Spring 2018

# An Assessment of Trihalomethanes and Haloacetic Acids on the Cancer Exposure Risk of Ohio Drinking Water Systems

Stephen Sykes
sms329@zips.uakron.edu

## Recommended Citation

Sykes, Stephen, "An Assessment of Trihalomethanes and Haloacetic Acids on the Cancer Exposure Risk of Ohio Drinking Water Systems" (2018). *Honors Research Projects*. 738.
http://ideaexchange.uakron.edu/honors_research_projects/738

# An Assessment of Trihalomethanes and Haloacetic Acids on the Cancer Exposure Risk of Ohio Drinking Water Systems

Stephen Sykes

University of Akron

# Abstract

The cancer exposure risk from drinking chlorine-based disinfection by-products (DBPs) such as trihalomethanes (THMs) and haloacetic acids (HAAs) has been established as a major concern to public health as 98% of the United States drinking water systems in operation use chlorinated systems to disinfect the water they provide [2]. Using data collected from the Ohio Environmental Protection Agency from January 2014 to September 2017 in the cites of Cleveland, Columbus, Cincinnati, Canton, and Akron this study attempts to look at the risk of cancer caused by the DBPs. To show the relative risk of several different systems in operation from the state of Ohio cancer exposure risk values were used to show the varying levels of risk of cancer from each of the studied drinking water systems. This study used an assumed ingestion rate of 2.0 liters per day of drinking water. With additional data, these risk values can be used to calculate disability-adjusted life years which are a standard measure of cancer exposure risk used by the World Health Organization. The highest averaging city system that was found during the duration of the study time was Akron (cancer exposure risk of 1.5927) which was 267 percent more likely that the lowest averaging risk was in Canton (cancer exposure risk of 0.5962). The highest recorded cancer exposure risk value from a single sampling site was in Akron (cancer exposure risk of 3.7889) which is 237 percent of the average value. This study attempted to use cancer exposure risk values to assess the relative cancer exposure risk factors of five cites in Ohio which will help in the prioritization of programs to reduce THMs and HAAs in the water provided by these systems.

## 1. Introduction

The process of disinfecting water systems is a necessary and vital step in order to keep drinking water clean and free of microbes or pathogens that might cause harm those drinking it. Unfortunately, this process can also cause additional health risks due to the disinfectant that most treatment plants use. Due to several factors, chlorine is used in many treatment plants and can react with natural substances in the water to form disinfection by-products (DBPs) which can have detrimental effects to the populations that ingest them. The main risk factors of these substances include an elevation in the risk of developing cancer, developmental impediments, and adverse effects on reproduction [1]. A rise in the incidence of bladder cancer is one of the effects that epidemiologic studies have been able to link to chlorinated drinking water [1]. Of the many DBPs, the two main classes are trihalomethanes (THMs) and haloacetic acids (HAAs).

Looking at previous work in this field, a series of equations were developed to help assess the risk of cancer with these classes of DBPs. The World Health Organization (WHO) recommends using disability-adjusted life years (DALYs) [1] for assessments of quality of life impacts on a given population. Instead of this measure, the relative cancer exposure risk of a source can also be found and used to compare the relative frequency of cancer incidences in given populations.

In the United States (US) about 98 percent of the drinking water systems use some form of chlorination to provide disinfection [2]. As a result, many populations are exposed to the DBPs produced by this use of chlorine. Therefore, analysis of the relative cancer exposure risk of several large cities within Ohio can help clarify the situation in the state. Unfortunately, due to a lack of resources and information, gathering enough data for a DALYs comparison of the cities was not possible. Instead, a relative risk assessment of the different drinking water systems of the five cities will be done without consideration of demographics.

## 2. Data and Methods

### *2.1 Source of Data*

The Ohio Environmental Protection Agency (Ohio EPA) has been collecting data on many different aspects of Ohio drinking water systems for several years now. This study covers the timeframe of January 2014 to September 2017 of the drinking water systems in Cleveland, Columbus, Cincinnati, Canton, and Akron Ohio. All of these systems were sampled quarterly and tested at multiple points. The sample sites for the different cities are spread throughout each system in order to gather data on various locations inside of each city. Each city must meet the regulatory number of sampling sites based on the size of the population it is serving and the type of water source being used (surface water or ground water).

Since many types of THMs and HAAs exist, each sample was analyzed for the most carcinogenic compounds (four-THMs and two HAAs) [1]. Though the data was obtained through the EPA, a detailed list of their acquisition, storage, and testing procedures were not available. One data set appears to have been improperly handled and can be pointed to as a possible error in the data.

### *2.2 Assumptions*

Several assumptions must be made when calculating for cancer indexes. This is because many of the living conditions and possible daily ingestion of different populations varies from city to city so some average data values for the whole US population were used to make the calculations as representative as possible.

**Table 1**

Average population data table for the entire US.

|  | Ingestion Rate (IR) (L/Day) | Body Weight (BW) (kg) | Average Lifetime (AT) (Years) | Exposure Requency (EF) (Day/Year) | Exposure Duration (ED) (Year) |
|---|---|---|---|---|---|
| Avg | 2.00 | 82.60 | 78.74 | 365.00 | 78.74 |

The ingestion rate (IR) was found in a previous study of Chinese drinking water cancer values [1]. Body weight (BW) and average lifetime (AT) were given by the Centers for Disease Control (CDC) [3]. This model uses a full year as the exposure frequency as most people drink from tap water frequently enough for this assumption to be valid.

### *2.3 Calculating the Cancer Indexes*

The first step to determine a cancer index for a source or city is to model the exposure of the population to the carcinogenic substances of interest. This has already been established by the Chinese study mentioned earlier so that they could provide accurate measures of the effects of the THMs and HAAs entering the human body through several different vectors such as ingestion, inhalation, and skin absorption. For this study, a modified version of the equation was used from a second study that looked at many cancer vectors [4]. The following equation for oral dose of ingested carcinogen ($D_i$) was used to model the exposure of the populations:

$$D_i = \frac{Cw \times EF \times ED \times IR}{BW \times AT \times (365\ days/year)} \tag{1}$$

Where $D_i$ represents contaminated water ingestion (mg $Kg^{-1}$ $day^{-1}$), $C_w$ represents the concentration of the contaminant in the water (mg $L^{-1}$), EF represents the exposure frequency (day/year), ED represents the expected duration of exposure in years, IR represents the exposure rate in liters per day of consumption, BW represents the average body weight of a person in kilograms, and AT represents the average lifespan of a person in the population. The oral dose of ingested carcinogen is then paired with its respective slope factor ($SF_i$) to give a cancer exposure risk index value of the specific carcinogen ($R_i$) and the total cancer exposure risk index value of a source (R) as seen in the following equations:

$$R_i = D_i \times SF_i \qquad (2)$$

$$R = \sum R_i \qquad (3)$$

These slope factors have already been established through experimentation in the previous Chinese study [1] where they were found by the US EPA and are given in the following table:

**Table 2**

Cancer exposure risk slope factors for THMs and HAAs

| TCM Slope Factor* | BDCM Slope Factor | DBCM Slope Factor | TBM Slope Factor | TCAA Slope Factor | DCAA Slope Factor |
|---|---|---|---|---|---|
| 0.00 | 1.40 | 0.69 | 0.09 | 2.12 | 0.93 |

*Carcinogenic factor lower than baseline cancer rates so it is excluded

Chloroform (TCM) is likely to be a carcinogenic compound but only under high concentration conditions by the EPA [1] and so was not used as a factor in the Chinese study and in this study.

