4 represent the survey responses to Q6, Q7, Q10 and Q11. β_0 is the intercept of the model, β_1 through β_4 are the coefficients of each predictor term, and ϵ is the residual error term.

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \epsilon \qquad \text{Eq. 2}$$

The variables x_1 and x_2 represent the daily dog walk location and fraction of time spent outdoors during the study based on the human daily activity log.

GLM in RStudio uses a link function to transform the measured exposure concentration to allow the best fitted model. The link function is determined by the type of data used for the predictor variable and the distribution predictor variable follows. All measured exposure concentration data is continuous but follow different distributions. For each pesticide, the type of distribution was determined by exploring histogram plots of the exposure concentration and exploring if the mean was larger than the median. For all GLMs a gamma link function was used to best fit the models.

Cancer Risk Analysis Method

A cancer risk analysis was performed for each pesticide. The following equation from the EPA's 1994 calculation of cancer risk from inhalation exposure was used to calculate the cancer risk *(Sivak, 2006)*:

$$\text{Cancer Risk} = \text{CSF x CDI} \qquad \text{Eq. 3}$$

CSF is the cancer slope factor in mg/kg-day)$^{-1}$ and CDI is the chronic daily intake. The CDI was calculated using Equation 4.

$$CDI = \frac{C_a \; x \; IR \; x \; EF \; x \; ED}{BW \; x \; AT} \qquad \text{Eq. 4}$$

C_a is the maximum or median concentration in air detected from the human sampler, IR is the inhalation rate, EF is the exposure frequency, ED is the exposure duration, BW is the body weight, and AT is the averaging time. The cancer risk levels were estimated with conservative assumptions of the study population and only includes inhalation risk. Personal body weight and health information were not collected from the participants in this study. IR was assumed to be 20 m^3/day, EF was assumed 90 days/year for the pesticide exposure peak months, ED was assumed to be 30 years, BW was assumed 60 kg, and AT is the duration of the study which was seven days *(Davis & Masten, 2013)*. A general acceptable cancer risk range is below 10^{-6} according to the EPA. Cancer risk levels below 10^{-6} means the risk is below one chance in a million and not a public health concern *(Cancer Risk and Noncancr Hazard Index: Fact Sheet for Contaminated Sites in California, 2020)*.

CHAPTER 3

RESULTS AND DISCUSSION

3.1. Results

The pesticides that were detected in each Fresh Air sampler, survey responses, daily dog walk locations, and time spent outdoors based on the activity logs were analyzed to understand the relationship between chemical exposure and daily behaviors.

Pesticides Detected

Out of 13 available calibration standards for pesticides, 12 pesticides were detected, and concentrations quantified in the Fresh Air samplers. Seven of the pesticides were organochlorine pesticides, one was a fungicide, one was an insecticide, one was nitrosamine, one was a general pesticide, and one was a pesticide synergist. Among the organochlorine pesticides was DDD and DDT. One pair of participants' samplers -- dog and human -- had DDD levels above the limit of detection by a factor of 86 for the human and 90 for the dog. Five dogs and five human participants' samplers had DDT levels above the limit of detection up to a factor of 551 for the humans and 30 for the dogs.

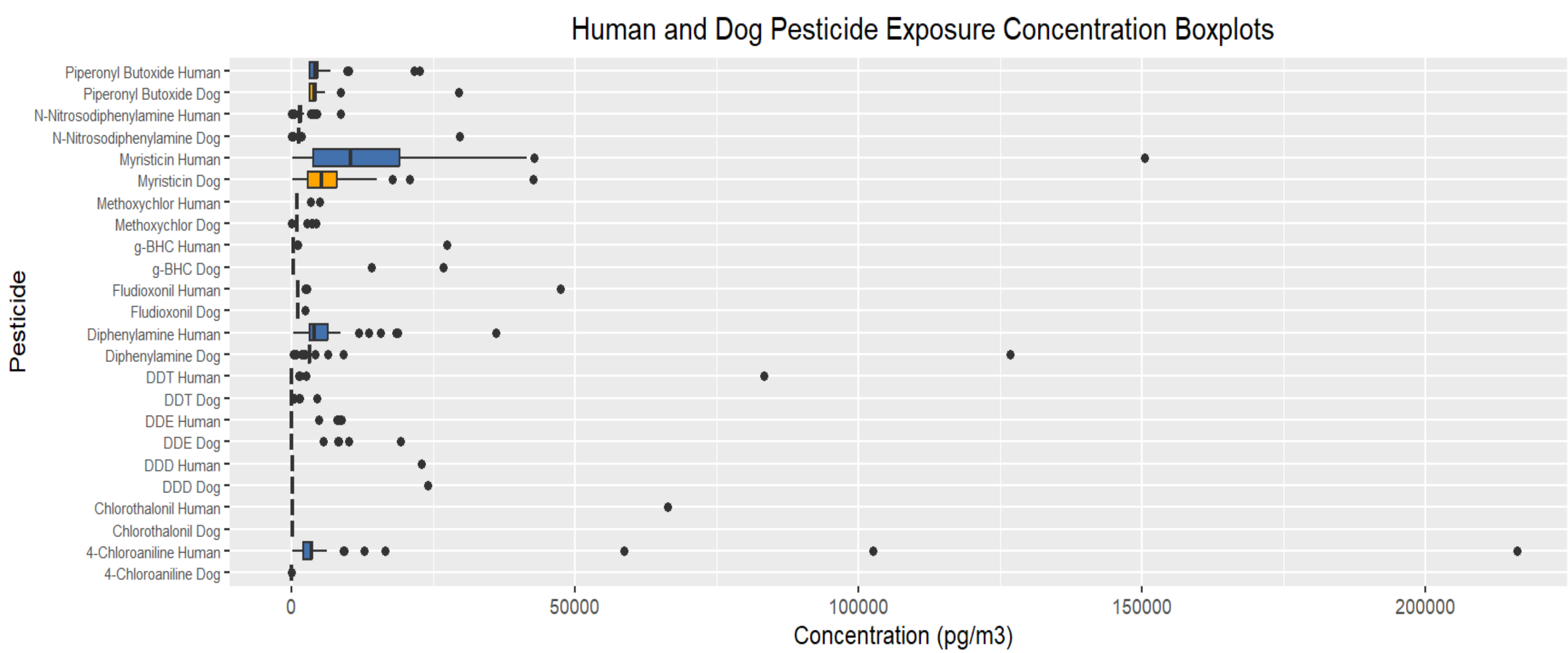


Figure 3. Exposure concentrations of the detected pesticides in Fresh Air sampler wristband and collar clip

The pesticides that had a median level above the LODx0.5 for the human samplers were myristicin, diphenylamine, piperonyl butoxide, and n-nitrosodiphenylamine, shown in Table 1. The pesticides that had a median level above the LODx0.5 for the dog samplers were myristicin and piperonyl butoxide, shown in Table 2.

Table 1. Statistical Description of Targeted Compounds in Human Fresh Air Samplers*

Class/Use	Compound Name	LOD (pg/m^3)	LODx0.5 (pg/m^3)	DF # above LOD	DF # above LODx0.5	Min (pg/m^3)	Med (pg/m^3)	Max (pg/m^3)
Insecticide	Myristicin	5877	29390	27	29	< LODx.5	10410	150500
Fungicide	Diphenylamine	6367	3184	10	29	< LODx.5	4003	36150
Pesticide synergist	Piperonyl Butoxide	6438	3219	5	23	< LODx.5	4133	22560
Nitrosamine	N-Nitrosodiphenylamine	2601	1301	5	22	< LODx.5	1433	8651

* Limit of detection = LOD; detection frequency = DF; minimum = Min; median = Med; maximum = Max

Table 2. Statistical Description of Targeted Compounds in Dog Fresh Air Samplers*

Class/Use	Compound Name	LOD (pg/m^3)	LODx0.5 (pg/m^3)	DF # above LOD	DF # above LODx0.5	Min (pg/m^3)	Med (pg/m^3)	Max (pg/m^3)
Insecticide	Myristicin	5877	2939	17	23	< LODx.5	5338	42720
Pesticide synergist	Piperonyl Butoxide	6438	3219	2	22	< LODx.5	4051	29530

* Limit of detection = LOD; detection frequency = DF; minimum = Min; median = Med; maximum = Max

Spearmen's rank correlation coefficient and two tailed Wilcoxon signed-rank tests were performed on myristicin and piperonyl butoxide to explore whether there was any association between human and dog exposures. Table 3 shows the results of the two tests.

