CEF_BTEX_Results

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Exploratory Data Analysis of BTEX data collected near CEF

Background: Compared to other air sampling studies, this dataset is unique due to the high density of air samplers situated within and around the Central Experimental Farm in Ottawa, Ontario. Unlike other studies, this provides higher data resolution, and we would be able to pinpoint the source of a pollutant. In this case, we are interested in nearest distance to gas stations, since gasoline evaporation is a source of BTEX (Benzene, Toluene, Xylene isomers) VOCs (Volatile Organic Compounds).

We are interested in: BTEX VOC concentrations differences between Fall and Winter, and the relationship between VOC concentrations and distance to the nearest gas station. We hypothesize that generally, BTEX VOC concentration decreases with increased distance from nearest gas station, since

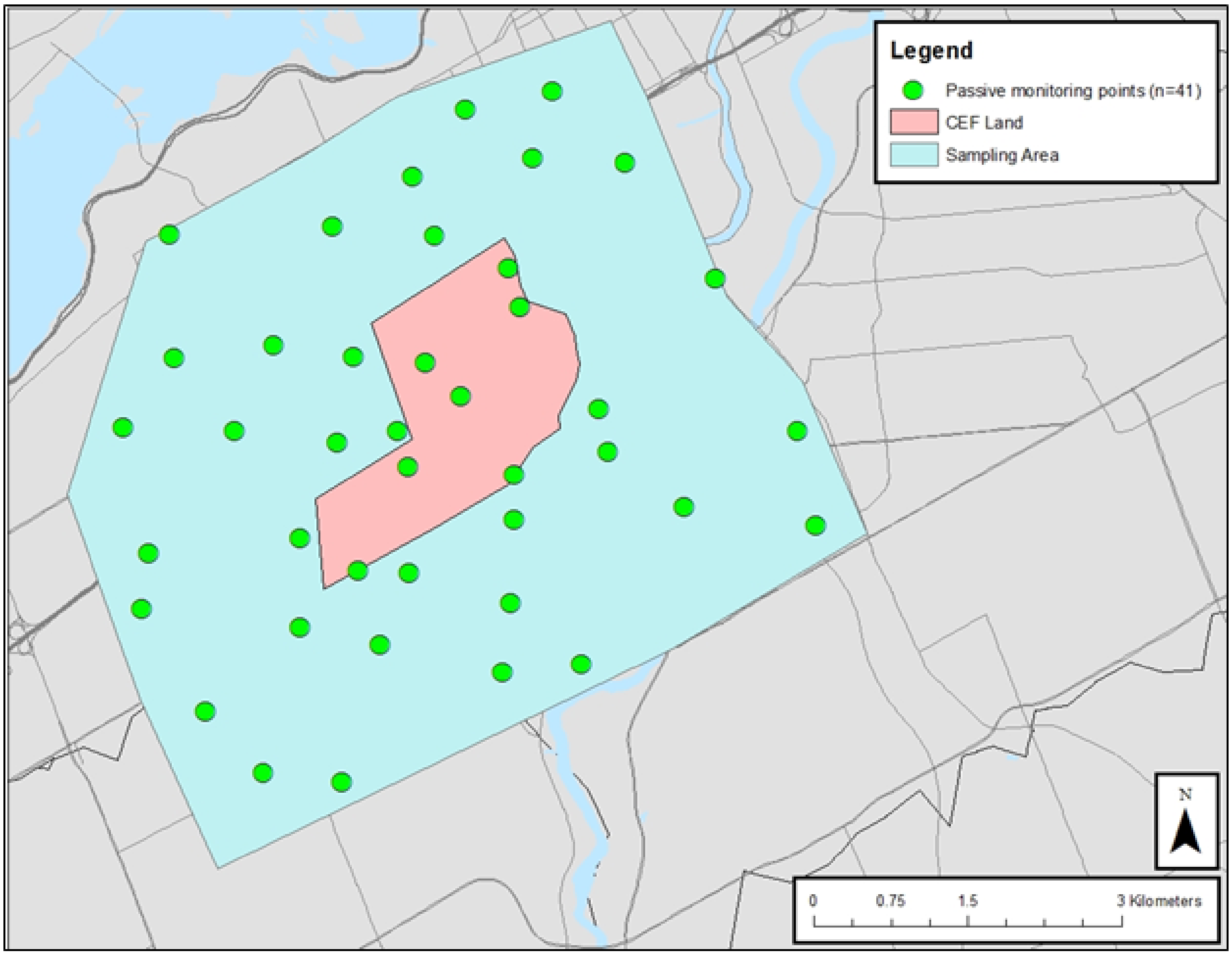


Figure 1: Locations of the 41 passive sampling points that collected measures for noise, NO2, and VOC in both fall and winter campaign.

Summary Statistics table

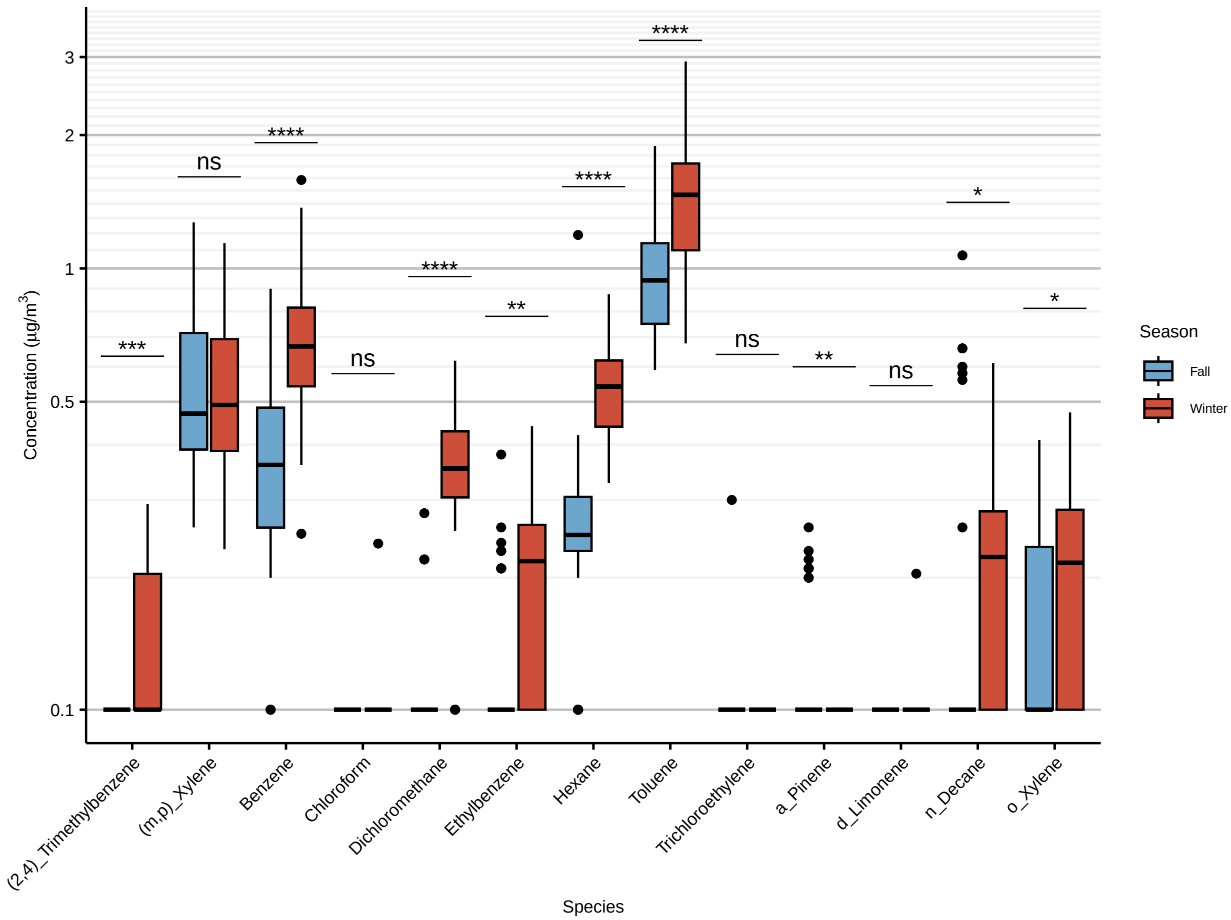
All VOCs and relevant summary statistics are shown in the following table. Note that many species were not detected (100% of samples below detection limit). For subsequent analyses, only VOC species that were detected at least once (< 100% BDL) were retained.