## 3. Results and Discussion

### *3.1 Total Cancer exposure risk*

The total cancer exposure risk of Cleveland, Columbus, Cincinnati, Canton, and Akron can be seen in Table 3. The data is divided up by quarter and shows that Akron has the highest overall average cancer exposure risk for 2014-2017 but also has the highest variation in cancer exposure risk per quarter. This is followed closely behind by Columbus while Cleveland, Cincinnati, and Canton trail behind in their average cancer exposure risk during the 2014-2017 study period. This can more clearly be seen in Figure 1 where it becomes apparent that something has happened to the data of Akron in the first quarter of 2015. The concentrations of the THMs and HAAs, and by extension the total cancer exposure risk values, of this quarter are extremely low and anomalous for the data set. This may be due to improper handling or storage of the samples, but having levels of DBPs at an almost undetectable level is not a normal occurrence.

**Table 3**

Total cancer exposure risk for the five cities broken down by quarter and with a total average cancer exposure risk for each city for the study period using assumed ingestion figures

| | Total Cancer exposure risk Values | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014-2017 | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 |
| Cleveland | 0.8250 | 1.1229 | 1.0203 | 0.8218 | 1.0304 | 0.5947 | 1.0006 | 1.0167 | 0.7785 | 0.5497 | 0.7511 | 0.9480 | 0.6659 | 0.4980 | 0.8144 | 0.7624 |
| Columbus | 1.4217 | 1.2006 | 1.8470 | 1.9039 | 1.3414 | 1.4295 | 1.5879 | 1.7160 | 1.6976 | 1.3407 | 1.3807 | 1.3392 | 1.0580 | 0.8087 | 1.2855 | 1.3889 |
| Cincinnati | 0.6313 | 0.4828 | 0.6948 | 0.5784 | 0.6325 | 0.6694 | 0.7306 | 0.6823 | 0.5619 | 0.6865 | 0.6594 | 0.5562 | 0.5185 | 0.6904 | 0.6757 | 0.6505 |
| Canton | 0.5962 | 0.4580 | 0.4012 | 0.8586 | 0.6593 | 0.4681 | 0.5529 | 0.5264 | 0.6492 | 0.5151 | 0.5272 | 0.7093 | 0.7999 | 0.5701 | 0.5132 | 0.7339 |
| Akron | 1.5927 | 0.9426 | 1.1660 | 3.4507 | 2.5365 | 0.0013 | 1.5831 | 2.0366 | 1.3675 | 1.2981 | 1.6397 | 1.7021 | 1.3274 | 1.1179 | 1.6415 | 2.0796 |