Table 3. Spearmen's Rank Correlation Coefficient and Two Tailed Wilcoxon Signed-Rank Test for Human and Dog Pesticide Exposure Concentration

Compound Name	SRCC* Rho	SRCC* P-Value	Wilcoxon P-Value
Myristicin	0.5669	1.68E-04	0.0101
Piperonyl Butoxide	0.7168	2.848E-07	0.4498

* Spearmen's rank correlation coefficient = SRCC

Myristicin and piperonyl butoxide spearmen's rank correlation coefficient showed a rho result of 0.5569 and 0.7168 with a p-value of 1.68×10^{-4} and 2.85×10^{-7} suggesting there was an association between the human and dog exposures, shown in Table 3 and Figure 4. The Wilcoxon p-value for myristicin was 0.0101 and for piperonyl butoxide was 0.4498.

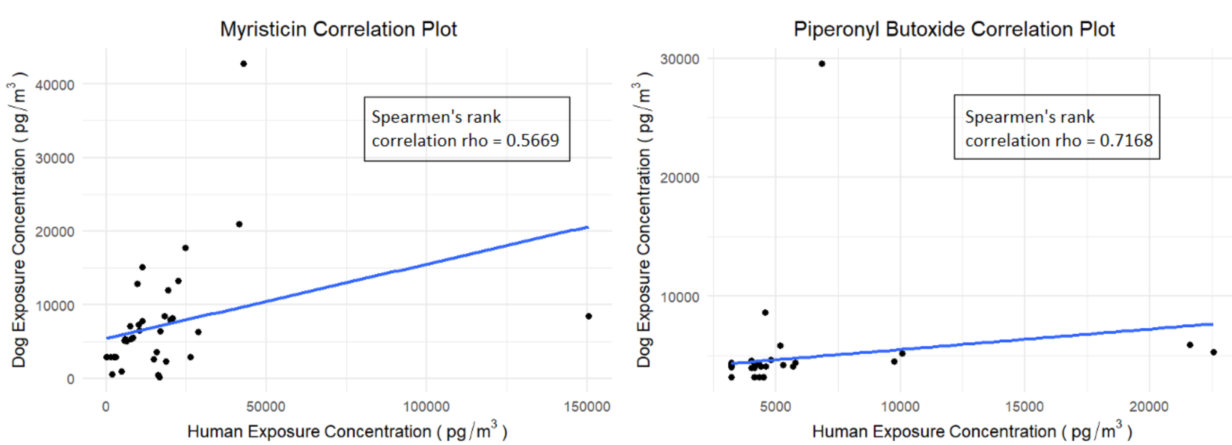


Figure 4. Myristicin and piperonyl butoxide human and dog participant correlation plots with spearmen's rank correlation coefficient rho for human and dog samples.

The outliers of myristicin human exposure concentration above 150000 pg/m^3 and myristicin dog exposure concentration above 40000 pg/m^3 were taken out to compare the spearmen rank correlation rho and Wilcoxon p-value values to the full data set for myristicin exposure. Without the outliers, the spearmen rank correlation rho is 0.51 with a p-value of 1.3×10^{-3} and Wilcoxon p-value is 1.1×10^{-2}. The outlier of piperonyl butoxide dog exposure concentration above 25000 pg/m^3 was taken out to compare the spearmen rank correlation rho and Wilcoxon p-value values to the full data set for piperonyl butoxide exposure. Without the outliers, the spearmen rank correlation rho is 0.7 with a p-value of 1.2×10^{-6} and Wilcoxon p-value is 0.421 Both spearmen rank correlation rho values are less than the rho values from the full data set. The Wilcoxon p-value for myristicin exposure increased by approximately 0.001 and for piperonyl butoxide exposure decreased by approximately 0.028.

The four pesticides from the human samplers and two pesticides from the dog samplers were used to be further analyzed with the survey responses, dog walk location, and time spent outdoors.

Survey Response

The survey responses were recorded and explored to better understand participant home characteristics and home habits. Questions varied from size of home to the amount of time spent at home and frequency of cleaning. Home characteristics responses were not used for data analysis.

Table 4. Survey Responses from All 39 Participants Regarding Home Habits

Survey Question	Response	
Q6: Does everyone usually take their shoes off when entering their home?	**Count**	**Percentage**
Yes	20	51.28%
No	19	48.72%
Q7: Do you open a window or turn on the hood over your stove when you cook?	**Count**	**Percentage**
Yes	23	58.97%
No	16	41.03%
Q10: On average how often do you vacuum and/or clean your floors?	**Count**	**Percentage**
Daily	0	0%
More than 3 time a week	5	12.82%
2-3 times a week	9	23.08%
Once a week	17	43.59%
Monthly	8	20.51%
Rarely	0	0%
Never	0	0%
Q11: How many hours of your workday do you typically spend at home?	**Count**	**Percentage**
Less than 4 hours	4	10.26%
4-8 hours	10	25.64%
8-12 hours	8	20.51%
More than 12 hours	12	30.77%
None	5	12.82%

Four questions from the survey were investigated to better understand if they had any impact on exposures to the four pesticides to which more than 50% of the sample population was exposed. The four survey questions analyzed are in Table 4.

The Spearmen's rank correlation coefficient test was performed to explore the relationship between each pesticide detected in human sampler and their responses to the four survey questions, shown in Table 5.

Table 5. Spearmen's Rank Correlation Coefficient Test for Human Pesticide Exposure Concentration and Survey Response

Compound Name	Q6 Rho	Q6 P-Value	Q7 Rho	Q7 P-Value	Q10 Rho	Q10 P-Value	Q11 Rho	Q11 P-Value
Myristicin	-0.1687	0.3046	0.06022	0.7157	0.1992	0.2241	0.1036	0.5301
Diphenylamine	0.02051	0.9014	-0.1227	0.4566	-0.2007	0.2204	-0.2697	0.09679
Piperonyl Butoxide	-0.01889	0.9091	-0.3023	0.06134	-0.01802	0.9133	0.1167	0.4794
N-Nitrosodiphenylamine	-0.1747	0.2875	0.1939	0.237	-0.04408	0.7899	-0.2735	0.09206

The relationship between each pesticide and the response to each survey question is denoted in Table 6. The coefficient estimate, standard error, confidence interval, and p-value are provided for each predictor that is the survey question.

Table 6. Generalized Linear Model Results for Human Pesticide Exposure Concentration and Survey Responses

Myristicin				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	4754.01	4904.40	533.47 – 50735.06	**<0.001**
Q10	1.25	0.27	0.79 – 2.04	0.306
Q11	1.20	0.19	0.80 – 1.73	0.245
Q6	0.79	0.33	0.32 – 1.92	0.577
Q7	1.15	0.50	0.43 – 2.94	0.749
R^2 Nagelkerke = 0.189				
Diphenylamine				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	20283.16	18001.93	2980.17 – 150723.56	**<0.001**
Q10	0.92	0.17	0.66 – 1.31	0.650
Q11	0.79	0.11	0.55 – 1.12	0.088
Q6	0.80	0.29	0.37 – 1.70	0.534
Q7	0.67	0.25	0.31 – 1.44	0.284
R^2 Nagelkerke = 0.094				
Piperonyl.Butoxide				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	8442.33	5866.52	1989.69 – 37877.23	**<0.001**
Q10	0.91	0.13	0.68 – 1.22	0.506
Q11	0.98	0.11	0.77 – 1.24	0.868
Q6	0.97	0.27	0.53 – 1.78	0.921
Q7	0.84	0.25	0.45 – 1.57	0.557
R^2 Nagelkerke = 0.038				

N.Nitrosodiphenylamine				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	1991.68	1308.62	515.04 – 8026.03	**<0.001**
Q10	1.08	0.15	0.82 – 1.43	0.595
Q11	0.92	0.09	0.73 – 1.15	0.417
Q6	0.80	0.21	0.47 – 1.35	0.401
Q7	0.96	0.27	0.54 – 1.70	0.892
R^2 Nagelkerke = 0.051				

Daily dog Walk Location and Time Spent Outdoors

Daily dog walk locations and fraction of the time spent outdoors during the study, based on the participants' activity logs, were analyzed with the four pesticides of interest for humans and the two pesticides for dogs. First, the spearmen's rank correlation coefficient test was used to explore the relationship between the pesticides and each the fraction of time spent outdoors and the location of the daily dog walk. These spearmen's rank correlation coefficient rho and p-values are in Table 7.