		Statistic									
Species	Season	n	n BDL	% BDL	μ	σ	min	Q1	median	Q3	max
Dichloromethane	fall	39	36	92.3	0.1	0.0	0.1	0.1	0.1	0.1	0.3
	winter	36	4	11.1	0.4	0.1	0.1	0.3	0.4	0.4	0.6
Hexane	fall	39	7	17.9	0.3	0.2	0.1	0.2	0.2	0.3	1.2
	winter	36	0	0.0	0.5	0.1	0.3	0.4	0.5	0.6	0.9
Chloroform	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	35	97.2	0.1	0.0	0.1	0.1	0.1	0.1	0.2
(2)_Dichloroethane	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Benzene	fall	39	3	7.7	0.4	0.2	0.1	0.3	0.4	0.5	0.9
	winter	36	0	0.0	0.7	0.3	0.3	0.5	0.7	0.8	1.6
Trichloroethylene	fall	39	38	97.4	0.1	0.0	0.1	0.1	0.1	0.1	0.3
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Toluene	fall	39	0	0.0	1.0	0.3	0.6	0.8	0.9	1.1	1.9
	winter	36	0	0.0	1.5	0.5	0.7	1.1	1.5	1.7	2.9
Tetrachloroethylene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Ethylbenzene	fall	39	30	76.9	0.1	0.1	0.1	0.1	0.1	0.1	0.4
	winter	36	17	47.2	0.2	0.1	0.1	0.1	0.2	0.3	0.4
(m,p)_Xylene	fall	39	0	0.0	0.6	0.2	0.3	0.4	0.5	0.7	1.3
	winter	36	0	0.0	0.5	0.2	0.2	0.4	0.5	0.7	1.1
o_Xylene	fall	39	26	66.7	0.2	0.1	0.1	0.1	0.1	0.2	0.4
	winter	36	13	36.1	0.2	0.1	0.1	0.1	0.2	0.3	0.5
Styrene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Cumene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
a_Pinene	fall	39	31	79.5	0.1	0.0	0.1	0.1	0.1	0.1	0.3
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
(1,2,2)_Tetrchloroethane	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1

Species	Season	Statistic									
		n	n BDL	% BDL	μ	σ	min	Q1	median	Q3	max
n_Decane	fall	39	31	79.5	0.2	0.2	0.1	0.1	0.1	0.1	1.1
	winter	36	14	38.9	0.2	0.1	0.1	0.1	0.2	0.3	0.6
(3,5)_Trimethylbenzene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
(2,4)_Trimethylbenzene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	25	69.4	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Pentachloroethane	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
d_Limonene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	35	97.2	0.1	0.0	0.1	0.1	0.1	0.1	0.2
p_Cymene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
(3)_Dichlorobenzene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
(4)_Dichlorobenzene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Hexachloroethane	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
(2,4)_Trichlorobenzene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Naphthalene	fall	39	39	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
	winter	36	36	100.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1

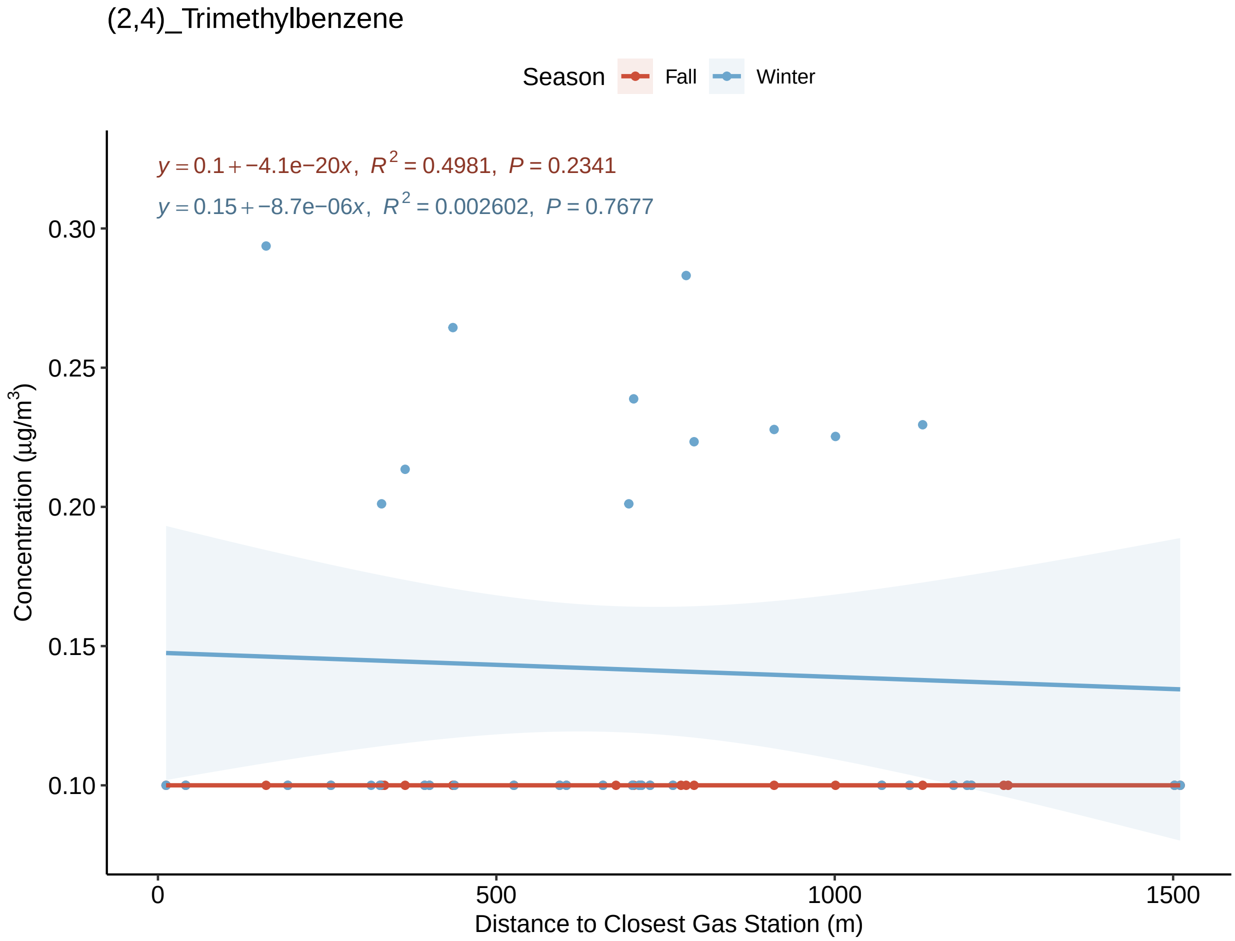
Visualizing Fall - Winter Differences in VOC Concentration

Data are visualised on a pseudo-log transformed scale. Dunn test (non parametric) was used to compared the differences in mean concentration between fall and winter seasons for selected BTEX VOC compounds (species with < 100% BDL). Statistical significance between seasons is denoted as follows - * : P <= 0.05; ** P <= 0.01; *** P <= 0.001; **** P <= 0.0001