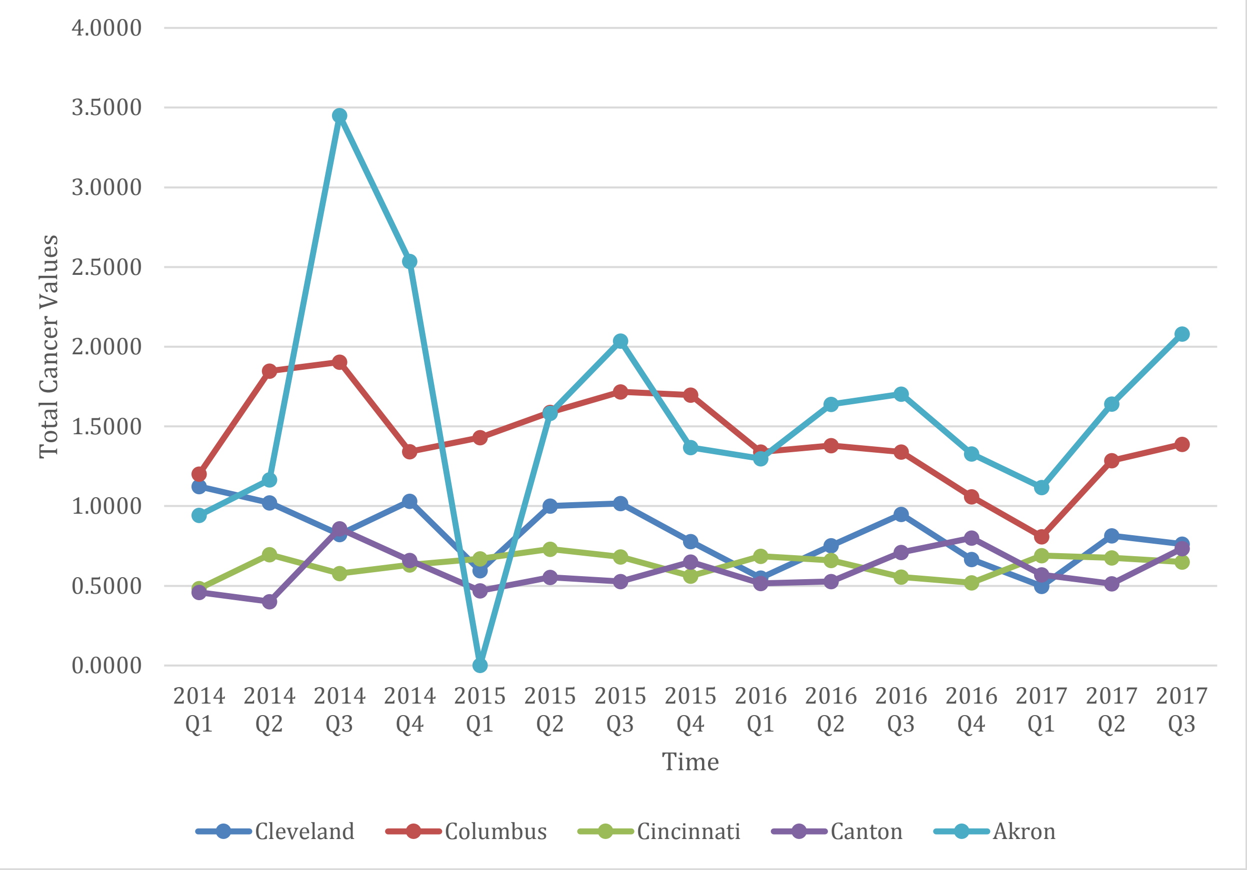


**Figure 1** Plot of the average total cancer exposure risk of each city in the study broken down by yearly quarter

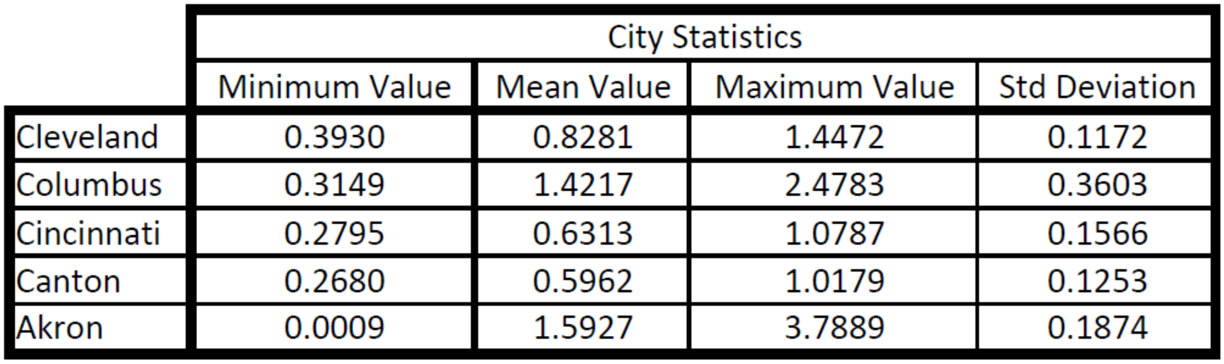
Each of the cities has several different sample sites and the distribution throughout the system is lost in this data set. Therefore, a more detailed analysis of each site was needed in order to compare them more accurately. The raw data can be found in Appendix A for the specific cities and their sample sites.

### *3.2 Local Site Comparison*

Due to the large amounts of data that needed to be collected and interpreted in this study several smaller tables were created. In table 4, there four statistically important values listed for the five cites being: the lowest value of cancer exposure risk for each city, the average value of the cancer exposure risk for each city, the maximum value of cancer exposure risk for each city, and the standard deviation of all cancer exposure risk assessment from the city. A more detailed set of tables has the same values of each city broken down by yearly quarter in Appendix A.

**Table 4**

Statistics on the cancer exposure risk of the five



| | City Statistics | | | |
|---|---|---|---|---|
| | Minimum Value | Mean Value | Maximum Value | Std Deviation |
| Cleveland | 0.3930 | 0.8281 | 1.4472 | 0.1172 |
| Columbus | 0.3149 | 1.4217 | 2.4783 | 0.3603 |
| Cincinnati | 0.2795 | 0.6313 | 1.0787 | 0.1566 |
| Canton | 0.2680 | 0.5962 | 1.0179 | 0.1253 |
| Akron | 0.0009 | 1.5927 | 3.7889 | 0.1874 |

Though each city has a multitude of sampling sites and many of the cities show relatively similar cancer exposure risk levels at each site, there are some outliers. A good representation of a tightly packed data set is that of Cleveland which is shown in Figure 2. This data shows a stable trend in each sample site and small standard deviation from the average for a quarter at only 0.1172. This is not to say that there is no variation in the data when comparing different sites within a given city. There are several occurrences of sampling sites having double the risk of another site in the same quarter.

Compared to Cleveland, Columbus is much more erratic as the average standard deviation is 0.3603 which is the highest of all the cities. Though it is unique as one sample site, DS2016, is consistently lower that every other site by a large margin. Without this one sampling site included the standard deviation of Columbus's data set drops to 0.2619 and though it is still the highest standard deviation of the five cities, it shows a 27.3% decrease with the exclusion of DS2016. This can be seen clearly in Figure 3, as DS216 consistently shows a value around 0.5 total cancer exposure risk, while the rest of the sampling sites tend to hover around the 1.25 to 2.0 level of risk. This means that DS216 is on average about three to four time less risky, if used for drinking water, than any other site in the Columbus system.

Cincinnati's standard deviation is the closest of the other large cities to Cleveland's at 0.1566. The cancer exposure risk values of each site have consistent levels. This leads to several of the highest averaging sampling sites such as DS209, DS203, and DS205 being nearly double that other the lowest averaging sites such as DS211 and DS208 almost every quarter. This can be clearly seen in Figure 4.

Canton has a standard deviation of 0.1253 but the slow decline in the number of sampling sites reported has skewed this number. This is due to the last four quarters only having two reported sampling sites. In Figure 5, it can be seen that initially Canton reported six sampling sites but only for the first quarter of data. Then the sampling sites drops from four to two in the fourth quarter of 2016. The four sampling sites that were dropped were on the extremes of the cancer exposure risk totals for Canton. As a result, DS203 and DS206 would have or did have half of the cancer exposure risk as the highest sampling site DS201 for a majority of the study time.

The standard deviation of Akron is the second highest at 0.1874. The standard deviation of the cancer exposure risk and would be smaller if the one anomalous piece of data in its Q1 of 2015 was taken out. Akron also has the highest variation in other categories as during the quarter directly after this anomaly (Q2 2015) the highest ratios between two sampling sites out of all of the cites can be seen as DS211 dwarfs DS206 as it has 4.7 times the cancer exposure risk. In Figure 6, the extreme variance of Q4 2014, Q1 2015, and Q2 2015 can be seen as not being representative of the Akron system in relation to the other quarters during the study period the sampling sites are very close in their cancer exposure risk values.