Table 7. Spearmen's Rank Correlation Coefficient Test for Human and Dog Pesticide Exposure Concentration with Time Spent Outdoors and Location of Daily Dog Walk *

Compound Name	Human FTO Rho	Human FTO P-Value	Human DDWL Rho	Human DDWL P-Value	Dog-Human FTO Rho	Dog-Human FTO P-Value	Dog DDWL Rho	Dog DDWL P-Value
Myristicin	0.3155	0.05041	-0.01877	0.9097	0.1471	0.3715	-0.04986	0.7631
Diphenylamine	0.1042	0.528	0.02506	0.8796	--	--	--	--
Piperonyl Butoxide	-0.06210	0.7072	-0.1900	0.2466	0.1335	0.4179	-0.1952	0.2337
N-Nitrosodiphenylamine	0.1849	0.2597	-0.03427	0.8359	--	--	--	--

* Daily dog walk location = DDWL, fraction of time outdoor = FTO

A GLM was performed for each pesticide for human exposure. The GLM for the human pesticide exposure included its relationship with time spent outdoors during the study and the daily dog walk location of the route chosen by the participant. The coefficient estimate, standard error, confidence interval, and p-value are provided for each predictor that are the daily dog walk location and fraction of time spent outdoor.

Table 8. Generalized Linear Model Results for Human Pesticide Exposure Concentration in Relationship with Daily Dog Walk Location and Fraction of Time Spent Outdoors

Myristicin				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	9906.33	6091.58	2188.16 – 50741.78	<0.001
Daily Dog Walk Location	0.94	0.11	0.70 – 1.28	0.639
Fraction of Time Outdoor	274.44	979.86	0.09 – 1274564.55	0.116
R^2 Nagelkerke = 0.133				
Diphenylamine				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	5220.12	2567.44	1951.46 – 15881.11	<0.001
Daily Dog Walk Location	1.02	0.10	0.82 – 1.26	0.846
Fraction of Time Outdoor	2.64	7.53	0.01 – 1108.52	0.734
R^2 Nagelkerke = 0.008				
Piperonyl.Butoxide				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	8083.15	2346.11	4585.34 – 14741.99	<0.001
Daily Dog Walk Location	0.88	0.05	0.79 – 0.98	0.023
Fraction of Time Outdoor	1.10	1.85	0.03 – 45.92	0.957
R^2 Nagelkerke = 0.206				
N.Nitrosodiphenylamine				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	1587.42	571.29	768.31 – 3480.44	<0.001
Daily Dog Walk Location	1.02	0.07	0.87 – 1.19	0.825
Fraction of Time Outdoor	2.06	4.31	0.05 – 132.56	0.729
R^2 Nagelkerke = 0.007				

Lastly, a GLM model was performed for each pesticide for dog exposure. The GLM for dog pesticide exposure included its relationship with the daily dog walk location in the City of Boulder and the fraction of time their human spent outdoors. The coefficient estimate, standard error, confidence interval, and p-value are provided for each predictor that are the daily dog walk location and fraction of time spent outdoor.

Table 9. Generalized Linear Model Results for Dog Pesticide Exposure Concentration in Relationship with Daily Dog Walk Location and Fraction of Time Spent Outdoors

Myristicin				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	4984.79	2302.80	2006.22 – 13482.99	<0.001
Daily Dog Walk Location	0.99	0.09	0.80 – 1.22	0.913
Fraction of Time Outdoor	23.81	63.86	0.16 – 4788.97	0.237
R^2 Nagelkerke = 0.070				
Piperonyl.Butoxide				
Predictors	Coefficient Estimates	Standard Error	Confidence Interval	P-Value
(Intercept)	3345.45	818.06	2087.49 – 5537.71	<0.001
Daily Dog Walk Location	0.95	0.05	0.87 – 1.05	0.321
Fraction of Time Outdoor	60.91	86.47	4.29 – 979.24	0.004
R^2 Nagelkerke = 0.338				

Cancer Risk

The cancer risk was calculated using the concentration cancer slope factor found in the EPA's CompTox Chemical Dashboard and the calculated chronic daily intake. The results of the cancer risks are in Table 10.

Table 10. Cancer Risk Factor Results for Detected Pesticide

Chemical Compound	Maximum level of concentration (mg/m^3)	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Chronic Daily Intake (mg/kg-day)	Cancer risk
Myristicin	150482	--	0.019347686	--
Diphenylamine	36148	2.80E-11	0.0046476	1.301E-13
4-Chloroaniline	216154	2.00E-01	0.027791229	0.005558
p,p'-DDT	83311	3.40E-01	0.010711414	0.003642
Fludioxonil	83311	--	0.010711414	--
Piperonyl Butoxide	22564	--	0.002901086	--
N-Nitrosodiphenylamine	8651	4.90E-03	0.001112271	5.450E-06
g-BHC	27448	1.30E+00	0.003529029	0.004588
Methoxychlor	4929	--	0.000633729	--
p,p'-DDD	23006	2.40E-01	0.002957914	0.0007099
Chlorothalonil	66391	1.70E-02	0.008535986	0.0001451
4'4'-DDE	8899	3.40E-01	0.001144157	0.0003890

Myristicin, fludioxonil, piperonyl butoxide, and methoxychlor did not have cancer slope factors in the EPA's CompTox Chemical Dashboard or other carcinogen risk and pesticide search engine.

Table 11. Cancer Risk Factor Results using Median Pesticide Exposure Above LODx0.5

Chemical Compound	Median level of concentration (mg/m^3)	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Chronic Daily Intake (mg/kg-day)	Cancer risk
Myristicin	10406	--	0.001338	--
Diphenylamine	4003	2.80E-11	0.0005147	1.441E-14
Piperonyl Butoxide	4133	--	0.0005314	--
N-Nitrosodiphenylamine	1433	4.90E-03	0.0001842	9.028E-07

The cancer risk was calculated again using the pesticide exposure concentrations that had a median above the LODx0.5. Using the median of these four pesticides and the conservative assumptions, the cancer risk results are shown in Table 11.

3.2. Discussion

Out of the 12 pesticides, myristicin, diphenylamine, piperonyl butoxide and n-nitrosodiphenylamine were present in more than half of the human participants at concentrations above LODx0.5. Myristicin and piperonyl butoxide were also in more than half of the dog participant population at concentrations above LODx0.5. Myristicin and piperonyl butoxide spearmen's rank correlation coefficient showed a rho result of 0.567 and 0.717 with a p-value of 1.68×10^{-4} and 2.84×10^{-7} suggesting there was an association between the human and dog exposures. The Wilcoxon p-value for myristicin was 0.0101 and for piperonyl butoxide was 0.45. This means there is a positive correlation between the dog and human exposure concentration of myristicin and piperonyl butoxide. However, the myristicin concentrations among the human and dog were not from similar distribution since the Wilcoxon p-value was less than 0.05. Piperonyl butoxide exposure to humans and dogs had similar distributions and had a positive correlation. Piperonyl butoxide and myristicin exposure between dog and human can differ due to chemical properties.

From the spearmen's rank correlation coefficient for human exposure concentrations and the survey responses to the four questions of interest, Q7 in relation to piperonyl butoxide also had a negative correlation of -0.302 with a p-value of 0.061. The negative correlation for the relationship of exposure concentration to Q7 means that those who open their windows or turn on their hood over the stove when cooking had less piperonyl butoxide exposure.

The location of where participants walked their dogs were spread throughout the City of Boulder, as seen in Figure 2. The daily dog walks were the one similar and frequent activity that each participant did for the seven days they were wearing their Fresh Air samplers. In the spearmen's rank correlation coefficient in Table 7, myristicin human exposure had a positive correlation with human's fraction of time spent outdoors with rho of 0.32 and a p-value of 0.05. The more hours spent outdoors by the human the higher the myristicin concentrations were.