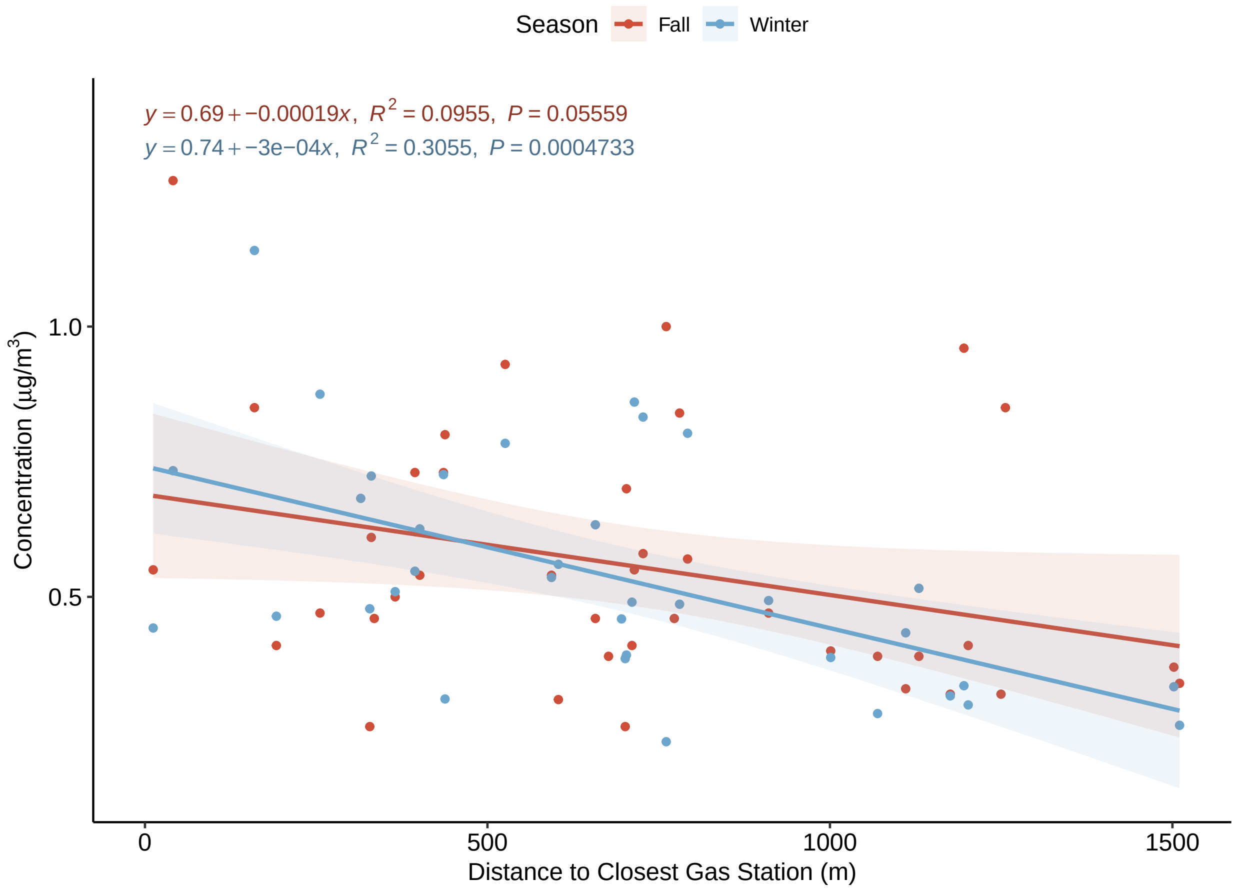


Effect of Gas Station - linear regression models

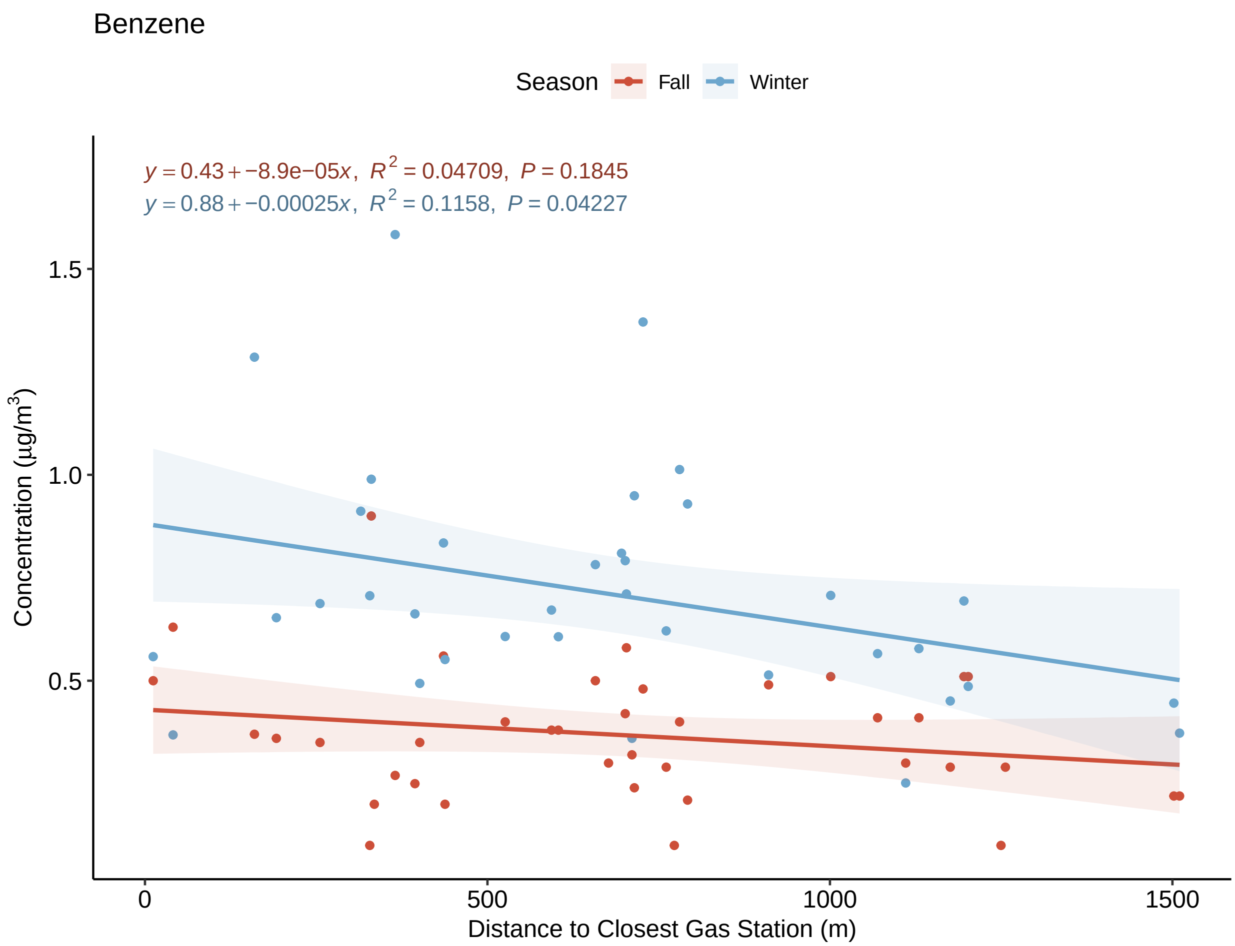
Next we examine the effect of gas station by simple linear regression. Each BTEX VOC compound with detectable values (< 100% BDL) were analysed using the lm() method, stratified by season. In general, for detected BTEX VOC species, there is a negative effect with distance to gas station (concentration decreases with increasing distance to gas station). For some species such as Benzene, Ethylbenzene,and o-Xylene, the slope is steeper in the winter compared to the fall. Due to the large variance in data (especially due to many data points < BDL) there are few statistically significant regressions. The slope for the following BTEX species (stratified by season) are statistically significant (P < 0.05): winter_(m,p)_Xylene, winter_Benzene, winter_Ethylbenzene, fall_Hexane, winter_o_Xylene.