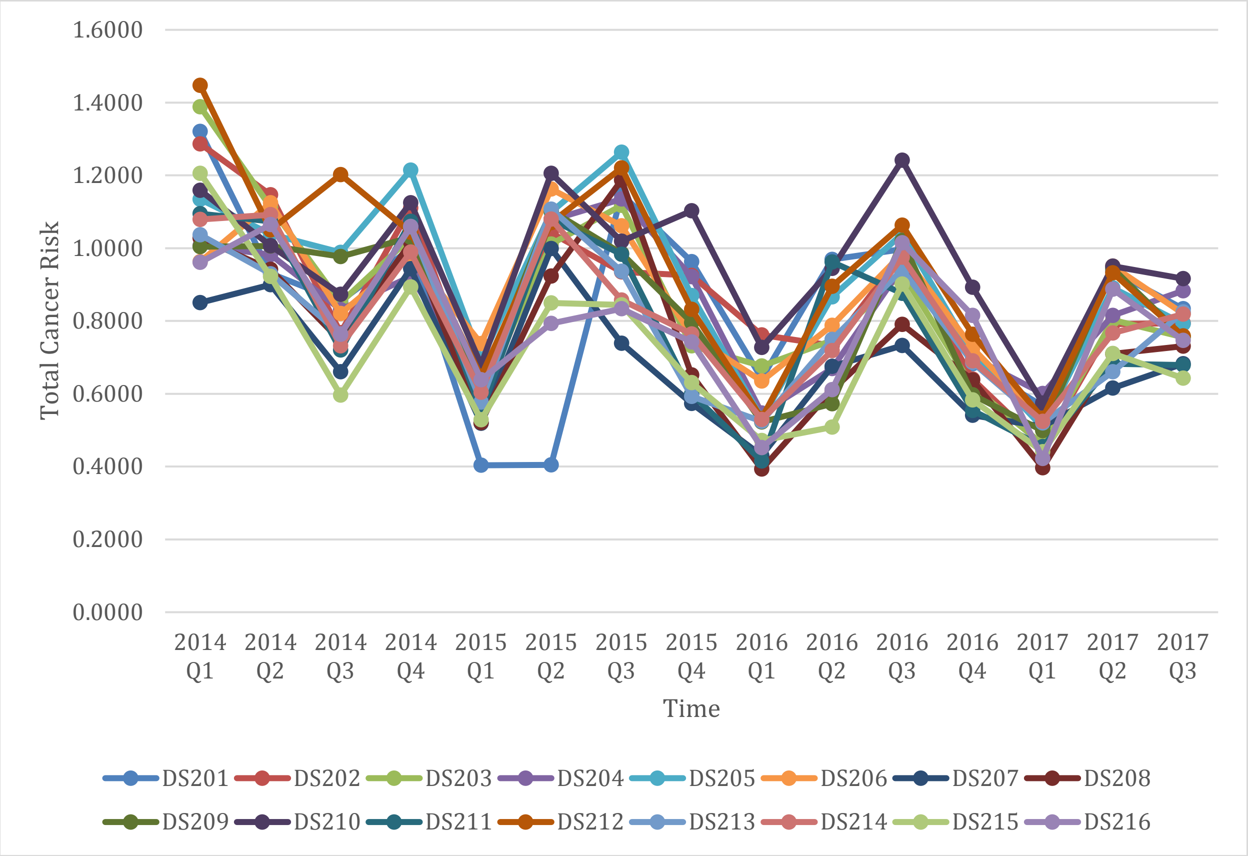


**Figure 2** Cleveland sample sources total cancer exposure risk broken down by yearly quarter

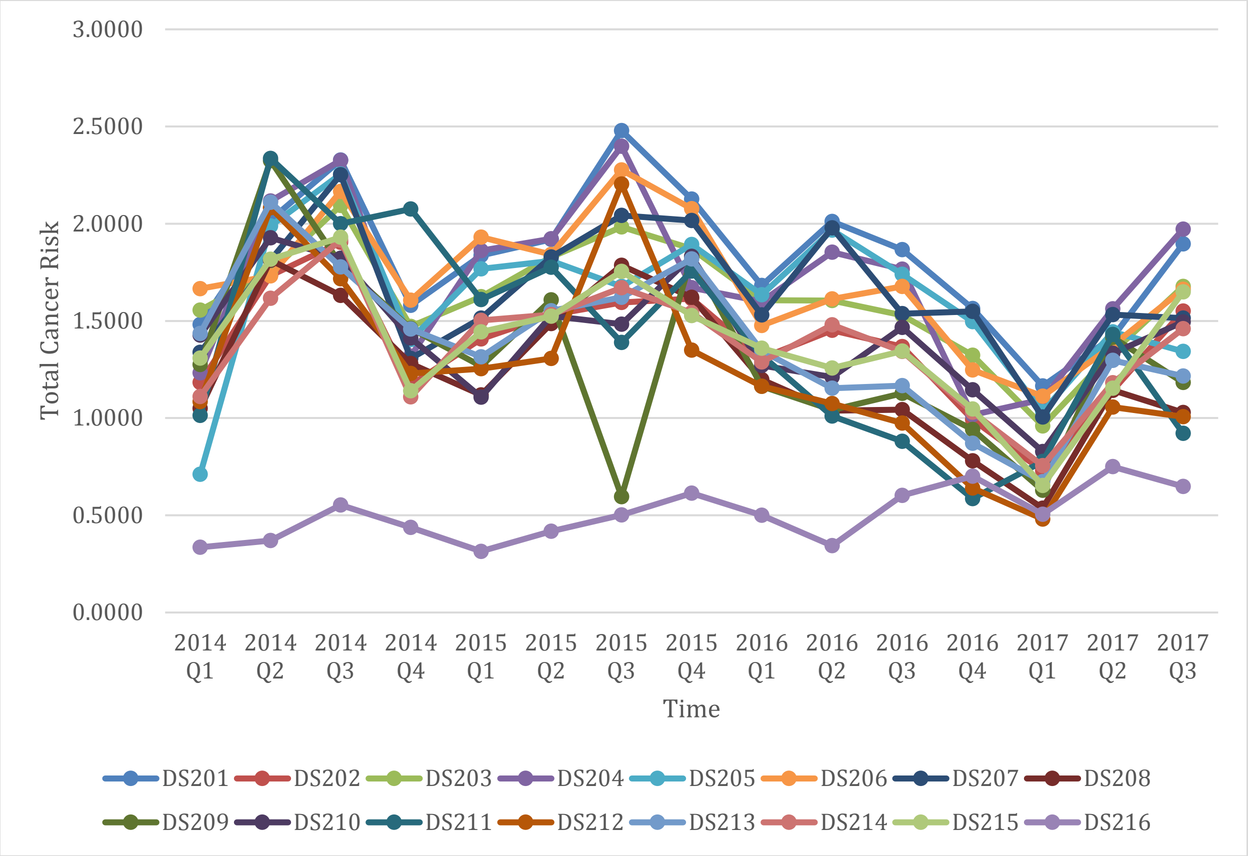


**Figure 2** Columbus sample sources total cancer exposure risk broken down by yearly quarter

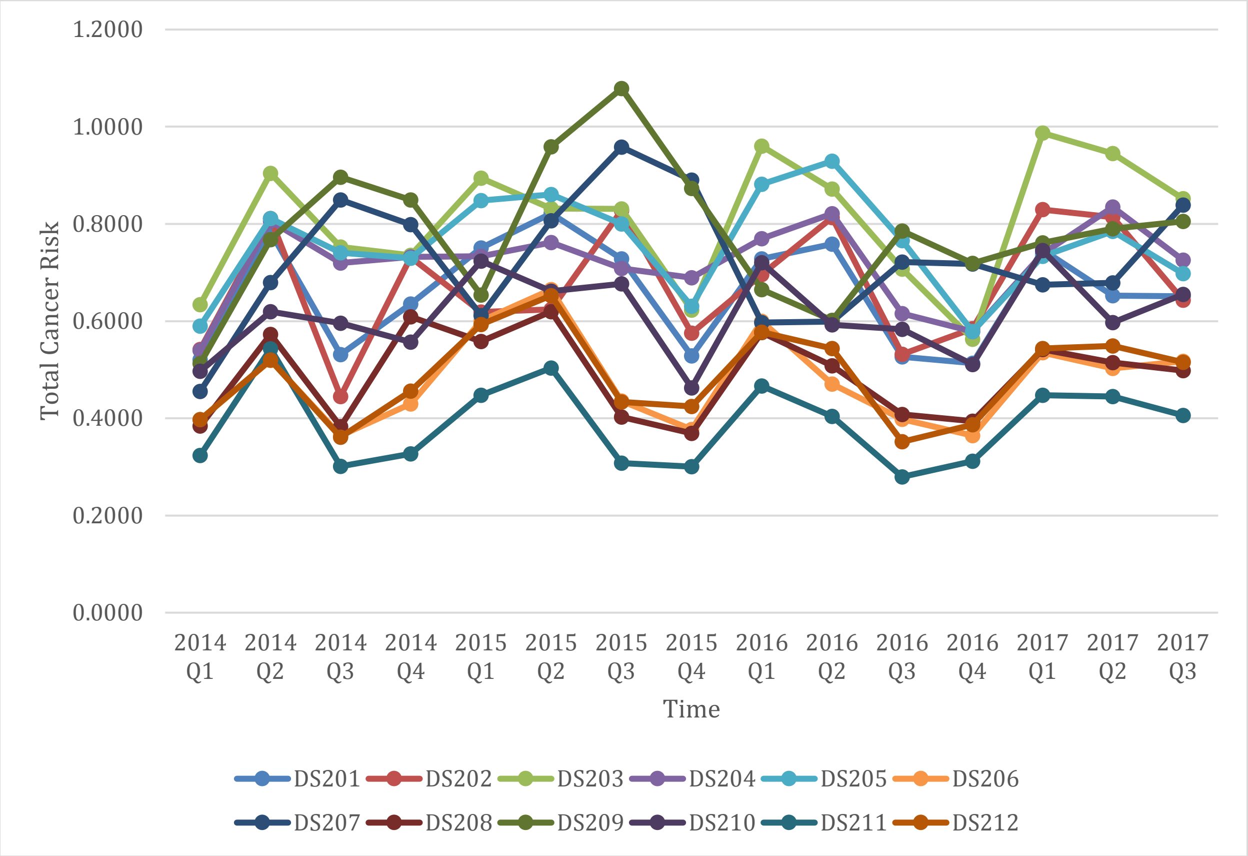


**Figure 4** Cincinnati sample sources total cancer exposure risk broken down by yearly quarter

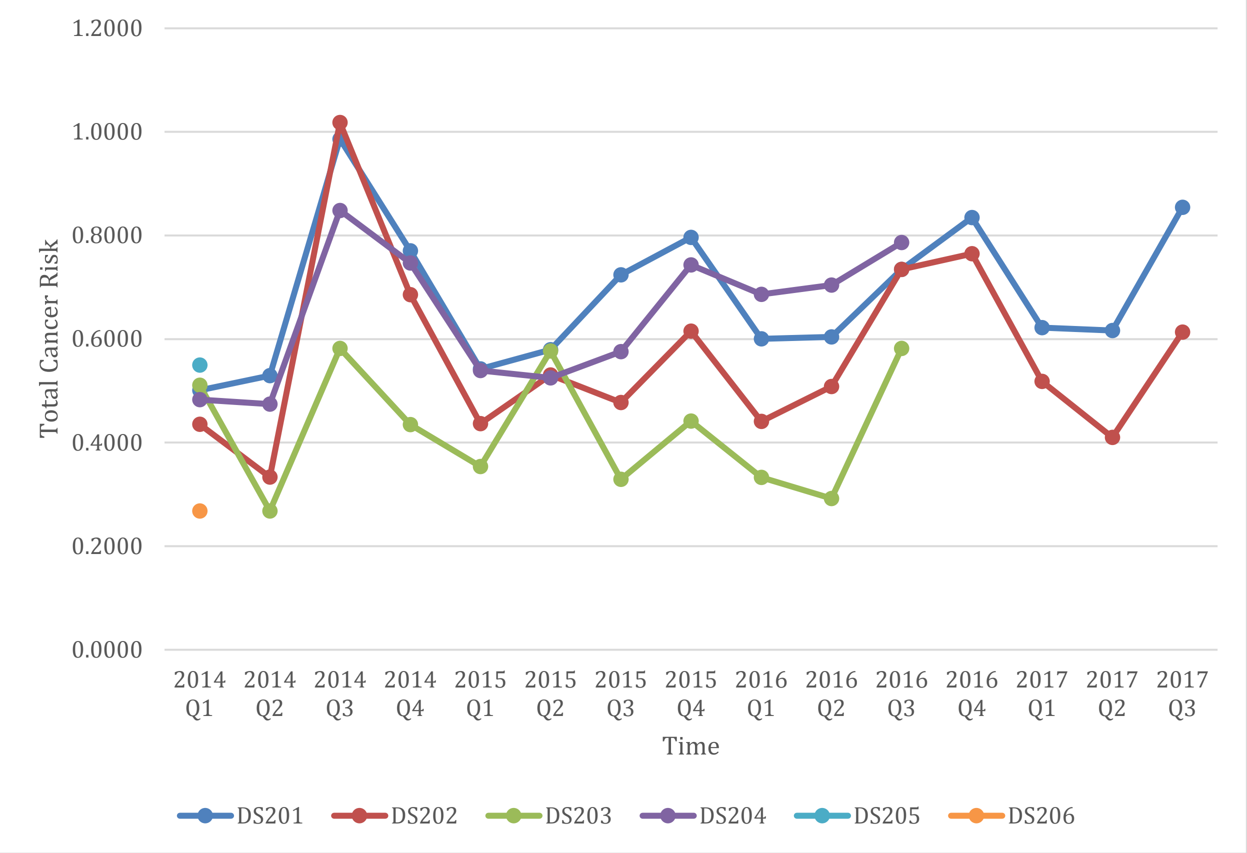


**Figure 5** Canton sample sources total cancer exposure risk broken down by yearly quarter

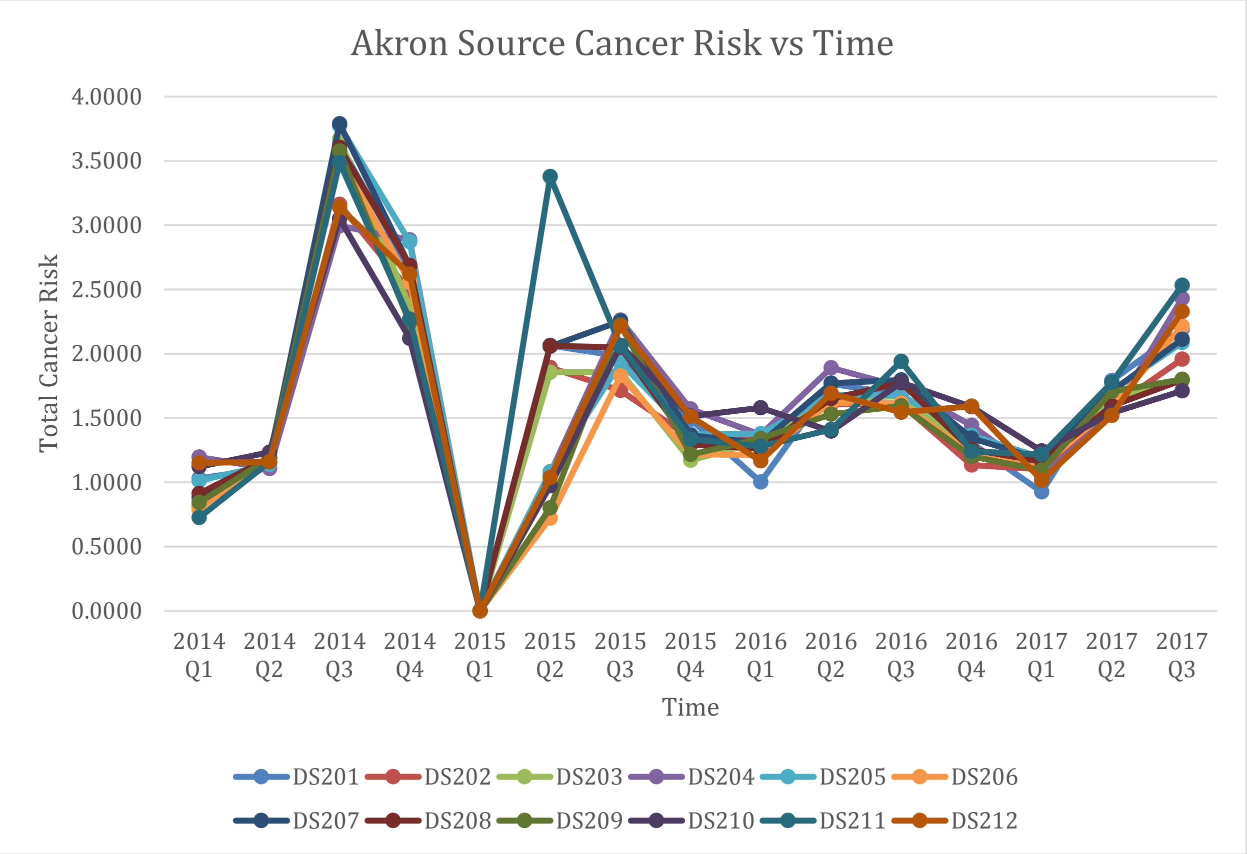


**Figure 6** Akron sample sources total cancer exposure risk broken down by yearly quarter

### *3.3 City to City Comparison*

When comparing these five cites to one another some allowances need to be made as cities like Columbus, Cleveland, and Cincinnati are much larger than Akron and Canton. Another factor to take into account is that Canton is a ground water system while the others are all surface water systems.

When looking at the overall health of each city's system in Table 3, Canton comes in with the lowest average total cancer exposure risk of 0.5962 and ranged from a high of 1.0179 to a low of 0.2680. Cincinnati has the second lowest average with a total cancer exposure risk of 0.6313, its highest total cancer exposure risk value being at 1.0787, and lowest total cancer exposure risk value being at 0.2795. Cleveland's average total cancer exposure risk of 0.8250 puts it squarely in the middle of the data range, its highest total cancer