In the GLM of the relationship of each pesticide with the daily dog walk location and the fraction of time spent outdoors, the fraction of time spent outdoors by the human had a large positive influence on the myristicin human exposure concentration, as shown by a coefficient of 274 and a p-value of 0.116 (Table 8). In the case of piperonyl butoxide human exposure, the location of the daily dog walk had a positive influence on the exposure concentration with a coefficient of 0.88 and p-value of 0.023. Piperonyl butoxide dog exposure also had a positive influence by the fraction of time the human spent outdoors with a coefficient of 60.9 with a p-value of 0.004. In other words, human piperonyl butoxide exposure concentrations increased when humans spent more time outdoors and did their daily dog walk in the southern region of the City of Boulder. Piperonyl butoxide dog exposure also increased when their human spent more time outdoors.

Among the pesticides that were detected in the Fresh Air samplers DDD and DDT, which are known as forever chemicals, were detected in participants at high levels. DDD was detected in one pair of human-dog at almost 90 times above the LOD for the pair. DDT was detected in five humans' and five dogs' Fresh Air samplers above the LOD. Participants who were exposed to DDD and DDT above LODx0.5 were located on the west side of 28th Street, which are loosely noted with stars in Figure 2. Although these two organochlorine pesticide compounds were only found in a few participants the cancer risk factors calculated, with conservative assumptions, were above the 10^{-6} acceptable risk level.

When windows or doors are open, it is possible for pesticides and other particles from the outdoors to drift into the home. Shoes that are also kept on when coming indoors can track in chemicals and particles to spread throughout the home *(Roberts & Dickey, 1995).* Mitigating the exposure to pesticides can start at home by using a door or track mat, taking off shoes when home, and keeping a clean home from dust and mud that might get tracked in after a long day out. Being aware of your surroundings when outdoors can help get a better idea of which areas to avoid. For example, when on a walk with your dog, noticing and avoiding the flagged grass areas can prevent pesticide exposure to you and your dog. On windy days, pesticide application should be avoided altogether. In the case of a daily walk or opening a window, being aware if any chemical application that is occurring outdoors can help in the decision to change paths upwind, away from the application sight, and keeping the windows closed. If pesticide application is necessary, alternative plant-based products can be useful in preventing harmful pesticide exposure at home *(Hossain, Rahman, & Khan, 2017).*

CHAPTER 4

CONCLUSION AND FUTURE WORK RECOMMENDATIONS

4.1. Conclusion

Human and domesticated dogs have shown a significant correlation between chemical exposure levels in past studies *(Wise, et al., 2022)*. In this study, human and dog piperonyl butoxide exposure concentrations were correlated. Even with a small population of 40 participants, the fraction of time spent outdoors by the human participant during the study showed an influence on piperonyl butoxide exposure concentrations in dog participants. The chemical properties of piperonyl butoxide may have a potential role in the exposure between human and dog.

Home habits like how often one spends their workday at home and ventilating the home during cooking via an open window or over the stove hood did influence the pesticide exposure concentration. There was a negative, or decreasing, influence on the piperonyl butoxide exposure concentration shown in human participants who ventilated their home by opening a window or turning on the hood over the stove when cooking. This relationship changes when combining home habits like taking off shoes on when indoors, increased cleaning/vacuuming floors/carpet at home, opening windows and turning on hood over the stove or opening windows when cooking, and spending more hours during the workday at home. The combination of home habits shows an increase in pesticide exposure concentrations.

On the other hand, the location of the daily dog walks and time spent outdoors according to the human daily activity logs during the study showed an increase in piperonyl butoxide exposure concentrations in human and dog. The more time the human spent outdoors, the greater the piperonyl butoxide exposure concentrations were in human and dog. The GLM also showed the further south the daily dog walks were the greater piperonyl butoxide human exposure concentration was.

With the conservative assumptions made to calculate the cancer risk, six out of the eight pesticides cancer risk factor resulted in levels above the acceptable 10^{-6} factor. These pesticides were DDD, DDT, DDE, 4-chloroaniline, g-BHC, and chlorothalonil.

Mitigation strategies to pesticide exposure could include keeping the home clean from dust and outdoor dirt that may be tracked in with shoes, increase awareness of surroundings in case of nearby spraying, and alternative chemical use for pesticide use. Using tools like a front door or track mat and designated shoe area before entering the house may lower the pesticide concentration in the home.

4.2. Recommendations for future work

In this study, the survey and walking instructions could be improved with more specific questions to best understand the home habits and characteristics. For example, the percentage of homes that are carpeted and frequency of cleaning the carpet and floors would be helpful to understand how dust and chemicals can be resuspended into the air. More detailed daily activities for both dog and human could be difficult to collect, however detailed description of when humans and dogs were both in and out of the home would give more information of how often both were exposed to outdoor or home indoor air. Chemical use during the study was not a question asked as well as occupation of participant until the end of the study. This could give more insight into the type of outdoor interaction the participant engages in during the study. An in-depth chemical understanding of each pesticide can explore the exposure relationship between dog, human, and influences of household characteristics. Lastly, a larger cohort would benefit the overall dataset that can be explored to view how each habit, location, and outdoor activity frequency can influence the pesticide exposure to humans and their dogs.

BIBLIOGRAPHY

(2020). Cancer Risk and Noncancr Hazard Index: Fact Sheet for Contaminated Sites in California. *Office of Environmental Health Hazard Assessment.*

Cole, J. (2022, October). INVESTIGATING ROUTES OF POLLINATOR EXPOSURE TO PESTICIDES. *Vermont: ProQuest. Retrieved from ProQuest.*

Davis, M., & Masten, S. (2013). Principles of Environmental Engineering and Science. *McGraw-Hill Education.*

EPA. (2023). Regional Removal Management Levels (RMLs) Frequent Questions. *Environmental Protection Agency.*

Goebes, M. D., Boehm, A. B., & Hildemann, L. M. (2010). Contributions of Foot Traffic and Outdoor Concentrations to Indoor Airborne Aspergillus. Aerosol Science and Technology*, 352-363. doi:https://doi.org/10.1080/02786826.2010.537712*

Hossain, L., Rahman, R., & Khan, M. S. (2017). Pesticide Residue in Foods. *Springer International Publishing.*

Kimbrough, R. A., & Litke, D. W. (1996, Feburary 26). Pesticides in Streams Draining Agricultural and Urban Areas in Colorado. Environmental Science & Technology*, 908-916. Retrieved from https://doi.org/10.1021/es950353b*

Lin, E. Z., Esenther, S., Mascelloni, M., Irfan, F., & Pollitt, K. J. (2020). The Fresh Air Wristband: A Wearable Air Pollutant Sampler. Environmental Science and Technology*, 308-314.*

López-Gálvez, N., Wagoner, R., Quirós-Alcalá, L., Van Horne, Y. O., Furlong, M., Avila, E., & Beamer, P. (2019). Systematic Literature Review of the Take-Home Route of Pesticide Exposure via Biomonitoring and Environmental Monitoring. MDPI, 16*(12), 2177. Retrieved from https://www.mdpi.com/1660-4601/16/12/2177#*

Meftaul, I. M., Venkateswarlu, K., Dharmarajan, R., Annamalai, P., & Megharaj, M. (2020). Pesticides in the urban environment: A potential threat that knocks at the door. The Science of the Total Environment, 711. *doi:10.1016/j.scitotenv.2019.134612*

Meftaul, I. M., Venkateswarlu, K., Dharmarajan, R., Annamalai, P., & Megharaj, M. (2020). Pesticides in the urban environment: A potential threat that knocks at the door. Science of The Total Environment*, 134612. Retrieved from https://doi.org/10.1016/j.scitotenv.2019.134612*

Nuckols, J., Blain, J., Beranger, R., & Fervers, B. (2019). Determinants of exposure to agricultural pesticide drift: Science-based evidence and its application in environmental health studies. Environmental Epidemiology*, 290-291. doi:10.1097/01.EE9.0000609140.98000.29*

Pollitt, K. (2023). Fresh Air Wristband Instructions - Boulder Dog Study. *Instruction Manual, New Haven.*

Reimer, A. P., & Prokopy, L. S. (2012). Environmental attitudes and drift reduction behavior among commercial pesticide applicators in a U.S. agricultural *landscape*. Journal of Environmental Management, 113*, 361-369. Retrieved from https://doi.org/10.1016/j.jenvman.2012.09.009*

Roberts, J. W., & Dickey, P. (1995). Exposure of children to pollutants in huose dust and indoor air. Reviews of Environmental and Toxicology: Continuation of Residue Reviews, 143*, 59-78.*

Sivak, M. (2006). Guidance for the Calculation of Cancer and Non-Cancer Risk from Inhalation Exposures: An Update. *EPA.*

Wise, C. F., Hammel, S. C., Herkert, N. J., Ospina, M., Calafat, A. M., Breen, M., & Stapleton, H. M. (2022). Comparative Assessment of Pesticide Exposures in Domestic Dogs and Their Owners Using Silicone Passive Samplers and Biomonitoring. Environmental Science and Technology*, 1149 - 1161.*

APPENDIX

In this appendix, an accumulation of images, graphs, and tables are included. These were tools used to collect participant responses and better understand the data for analysis.