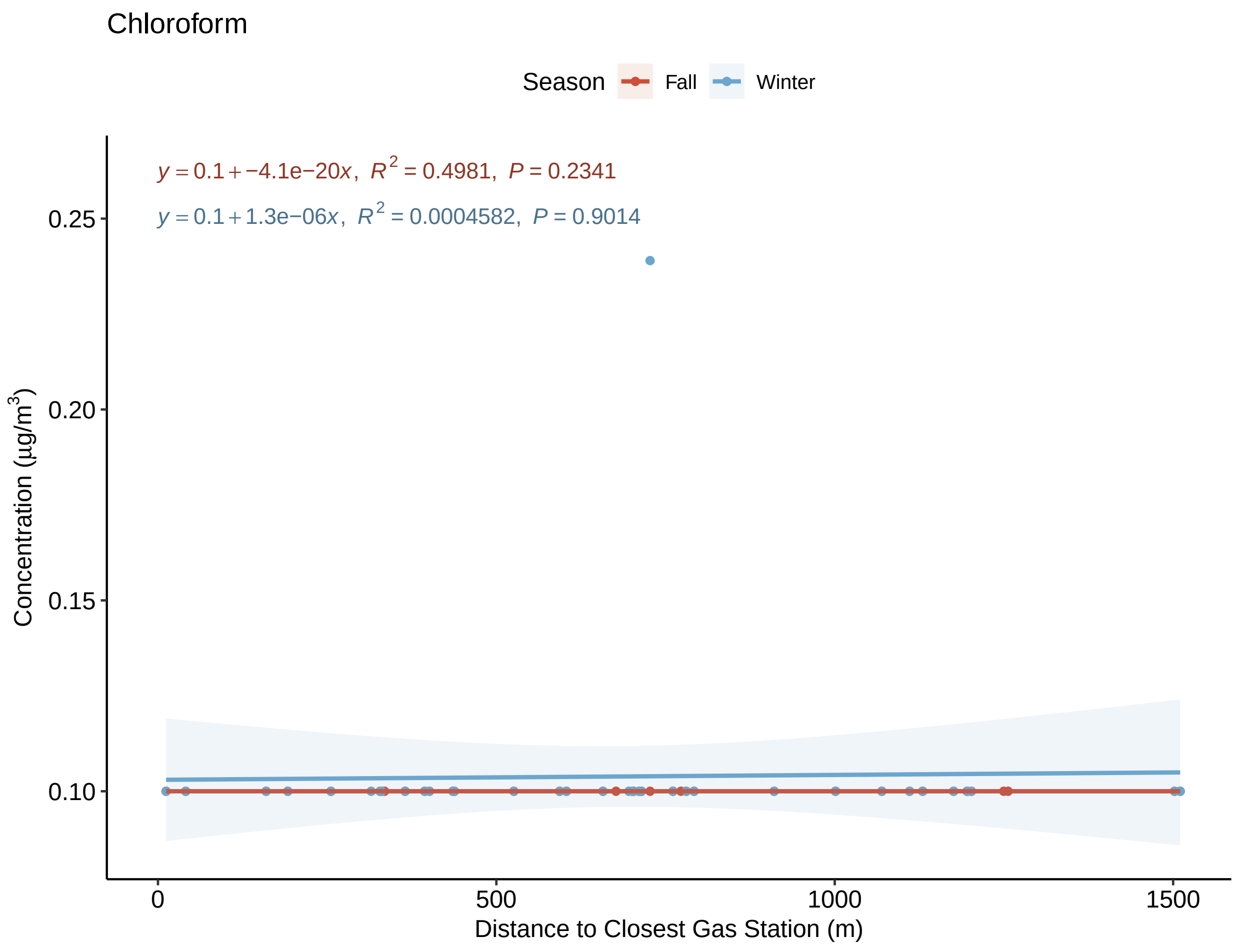


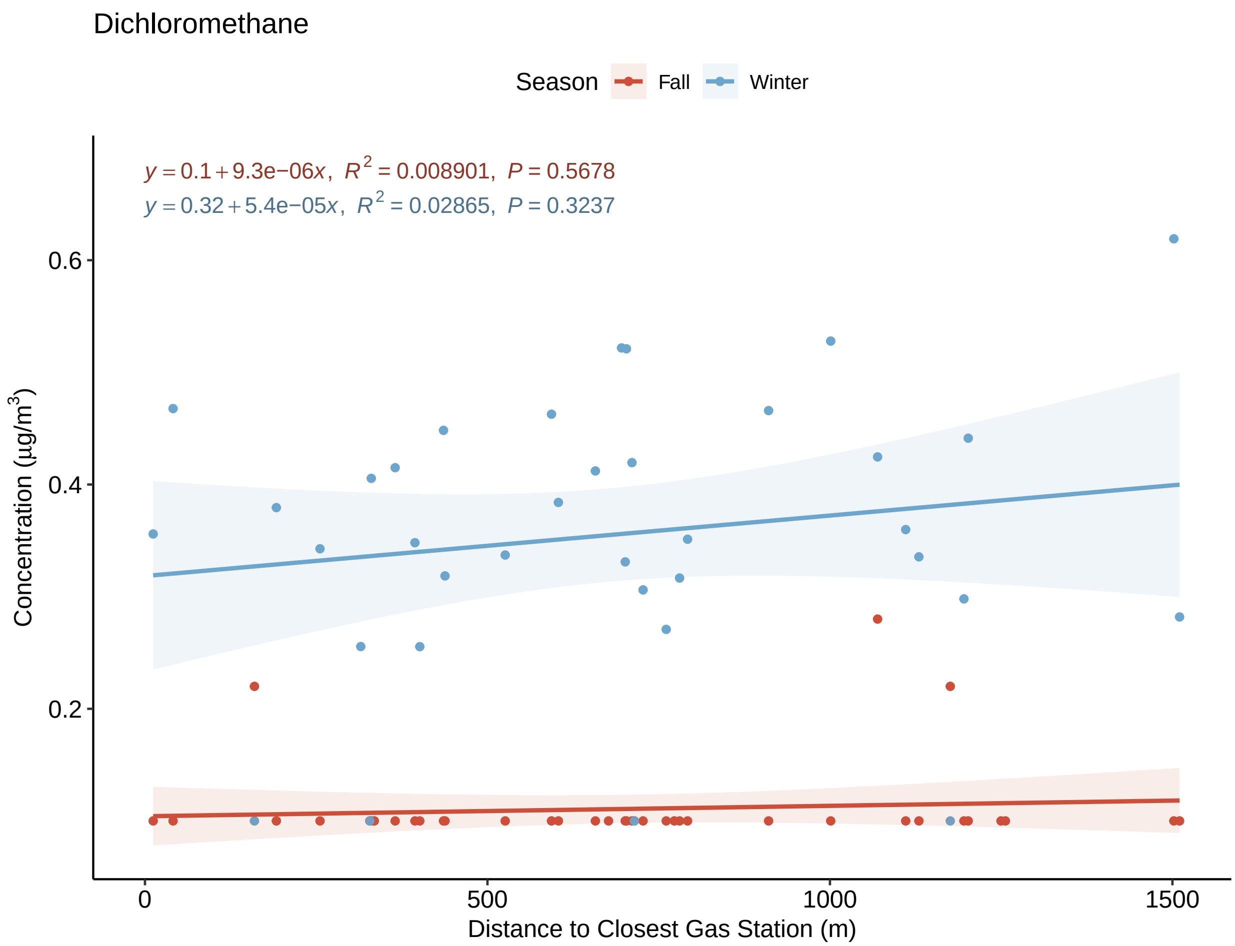
(m,p)_Xylene

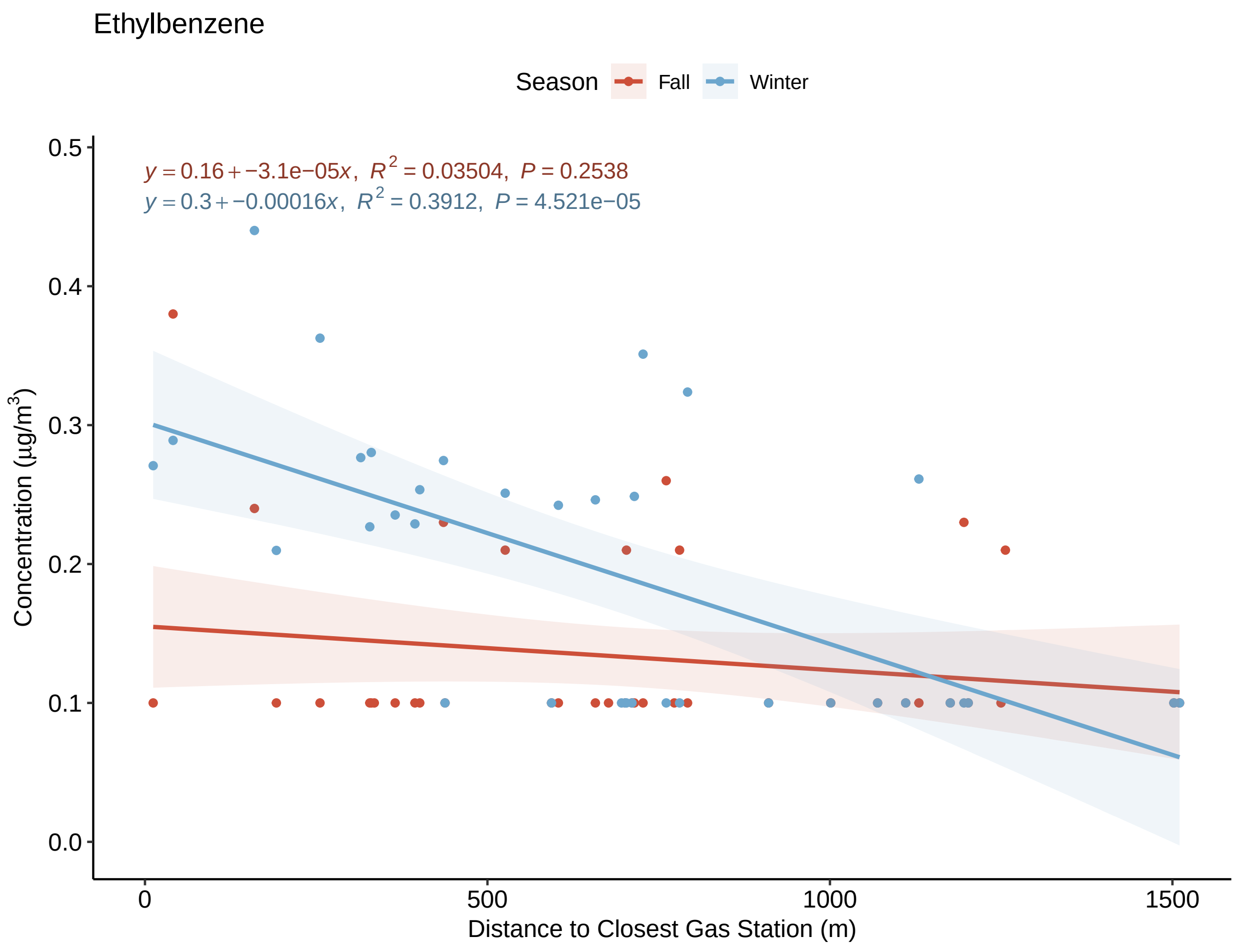


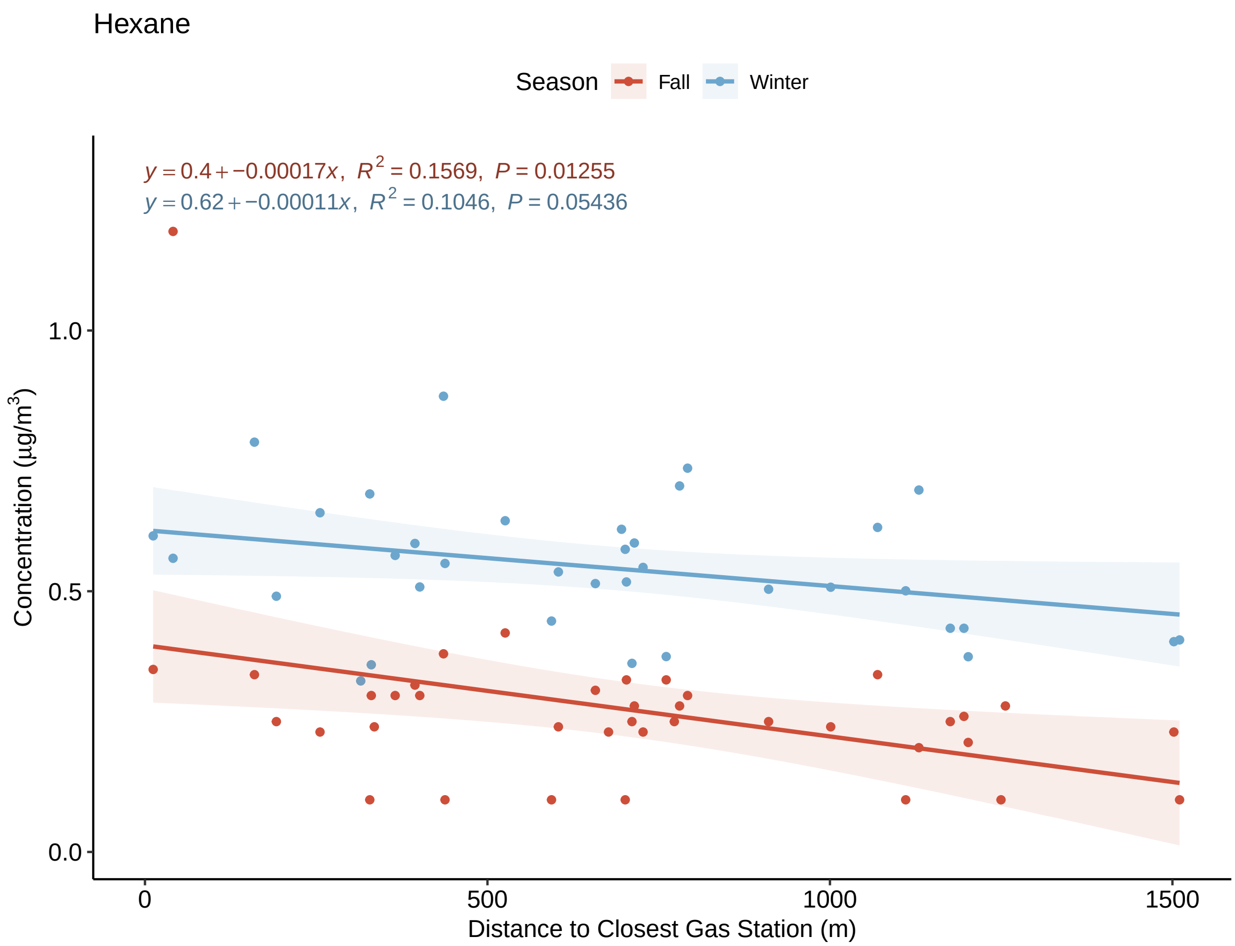
Season
Fall
Winter
$y = 0.69 + -0.00019x,\ R^2 = 0.0955,\ P = 0.05559$
$y = 0.74 + -3e-04x,\ R^2 = 0.3055,\ P = 0.0004733$
Concentration (μg/m³)
1.0
0.5
0
500
1000
1500
Distance to Closest Gas Station (m)