exposure risk value being at 1.4472, and lowest total cancer exposure risk value being at 0.3930. Columbus is the second highest with an average total cancer exposure risk of 1.4217, its highest total cancer exposure risk value being at 2.4783, and lowest total cancer exposure risk value being at 0.3149. Akron is the highest out of all of the cities at an average total cancer exposure risk of 1.5927, its highest total cancer exposure risk value being at 3.7889, and lowest total cancer exposure risk value being at 0.0009.

Using the mean values of the different cities trend lines were developed to see the trajectory of the cancer exposure risk values and are in Appendix A. Cleveland, Columbus, and Akron have a downward sloping trend of 0.023, 0.034, and 0.004 of a cancer exposure risk per quarter respectively. Cincinnati and Canton have an upward trend of 0.002 and 0.009 of a cancer exposure risk per quarter respectively.

## **4. Conclusion**

In the above analysis, the following three conclusions can be made: (1) The risk in Akron is the highest (cancer exposure risk value of 1.5927) which is 267 percent more risk than the lowest which was Canton (cancer exposure risk value of 0.5962). Both the highest and lowest cancer exposure risk was seen in Akron at a cancer exposure risk value of 3.7889 (374 percent of the average value of all cites) and 0.0009 (0.09 percent of the average values of all cites) respectively. (2) Akron has a relative exposure risk of 267 percent of the baseline, Columbus has a relative exposure risk of 238 percent of the baseline, Cleveland has a relative exposure risk of 139 percent of the baseline value, Cincinnati has a relative exposure risk of 106 percent of the baseline value, and Canton has a relative exposure risk of 100 percent of the baseline value. Relative exposure factors of the cities use Canton as the baseline value because it has the smallest average cancer exposure risk. (3) The median value of the cancer exposure risk for the five cites is 1.0134 which is only 27 percent of the highest recorded value. As no direct measurement of the health risk posed by this problem can be stated without a DALY calculation, all of the stated cancer risk exposure values are relative values to one another and not a number of cancer patients of cancer caused by DBPs. This means the relative cancer exposure rate is the important value of this study, not the overall value.

Since each city has a different source water to draw from this is likely the main factor in the creation of DBPs and by extension the cancer exposure risk associated with each city. This is due to different dissolved organic carbon concentrations in each water source. For example, Akron is the first major city to use the water from the Cuyahoga River with many farming communities upstream from it which may contribute to the high values of its cancer exposure risk. On the other hand, Canton uses groundwater for its drinking water and so the possibility of it having contaminated water through agricultural or industrial depositing organic carbon into its source water.