A. PARTICIPATION ACTIVITY LOG TEMPLATE

STUDY ACTIVITY LOG
Fresh Air Study

Please think about how you spent your time on each of the days that you wore the Fresh Air sampler and complete the table below. For example, “biking on busy road, outdoors, 8:00am-8:45am.” Please be as specific as possible – this will allow us to better interpret your results.

Date	Location (*e.g.*, at home, commuting, etc.)	Indoors or outdoors?	Start time	Stop time

Figure S1. Snippet of the activity log that was given to the participants in paper copy form. Participants were allowed to make activity description and location general as long as indoor or outdoor type was specified clearly along with the most accurate start and stop time as possible.

B. PESTICIDE PROJECT SURVEY

Table S1. Qualtrics survey questions with response options. Response numerical values were assigned for easy R-Studio coding purposes.

Question #	**Question Text**	**Response Options**	**Response Value**
Q2	What is your gender?	Female	1
		Male	0
Q5	Do you know what cleaning/beauty products could help improve the indoor air quality of your home?	Yes	1
		No	0
		I do not know	2
Q6	Does everyone usually take their shoes off when entering your home?	Yes	1
		No	0
		I do not know	2
Q7	Do you open a window or turn on the hood over your stove when you cook?	Yes	1
		No	0
		I do not know	2
Q8	Does your hood vent to the outdoors?	Yes	1
		No	0
		I do not know	2
Q9	How often are you cooking at home?	Every day 3 times	2
		More than 3 times a week	1
		Rarely	0
Q10	On average how often do you vacuum and/or clean your floors?	Daily	6
		More than 3 times a week	5
		2-3 times a week	4
		Once a week	3
		Monthly	2
		Rarely	1
		Never	0
Q11	How many hours of your work day do you typically spend at home?	Less than 4 hours	4
		4-8 hours	3
		8-12 hours	2
		More than 12 hours	1
		None	0
Q12	Do you know how to improve the indoor air quality of your home?	Yes	1
		No	0
		I do not know	2
Q13	Are you familiar with the termi0logy used to describe and talk about indoor air quality?	Yes	1
		No	0
		I do not know	2
Q14	Do you know what daily activities impact the indoor air quality of your home?	Yes	1
		No	0

		I do not know	2
Q15	Do you feel like you have the capacity/knowledge to improve the indoor air quality of your home?	Yes	1
		No	0
		I do not know	2
Q16	Do you know about the potential health benefits of improving the indoor air quality of your home for you and your family?	Yes	1
		No	0
		I do not know	2
Q17	Do you know about the benefits of using a door mat at the entrance of your home?	Yes	1
		No	0
		I do not know	2
Q21	What is your dog's bedding material?	Not sure	0

C. TARGETED AND NON-TARGETED DATA

Table S2. Statistical Description of 12 Targeted Compounds Detected in Human Fresh Air Samplers *

Class/Use	Compound Name	LOD (pg/m^3)	LODx0.5 (pg/m^3)	DF # above LOD	DF # above LODx0.5	Min (pg/m^3)	Med (pg/m^3)	Max (pg/m^3)
Insecticide	Myristicin**	5877	2939	27	29		10410	150500
Fungicide	Diphenylamine**	6367	3184	10	29	0	4003	36150
Organochlorine Pesticide	4-Chloroaniline	6976	3488	7	11	0	1568	216200
Organochlorine Pesticide	p,p'-DDT	151	75.5	5	5	0	0	83310
Pesticide	Fludioxonil	2197	1099	5	5	0	0	47380
Pesticide synergist	Piperonyl Butoxide**	6438	3219	5	23	0	4133	22560
Nitrosoamine	N-Nitrosodiphenylamine**	2601	1301	5	22	0	1433	8651
Organochlorine Pesticide	g-BHC	563	281.5	3	3	0	0	27450
Organochlorine Pesticide	Methoxychlor	1863	931.5	2	2	0	0	4929
Organochlorine Pesticide	p,p'-DDD	267	133.5	1	1	0	0	23006
Organochlorine Pesticide	Chlorothalonil	498	249	1	1	0	0	66390
Organochlorine Pesticide	4'4'-DDE	TBD	TBD	TBD	TBD	0	0	8899

* Limit of detection = LOD, detection frequency = DF, minimum = Min, median = Med, maximum = Max
** Compound where median > LODx0.5

Note: Sample data were analyzed for compounds where the median was above the LODx0.5 by replacing the zeros with LODx0.5.

Table S3. Statistical Description of 12 Targeted Compounds Detected in Dog Fresh Air Samplers *

Class/Use	Compound Name	LOD (pg/m^3)	LODx0.5 (pg/m^3)	DF # above LOD	DF # above LODx0.5	Min (pg/m^3)	Med (pg/m^3)	Max (pg/m^3)
Insecticide	Myristicin**	5877	2939	17	23	0	5338	42720
Fungicide	Diphenylamine	6367	3184	3	18	0	3070	126800
Organochlorine Pesticide	4-Chloroaniline	6976	3488	4	8	0	1251	52850
Organochlorine Pesticide	p,p'-DDT	151	75.5	5	5	0	0	4552
Pesticide	Fludioxonil	2197	1099	1	1	0	0	2442
Pesticide synergist	Piperonyl Butoxide**	6438	3219	2	22	0	4051	29530
Nitrosoamine	N-Nitrosodiphenylamine	2601	1301	1	15	0	330	29630
Organochlorine Pesticide	g-BHC	563	281.5	2	2	0	0	26730
Organochlorine Pesticide	Methoxychlor	1863	931.5	5	5	0	0	4295
Organochlorine Pesticide	p,p'-DDD	267	133.5	1	1	0	0	24000
Organochlorine Pesticide	Chlorothalonil	498	249	0	0	0	0	0
Organochlorine Pesticide	4'4'-DDE	TBD	TBD	TBC	TBD	0	0	19300

* Limit of detection = LOD, detection frequency = DF, minimum = Min, median = Med, maximum = Max
** Compound where median > LODx0.5

Note: Sample data were analyzed for compounds where the median was above the LODx0.5 by replacing the zeros with LODx0.5.

Table S4. List of Non-Targeted Chemical Compound Detected in Fresh Air Samplers.

Compound Name	*EPA: Pesticide Inerts Fragrance Ingredient List*	*Pesticides: InertFinder*	*Pesticides and residues detected by non-targeted analysis*	*EPA: List of Active Pesticide Ingredients*	*Pesticide Properties DataBase*	*Pesticides and Transformation Products from SLU, Sweden*	*Swiss Pesticides and Transformation Products*	*Swiss Pesticides and Metabolites from Keifer et al 2019*
Oleic acid	*Y*	*Y*	-	-	-	-	-	*Y*
1-Dodecanol	*Y*	*Y*	-	-	*Y*	-	-	*Y*
Decanoic acid	*Y*	*Y*	-	-	-	-	-	*Y*
Octinoxate	*Y*	*Y*	-	-	-	-	-	-
gamma-Nonanolactone	*Y*	*Y*	-	-	-	-	-	-
Phthalimide	-	*Y*	-	-	-	*Y*	*Y*	*Y*
Dehydroacetic acid	-	*Y*	-	-	*Y*	-	-	-
Caffeine	-	*Y*	-	-	-	-	-	-
2-Naphthalenol	-	*Y*	-	-	-	-	-	-
Diphenylamine	-	-	*Y*	*Y*	*Y*	-	-	-
2-Isopropyl-6-methyl-4-pyrimidone	-	-	-	-	-	-	*Y*	*Y*
Diphenylsulfone	-	-	-	-	-	-	-	-
4-(1,1-Dimethylethyl)phenol	-	-	-	-	-	-	-	-
Methyl stearate	*Y*	*Y*	-	-	-	-	-	-
(3Z)-Hexenyl salicylate	*Y*	*Y*	-	-	-	-	-	-
Heptanoic acid	*Y*	*Y*	-	-	-	-	-	-
4-Methoxybenzaldehyde	*Y*	*Y*	-	-	-	-	-	-
4-tert-Butylcyclohexanol	*Y*	*Y*	-	-	-	-	-	-
Isobutyl salicylate	*Y*	*Y*	-	-	-	-	-	-