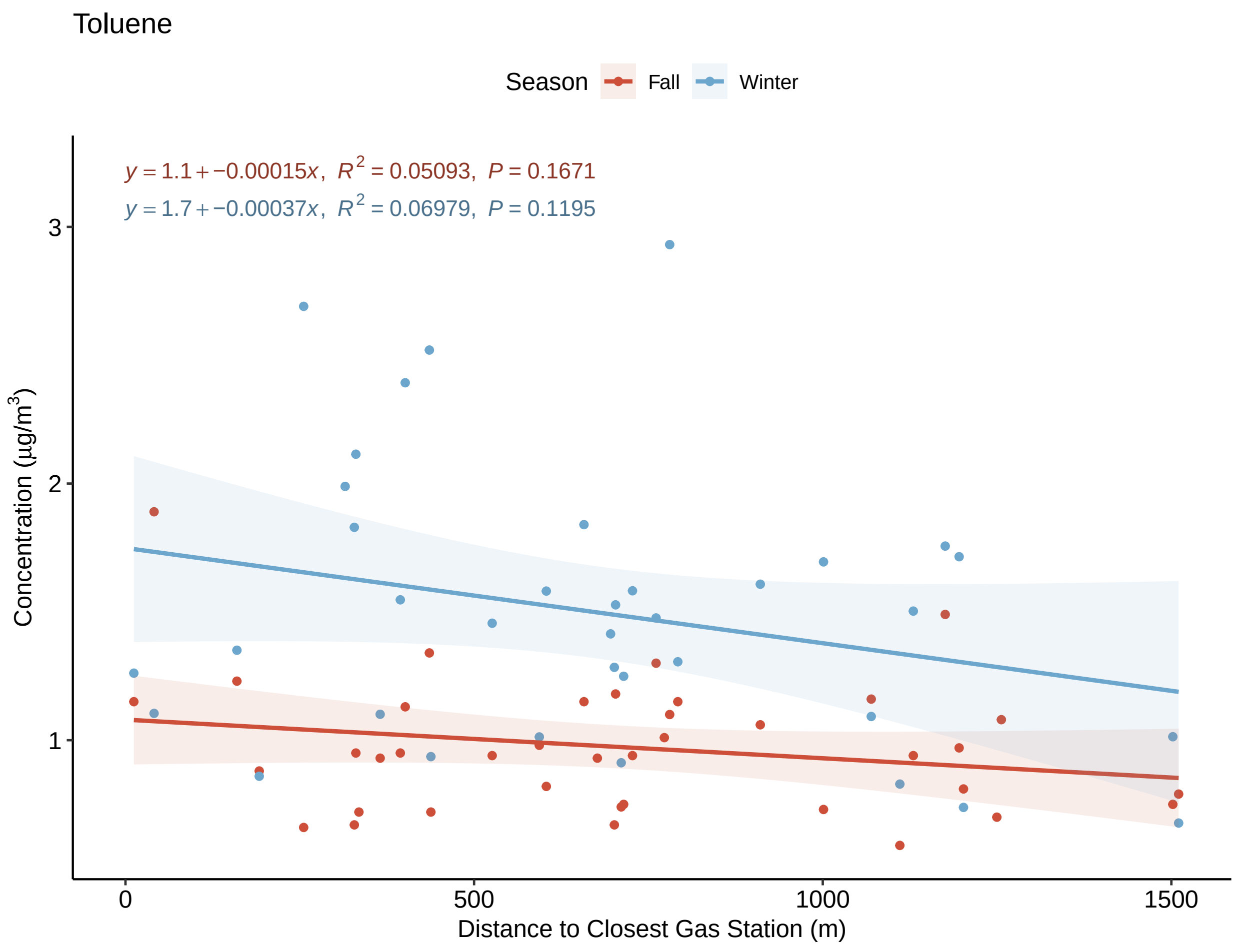

Benzene
Season
Fall
Winter
y = 0.43 + −8.9e−05x, R2 = 0.04709, P = 0.1845
y = 0.88 + −0.00025x, R2 = 0.1158, P = 0.04227
Concentration (µg/m3)
1.5
1.0
0.5
0
500
1000
1500
Distance to Closest Gas Station (m)

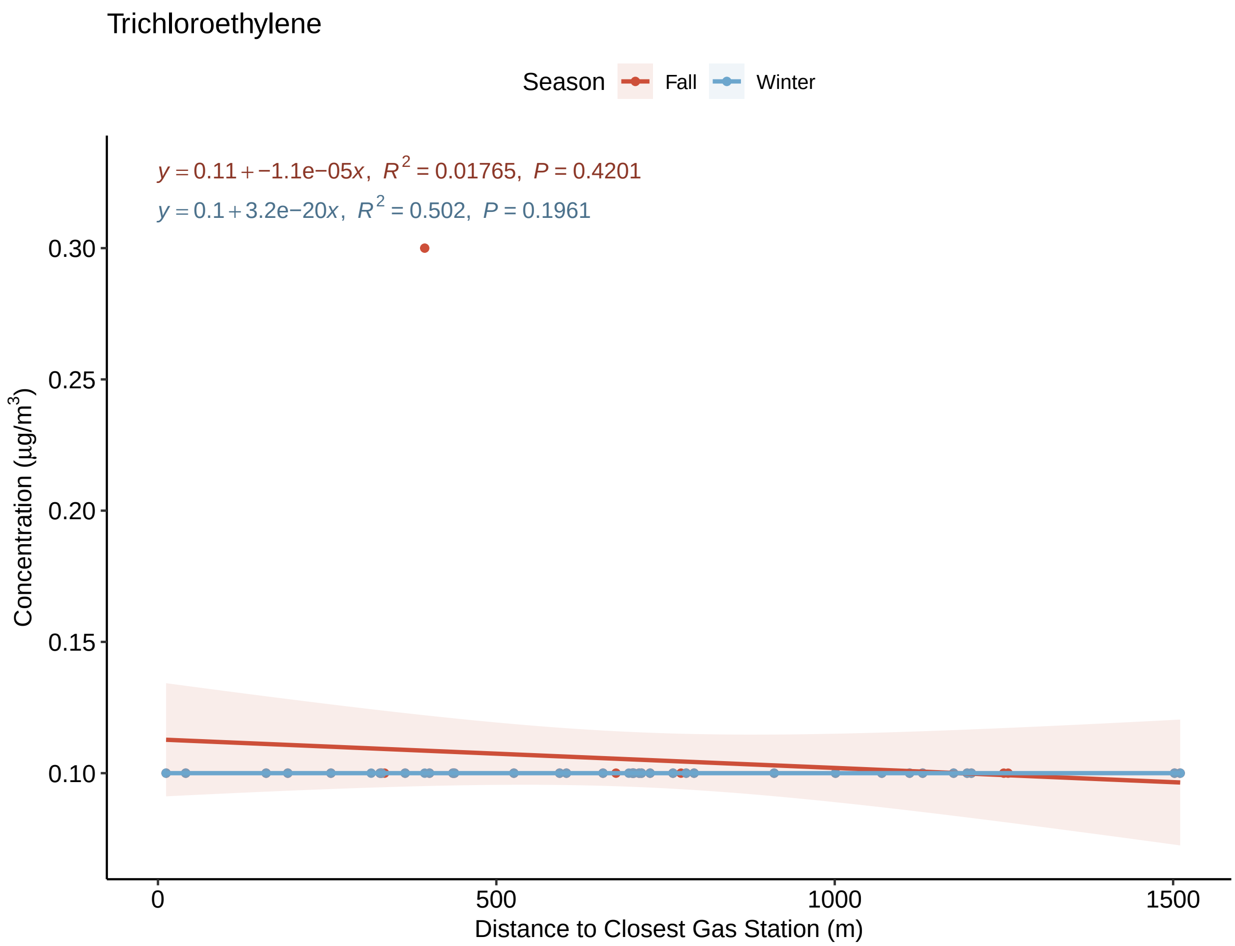

Chloroform
Season
Fall
Winter
y = 0.1 + −4.1e−20x, R2 = 0.4981, P = 0.2341
y = 0.1 + 1.3e−06x, R2 = 0.0004582, P = 0.9014
0.25
0.20
0.15
0.10
Concentration (µg/m3)
0
500
1000
1500
Distance to Closest Gas Station (m)