Cleveland, Columbus, and Akron have a downward trend in the cancer exposure rate of their drinking water systems. This may be because of US and Ohio EPA regulations that have now begun to attempt to limit the agricultural and industrial waste that is let into the river systems. This could also be from natural fluctuations as this study is over too short of a time to make assertions for sure as to the cause of this change. Cincinnati and Canton have a slowly increasing cancer exposure risk over time but no know reason for this can be ascertained by the data collected so far.

With additional data on population figures, cancer rates, and disability factors of the given cities this data could be turned into DALY values and more easily compared to other studies of this type or WHO values for tolerable levels of disability life years. Even without this additional data their high levels of cancer exposure risk in Akron and Columbus means that additional attention should be given to their intake sites or possible cleanup of their source water so that organic carbon intake can be lowered and less DBPs will be produced. The high variance of Columbus, Akron, and Cincinnati indicates that attempts to make these drinking water systems more consistent should be undertaken to provide better quality to the populations using these systems.

## Acknowledgements

The Ohio EPA, University of Akron Honor’s College, University of Akron Civil Engineering Department, and Dr. Miller of the University of Akron all supported this project though data acquisition and resources provided in the completion of the study. Shenling Pan, Wei An, Hongyan Li, Ming Su, Jinliang Zhang, and Min Yang are acknowledged for making the initial equations used and Ramon Lopez-Roldan, Alicia Rubalcaba, Jordi Martin-Alonso, Susana Gonzalez, Vicenc Marti, and JoseLuis Cortina are acknowledged for making the modified calculations used in this project.

# References

[1] Pan, S., An, W., Li, H., Su, M., Zhang, J., & Yang, M. (2014). Cancer exposure risk assessment on trihalomethanes and haloacetic acids in drinking water of China using disability-adjusted life years. Journal of Hazardous Materials, 280, 288-294. doi:10.1016/j.jhazmat.2014.07.080

[2] American Chemistry Council. (n.d.). Chlorine Chemistry. Retrieved from https://chlorine.americanchemistry.com/Chlorine/DrinkingWaterFAQ/

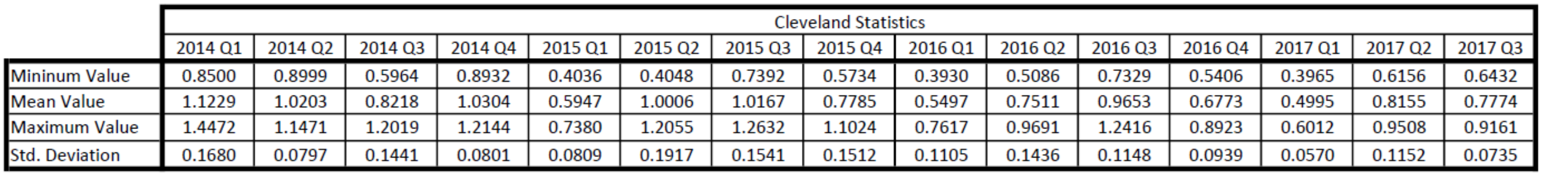
[3] National Center for Health Statistics. (2017, May 03). Retrieved April 22, 2018, from https://www.cdc.gov/nchs/fastats/body-measurements.htm

[4] López-Roldán, R., Rubalcaba, A., Martin-Alonso, J., González, S., Martí, V., & Cortina, J. L. (2016). Assessment of the water chemical quality improvement based on human health risk indexes: Application to a drinking water treatment plant incorporating membrane technologies. Science of The Total Environment, 540, 334-343. doi:10.1016/j.scitotenv.2015.04.045

## Appendix A. Expanded Data Sets

### Table A1

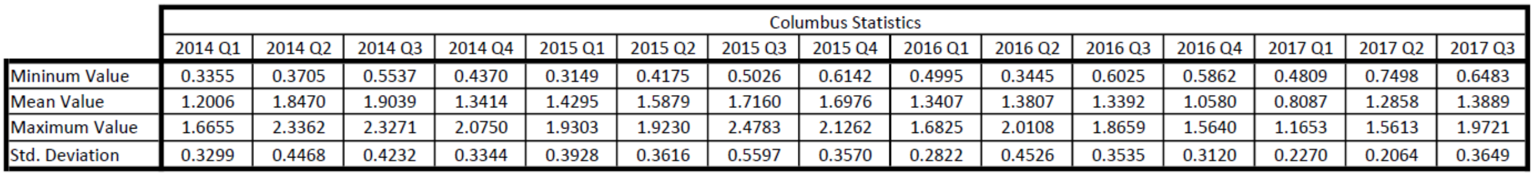
Cleveland statistical analysis of the raw cancer exposure risk data



| | Cleveland Statistics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 |
| Mininum Value | 0.8500 | 0.8999 | 0.5964 | 0.8932 | 0.4036 | 0.4048 | 0.7392 | 0.5734 | 0.3930 | 0.5086 | 0.7329 | 0.5406 | 0.3965 | 0.6156 | 0.6432 |
| Mean Value | 1.1229 | 1.0203 | 0.8218 | 1.0304 | 0.5947 | 1.0006 | 1.0167 | 0.7785 | 0.5497 | 0.7511 | 0.9653 | 0.6773 | 0.4995 | 0.8155 | 0.7774 |
| Maximum Value | 1.4472 | 1.1471 | 1.2019 | 1.2144 | 0.7380 | 1.2055 | 1.2632 | 1.1024 | 0.7617 | 0.9691 | 1.2416 | 0.8923 | 0.6012 | 0.9508 | 0.9161 |
| Std. Deviation | 0.1680 | 0.0797 | 0.1441 | 0.0801 | 0.0809 | 0.1917 | 0.1541 | 0.1512 | 0.1105 | 0.1436 | 0.1148 | 0.0939 | 0.0570 | 0.1152 | 0.0735 |