2,6-Dimethyloctan-2-ol	*Y*	*Y*	-	-	-	-	-	-
Hexyl salicylate	*Y*	*Y*	-	-	-	-	-	-
Formic acid, 2-phenylethyl ester	*Y*	*Y*	-	-	-	-	-	-
Hexadecane	*Y*	*Y*	-	-	-	-	-	-
Isoamyl salicylate	*Y*	*Y*	-	-	-	-	-	-
Isoeugenol	*Y*	*Y*	-	-	-	-	-	-
2-Methylpyrazine	*Y*	*Y*	-	-	-	-	-	-
Isobutyl benzoate	*Y*	*Y*	-	-	-	-	-	-
Ethyl nonanoate	*Y*	*Y*	-	-	-	-	-	-
1-Methoxy-4-methylbenzene	*Y*	*Y*	-	-	-	-	-	-
Veratraldehyde	*Y*	*Y*	-	-	-	-	-	-
Dimethyl adipate	-	*Y*	-	-	-	-	-	-
Dimethyl glutarate	-	*Y*	-	-	-	-	-	-
Methyl decanoate	-	*Y*	-	-	-	-	-	-
(+)-trans-Permethrin	-	-	-	-	*Y*	-	-	-

VH - Very High | H - High | M - Medium | L - Low | I - Inconclusive | No Data | **Authoritative** | Screening | *QSAR Model*

Name	Human Health Effects: Acute Mammalian Toxicity: Oral	Inhalation	Dermal	Carcinogenicity	Genotoxicity Mutagenicity	Endocrine Disruption	Reproductive	Developmental	Neurotoxicity: Repeat Exposure	Neurotoxicity: Single Exposure	Systemic Toxicity: Repeat Exposure	Systemic Toxicity: Single Exposure	Skin Sensitization	Skin Irritation	Eye Irritation	Ecotoxicity: Acute Aquatic Toxicity	Ecotoxicity: Chronic Aquatic Toxicity	Fate: Persistence	Fate: Bioaccumulation	Exposure
(3Z)-Hexenyl salicylate	L		L		L		M							H		H	H	M	L	H
Heptanoic acid	L	I	M	I	L		L	L	I		L		I	VH	VH	M	L	L	L	H
Octinoxate	L	I	I		H	H	L									L	VH	M	L	VH
4-Methoxybenzaldehyde	M	I	L	I	VH		M	M	I	I	M	I	L	L	L	M	L	M	L	H
1-Dodecanol	L	L	M	I	L	H	L	L	I		I	H	L	L	M	H	VH	M	L	H
4-tert-Butylcyclohexanol	L	I	L		L	H		H			M			H		H		M	L	H
Isobutyl salicylate	M		I		VH											L		M	L	M
2,6-Dimethyloctan-2-ol					L									H	H	L	M	M	L	H
Hexyl salicylate	L	I	L	I	L	H	M	H	I	I	I	I	M	H	I	H	VH	M	L	H
gamma-Nonanolactone	L		L		VH	L		H			M			H	H	H		L	L	H
Formic acid, 2-phenylethyl ester	L		L		VH											L		M	L	M
Hexadecane	L	H	L		L	L	L	L						H		L		L	L	L
Methyl stearate	L	I			L		L									L	L	M	L	H
Isoamyl salicylate	L				VH	H		H			H			H		L	H	M	L	M
Diphenylsulfone	H		L	I	L		M				H		H					M	L	H
4-(1,1-Dimethylethyl)phenol	M	L	M	I	L	H	M	M	I		I	M	H	H	VH	H	M	M	M	M
2-Methylpyrazine	M	I	I	I	L	L	I	L	I	I	I	I	I	I	I	L	I	M	L	M
Isobutyl benzoate	L				L											L		M	L	H
Phthalimide	L		L		L	L		L						H	H	M		M	L	M
2-Naphthalenol	M	M	L	I	L	H	I	I	H	H	H	H	H	L	H	VH	VH	M	L	H
Dehydroacetic acid	M	I	I	I	VH	L	I	H	I	I	I	I	I	I	I	L	I	M	M	H
Ethyl nonanoate	L				L	L		L								H		M	L	H
2-Isopropyl-6-methyl-4-pyrimidone	L				VH											L		M	L	H
Oleic acid	L		L		L	H		H			L			H	H	L		M	L	H
1-Methoxy-4-methylbenzene	M	I	L		VH	H	M	L			M					L		M	L	H
Veratraldehyde	M	I	L	I	L	L	L	H	I	I	I	I	I	H	I	L	I	M	L	H
Diphenylamine	H	H	H	H	VH		H	L		H	H	M	I	L	VH	VH	VH	M	M	H
Dimethyl adipate	M	I	L		L	L		H								M		M	L	H
Dimethyl glutarate	L	I	L		VH										H	L	L	M	L	VH
(+)-trans-Permethrin	M				L	L		H								VH			M	M
Methyl decanoate	L	I	I	I	H	L	L	H	I	I	I	I	I	H	I	H		M	L	H