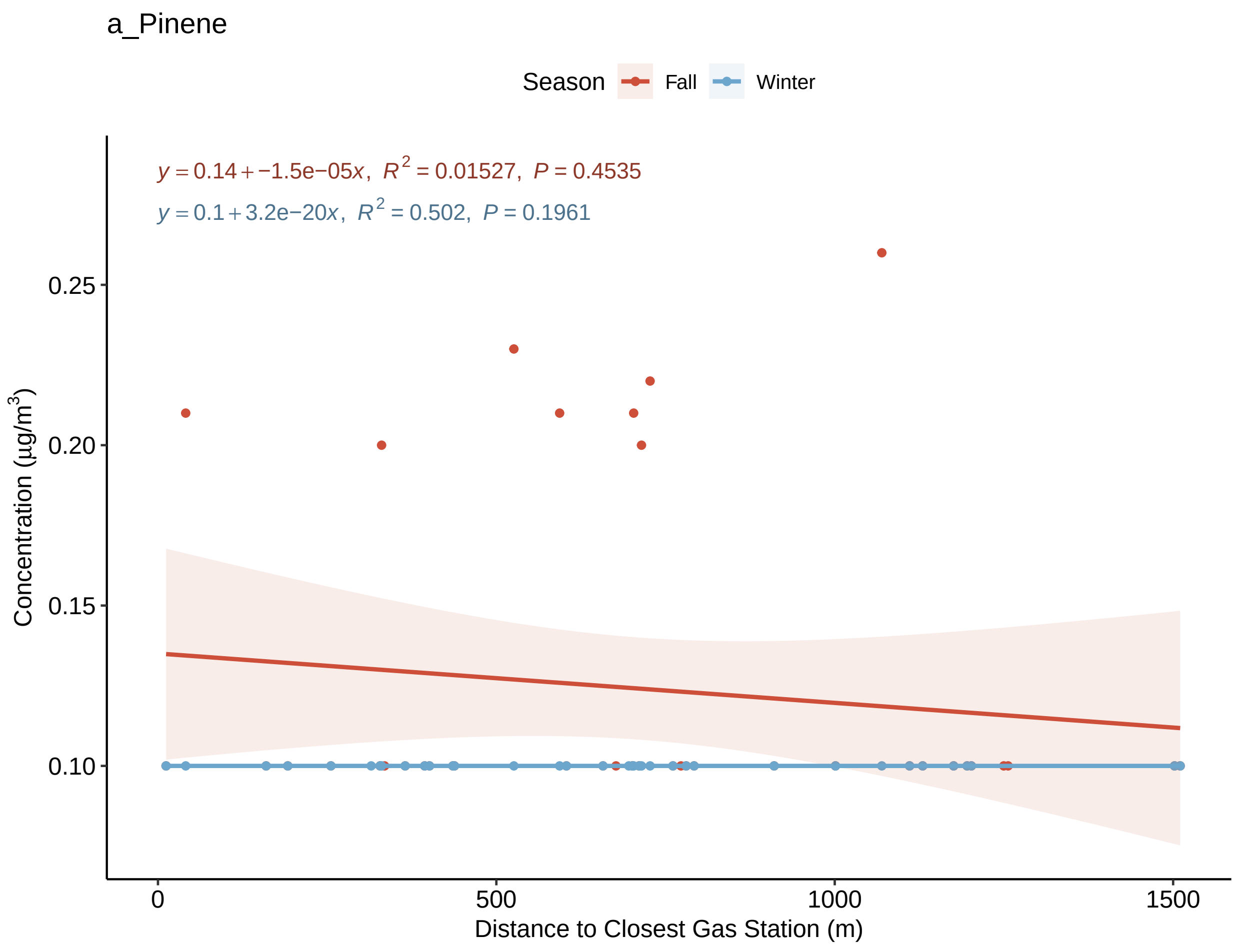

Dichloromethane
Season
Fall
Winter
y = 0.1 + 9.3e−06x, R² = 0.008901, P = 0.5678
y = 0.32 + 5.4e−05x, R² = 0.02865, P = 0.3237
Concentration (µg/m³)
0.6
0.4
0.2
0
500
1000
1500
Distance to Closest Gas Station (m)

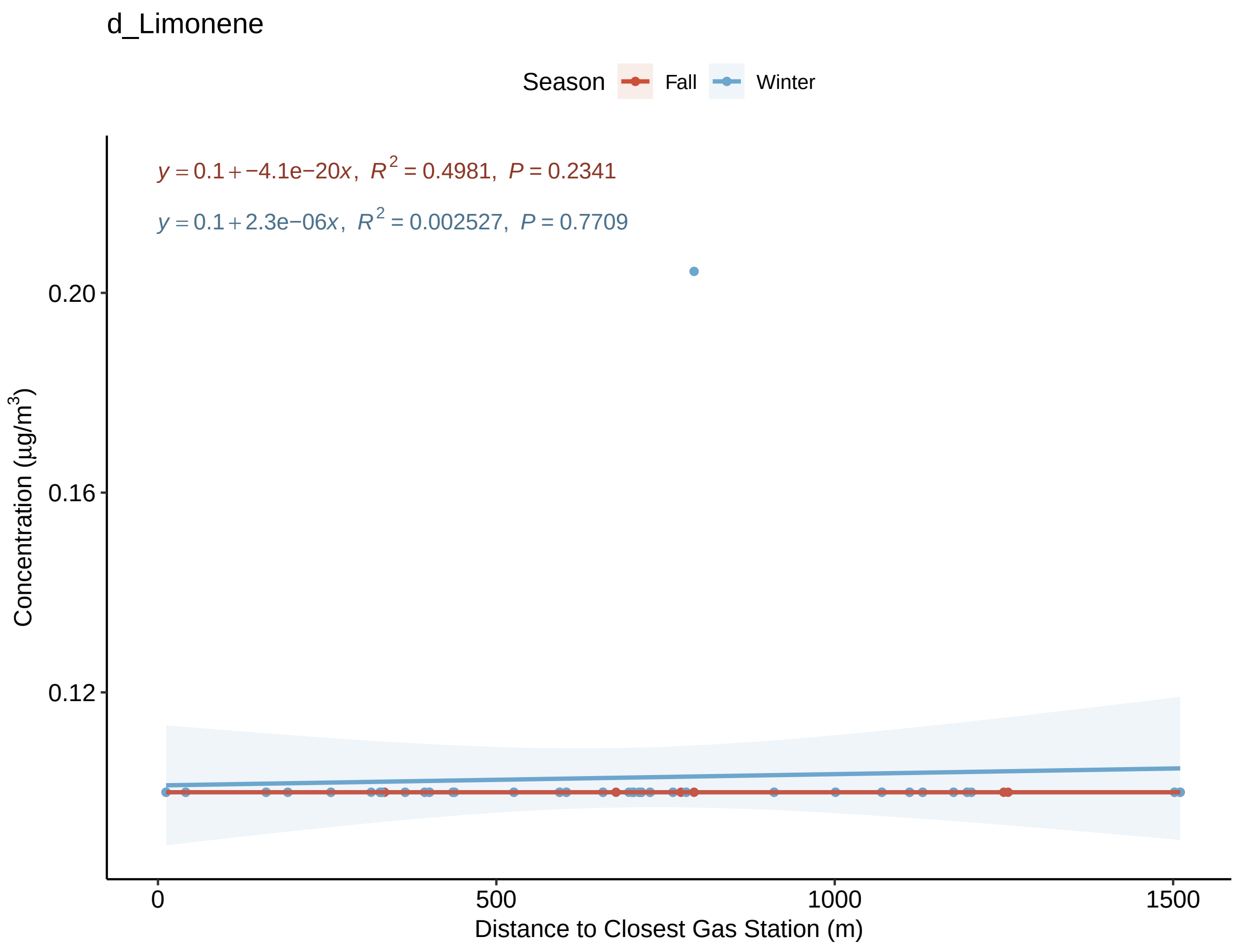

Ethylbenzene
Season
Fall
Winter
y = 0.16 + −3.1e−05x, R2 = 0.03504, P = 0.2538
y = 0.3 + −0.00016x, R2 = 0.3912, P = 4.521e−05
Concentration (µg/m3)
0.5
0.4
0.3
0.2
0.1
0.0
0
500
1000
1500
Distance to Closest Gas Station (m)


Hexane
Season Fall Winter
$y = 0.4 + -0.00017x$, $R^2 = 0.1569$, $P = 0.01255$
$y = 0.62 + -0.00011x$, $R^2 = 0.1046$, $P = 0.05436$
Concentration (µg/m³)
1.0
0.5
0.0
0
500
1000
1500
Distance to Closest Gas Station (m)