Table S5. Hazardous Profiles of Non-Targeted Pesticides

D. HISTOGRAMS AND SCATTER PLOTS

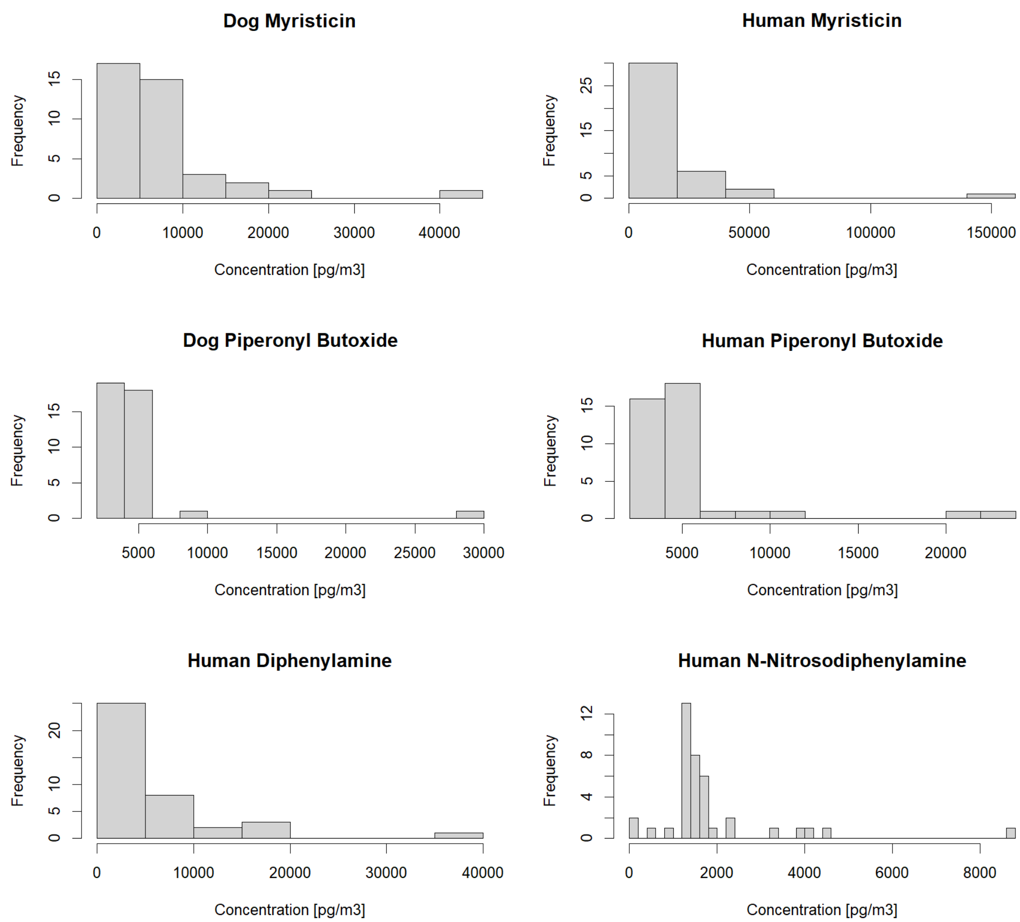


Figure S2. Targeted Pesticide Compound Histograms for Human and Dog

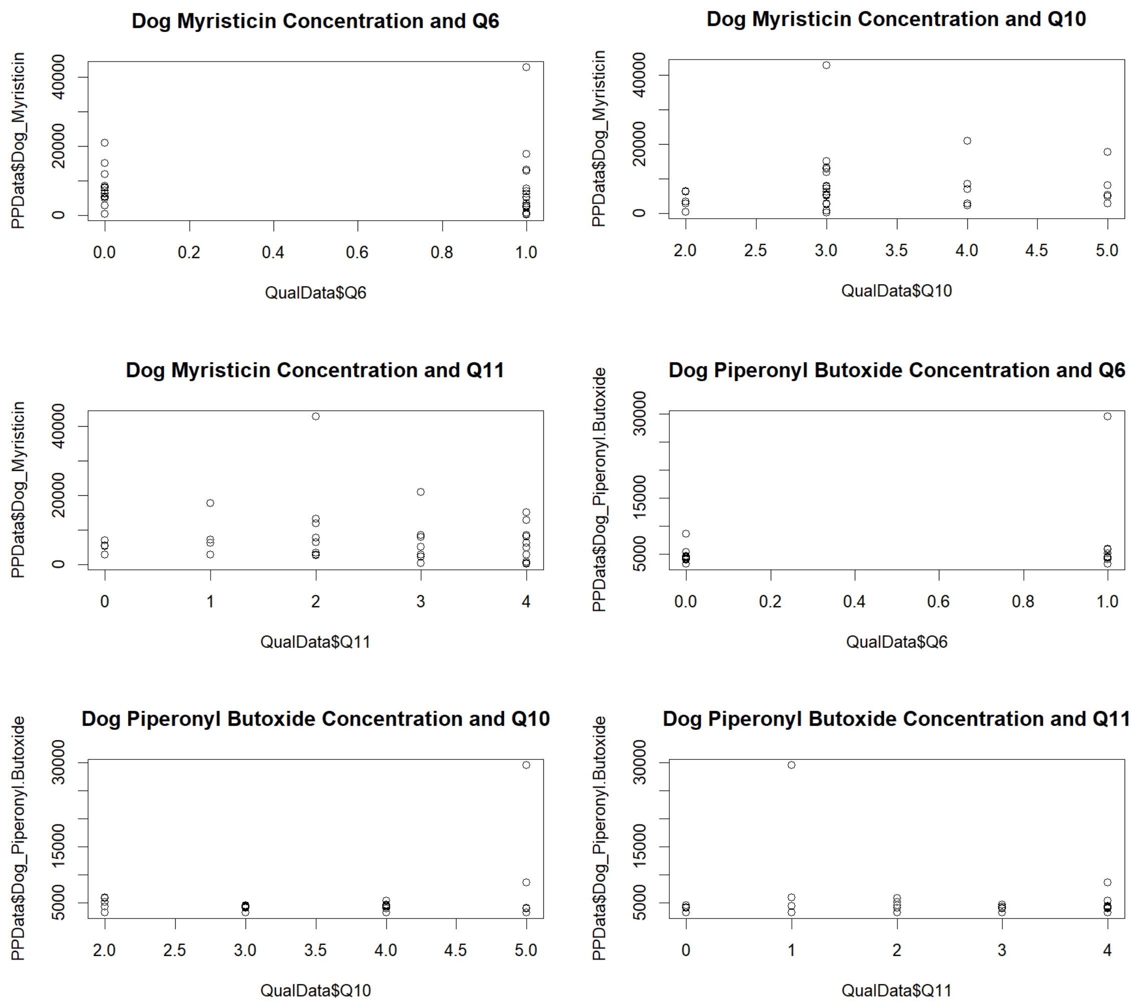
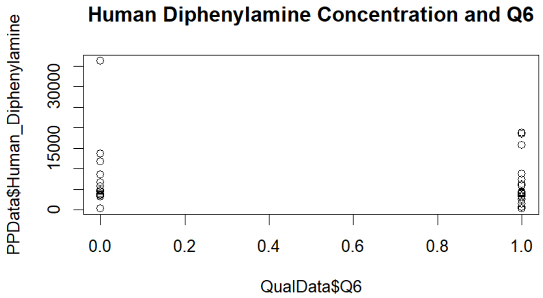
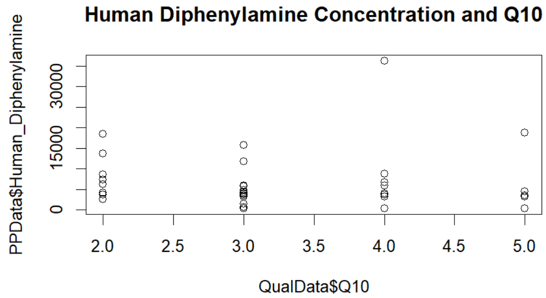
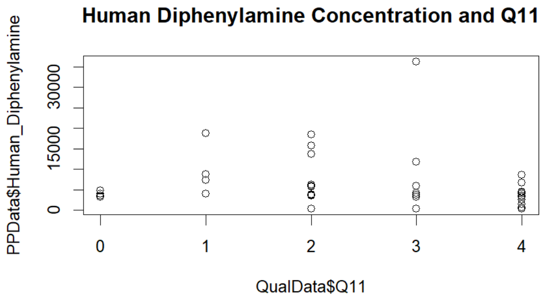
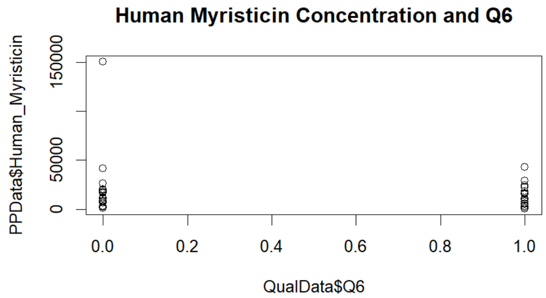


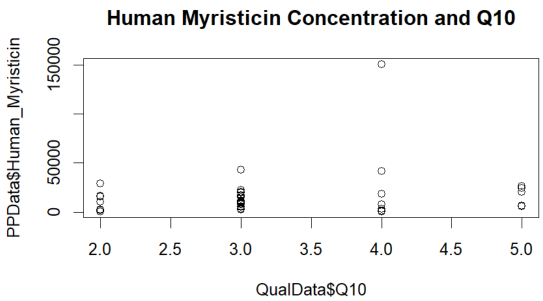
Figure S3. Dog Pesticide Exposure and Survey Response Scatter Plot Relationship

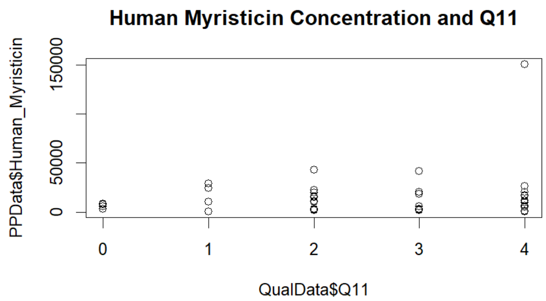

Human Diphenylamine Concentration and Q6
PPData$Human_Diphenylamine
0
15000
30000
0.0
0.2
0.4
0.6
0.8
1.0
QualData$Q6

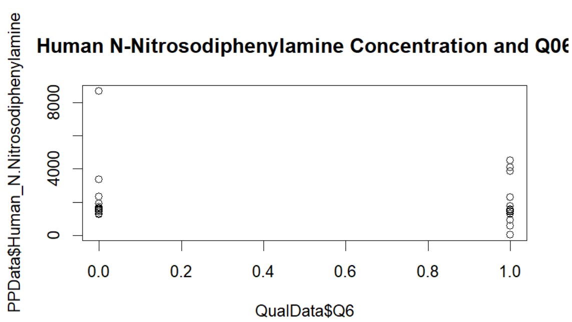

Human Diphenylamine Concentration and Q10
PPData$Human_Diphenylamine
0
15000
30000
2.0
2.5
3.0
3.5
4.0
4.5
5.0
QualData$Q10