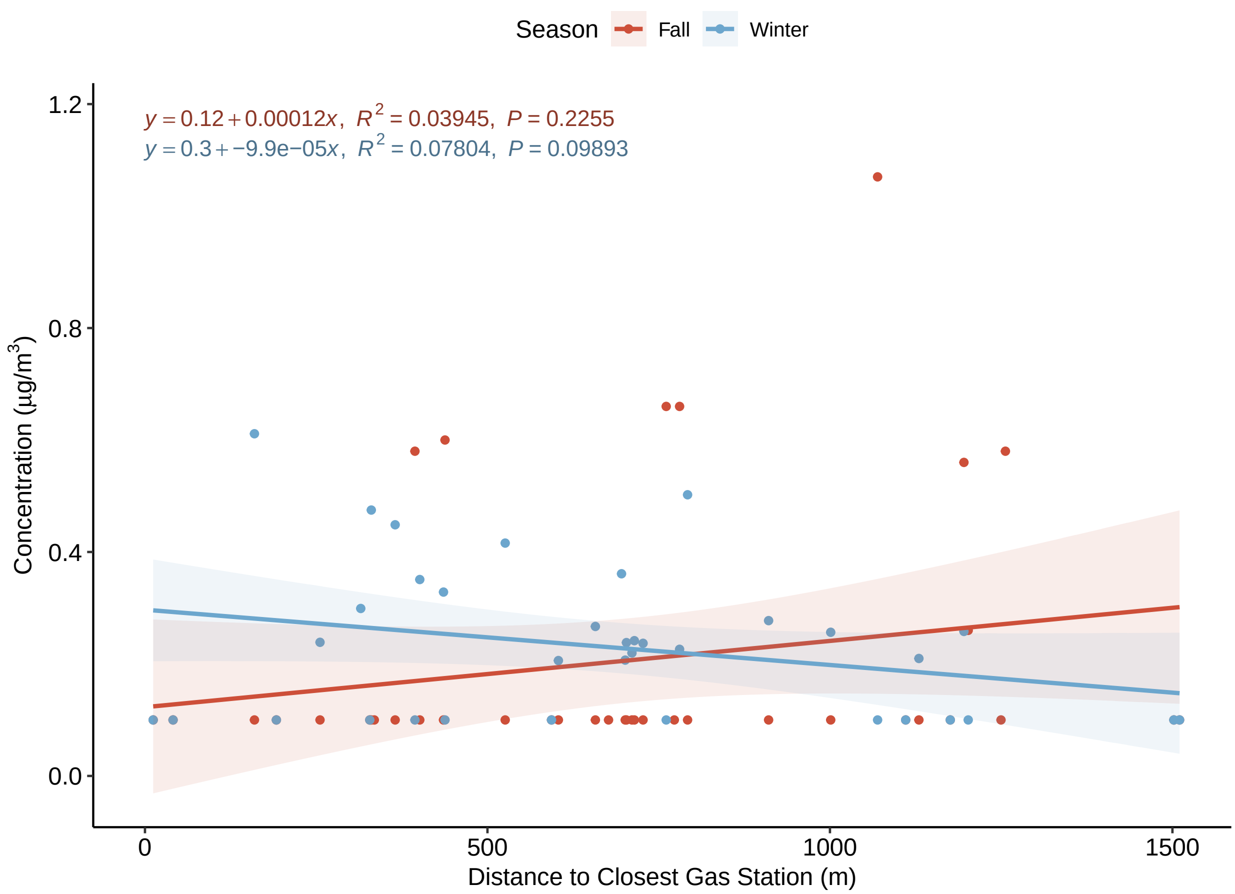

Toluene
Season
Fall
Winter
$y = 1.1 + -0.00015x,\ R^2 = 0.05093,\ P = 0.1671$
$y = 1.7 + -0.00037x,\ R^2 = 0.06979,\ P = 0.1195$
Concentration (µg/m³)
3
2
1
0
500
1000
1500
Distance to Closest Gas Station (m)


Trichloroethylene
Season Fall Winter
y = 0.11 + −1.1e−05x, R2 = 0.01765, P = 0.4201
y = 0.1 + 3.2e−20x, R2 = 0.502, P = 0.1961
0.30
0.25
0.20
0.15
0.10
Concentration (µg/m3)
0
500
1000
1500
Distance to Closest Gas Station (m)


a_Pinene
Season
Fall
Winter
$y = 0.14 + -1.5e-05x,\ R^2 = 0.01527,\ P = 0.4535$
$y = 0.1 + 3.2e-20x,\ R^2 = 0.502,\ P = 0.1961$
Concentration (µg/m³)
0.25
0.20
0.15
0.10
0
500
1000
1500
Distance to Closest Gas Station (m)

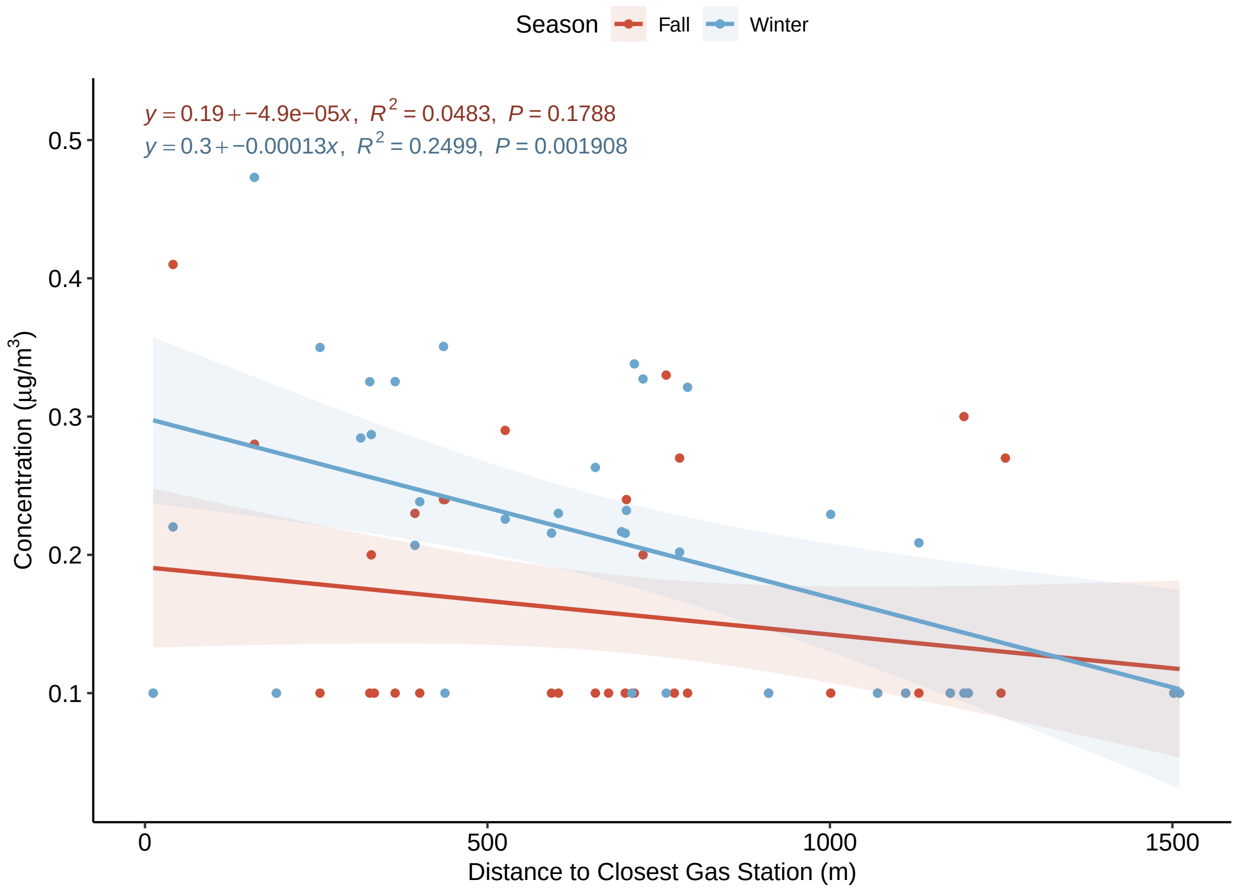

d_Limonene
Season
Fall
Winter
$y = 0.1 + -4.1e-20x$, $R^2 = 0.4981$, $P = 0.2341$
$y = 0.1 + 2.3e-06x$, $R^2 = 0.002527$, $P = 0.7709$
Concentration (µg/m^3)
0.20
0.16
0.12
0
500
1000
1500
Distance to Closest Gas Station (m)

n_Decane



Season
Fall
Winter
y = 0.12 + 0.00012x, R^2 = 0.03945, P = 0.2255
y = 0.3 + −9.9e−05x, R^2 = 0.07804, P = 0.09893
1.2
0.8
0.4
0.0
Concentration (μg/m^3)
0
500
1000
1500
Distance to Closest Gas Station (m)

o_Xylene



Season
Fall
Winter
$y = 0.19 + -4.9e{-}05x,\ R^2 = 0.0483,\ P = 0.1788$
$y = 0.3 + -0.00013x,\ R^2 = 0.2499,\ P = 0.001908$
Concentration (µg/m^3)
0.5
0.4
0.3
0.2
0.1
0
500
1000
1500
Distance to Closest Gas Station (m)