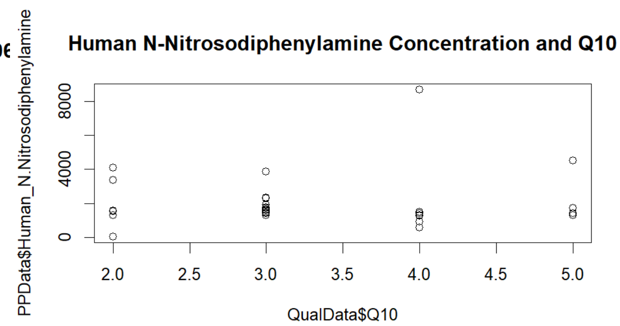

Human Diphenylamine Concentration and Q11
PPData$Human_Diphenylamine
0
15000
30000
0
1
2
3
4
QualData$Q11


Human Myristicin Concentration and Q6
PPData$Human_Myristicin
0
50000
150000
0.0
0.2
0.4
0.6
0.8
1.0
QualData$Q6


Human Myristicin Concentration and Q10
PPData$Human_Myristicin
0
50000
150000
2.0
2.5
3.0
3.5
4.0
4.5
5.0
QualData$Q10


Human Myristicin Concentration and Q11
PPData$Human_Myristicin
0
50000
150000
0
1
2
3
4
QualData$Q11


Human N-Nitrosodiphenylamine Concentration and Q06
PPData$Human_N.Nitrosodiphenylamine
0
4000
8000
0.0
0.2
0.4
0.6
0.8
1.0
QualData$Q6


Human N-Nitrosodiphenylamine Concentration and Q10
PPData$Human_N.Nitrosodiphenylamine
0
4000
8000
2.0
2.5
3.0
3.5
4.0
4.5
5.0
QualData$Q10

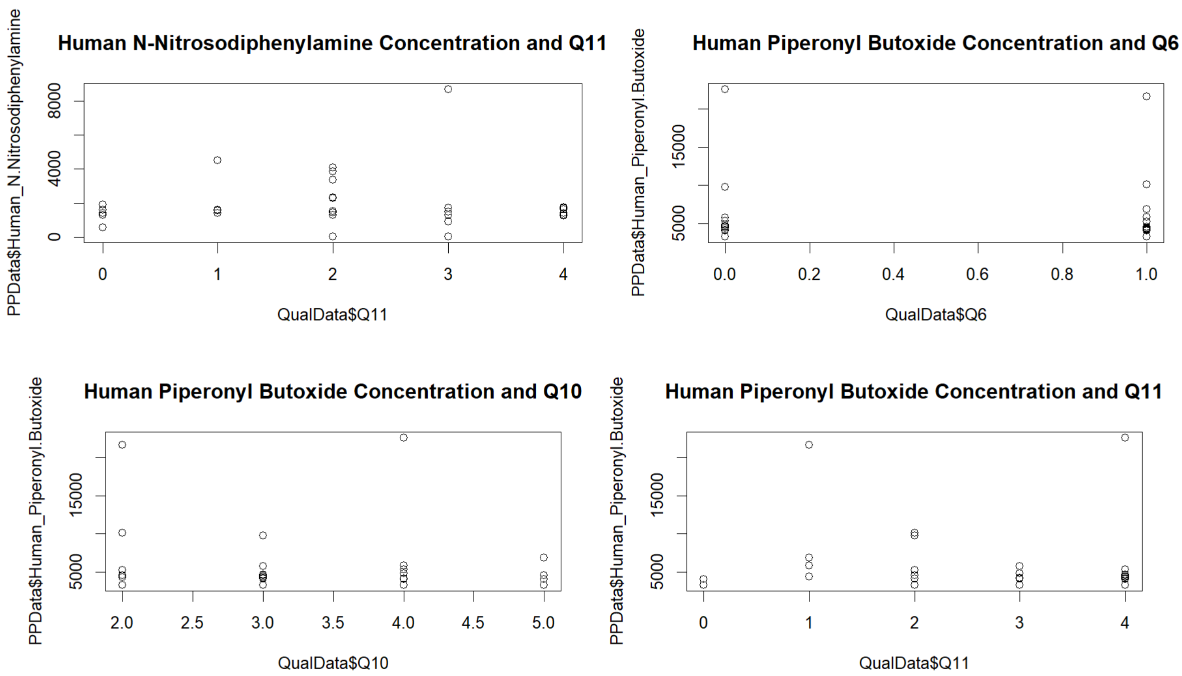


Figure S4. Human Pesticide Exposure and Survey Response Scatter Plot Relationship

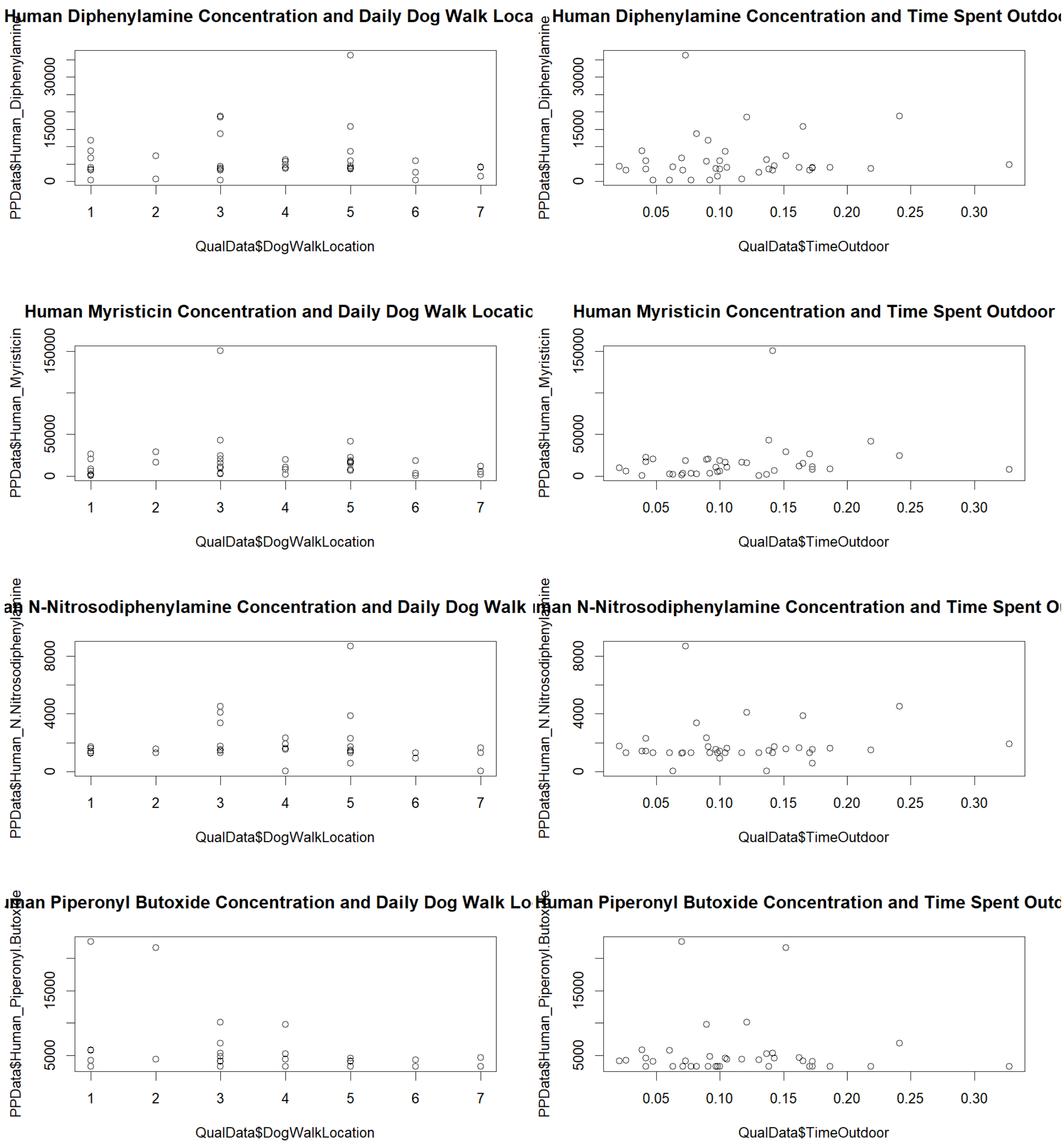


Figure S5. Human Pesticide Exposure Concentration in Relationship with the Location of Daily Dog Walk and Time Spent Outdoors