### Table A2

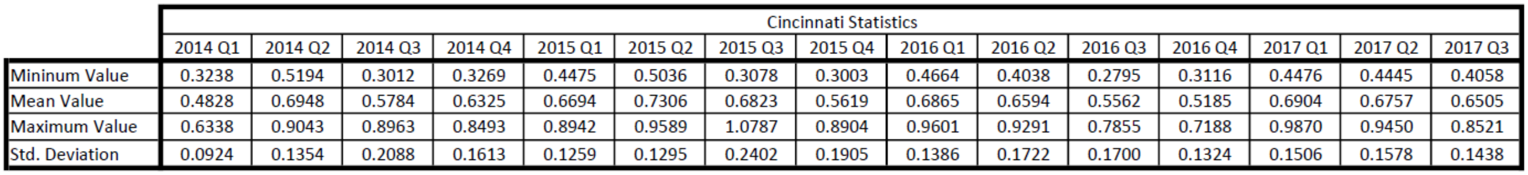
Columbus statistical analysis of the raw cancer exposure risk data



| | Columbus Statistics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 |
| Mininum Value | 0.3355 | 0.3705 | 0.5537 | 0.4370 | 0.3149 | 0.4175 | 0.5026 | 0.6142 | 0.4995 | 0.3445 | 0.6025 | 0.5862 | 0.4809 | 0.7498 | 0.6483 |
| Mean Value | 1.2006 | 1.8470 | 1.9039 | 1.3414 | 1.4295 | 1.5879 | 1.7160 | 1.6976 | 1.3407 | 1.3807 | 1.3392 | 1.0580 | 0.8087 | 1.2858 | 1.3889 |
| Maximum Value | 1.6655 | 2.3362 | 2.3271 | 2.0750 | 1.9303 | 1.9230 | 2.4783 | 2.1262 | 1.6825 | 2.0108 | 1.8659 | 1.5640 | 1.1653 | 1.5613 | 1.9721 |
| Std. Deviation | 0.3299 | 0.4468 | 0.4232 | 0.3344 | 0.3928 | 0.3616 | 0.5597 | 0.3570 | 0.2822 | 0.4526 | 0.3535 | 0.3120 | 0.2270 | 0.2064 | 0.3649 |

### Table A3

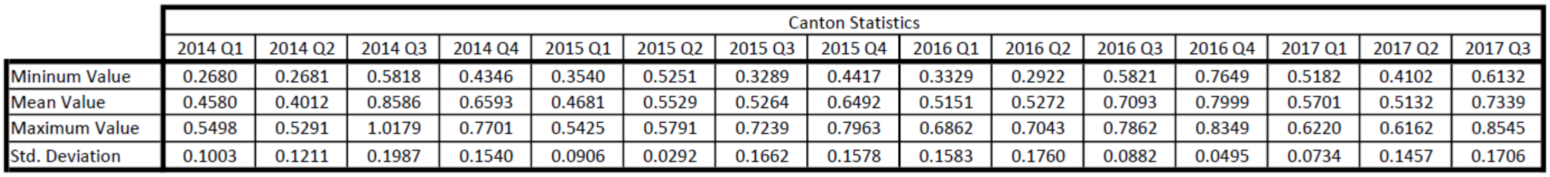
Cincinnati statistical analysis of the raw cancer exposure risk data



| | Cincinnati Statistics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 |
| Mininum Value | 0.3238 | 0.5194 | 0.3012 | 0.3269 | 0.4475 | 0.5036 | 0.3078 | 0.3003 | 0.4664 | 0.4038 | 0.2795 | 0.3116 | 0.4476 | 0.4445 | 0.4058 |
| Mean Value | 0.4828 | 0.6948 | 0.5784 | 0.6325 | 0.6694 | 0.7306 | 0.6823 | 0.5619 | 0.6865 | 0.6594 | 0.5562 | 0.5185 | 0.6904 | 0.6757 | 0.6505 |
| Maximum Value | 0.6338 | 0.9043 | 0.8963 | 0.8493 | 0.8942 | 0.9589 | 1.0787 | 0.8904 | 0.9601 | 0.9291 | 0.7855 | 0.7188 | 0.9870 | 0.9450 | 0.8521 |
| Std. Deviation | 0.0924 | 0.1354 | 0.2088 | 0.1613 | 0.1259 | 0.1295 | 0.2402 | 0.1905 | 0.1386 | 0.1722 | 0.1700 | 0.1324 | 0.1506 | 0.1578 | 0.1438 |

### Table A4

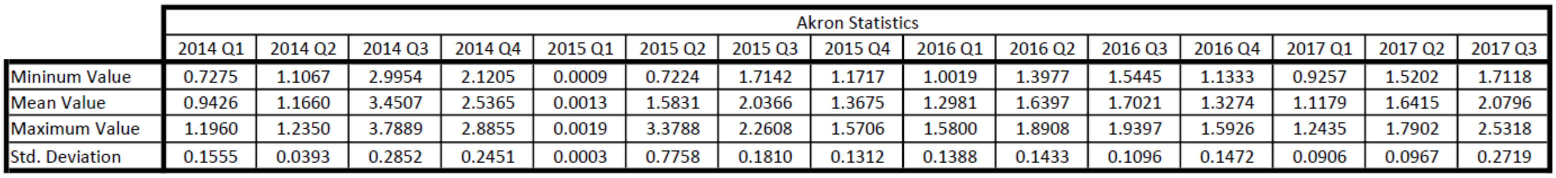
Canton statistical analysis of the raw cancer exposure risk data



| | Canton Statistics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 |
| Mininum Value | 0.2680 | 0.2681 | 0.5818 | 0.4346 | 0.3540 | 0.5251 | 0.3289 | 0.4417 | 0.3329 | 0.2922 | 0.5821 | 0.7649 | 0.5182 | 0.4102 | 0.6132 |
| Mean Value | 0.4580 | 0.4012 | 0.8586 | 0.6593 | 0.4681 | 0.5529 | 0.5264 | 0.6492 | 0.5151 | 0.5272 | 0.7093 | 0.7999 | 0.5701 | 0.5132 | 0.7339 |
| Maximum Value | 0.5498 | 0.5291 | 1.0179 | 0.7701 | 0.5425 | 0.5791 | 0.7239 | 0.7963 | 0.6862 | 0.7043 | 0.7862 | 0.8349 | 0.6220 | 0.6162 | 0.8545 |
| Std. Deviation | 0.1003 | 0.1211 | 0.1987 | 0.1540 | 0.0906 | 0.0292 | 0.1662 | 0.1578 | 0.1583 | 0.1760 | 0.0882 | 0.0495 | 0.0734 | 0.1457 | 0.1706 |

### Table A5

Akron statistical analysis of the raw cancer exposure risk data



| | Akron Statistics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 |
| Mininum Value | 0.7275 | 1.1067 | 2.9954 | 2.1205 | 0.0009 | 0.7224 | 1.7142 | 1.1717 | 1.0019 | 1.3977 | 1.5445 | 1.1333 | 0.9257 | 1.5202 | 1.7118 |
| Mean Value | 0.9426 | 1.1660 | 3.4507 | 2.5365 | 0.0013 | 1.5831 | 2.0366 | 1.3675 | 1.2981 | 1.6397 | 1.7021 | 1.3274 | 1.1179 | 1.6415 | 2.0796 |
| Maximum Value | 1.1960 | 1.2350 | 3.7889 | 2.8855 | 0.0019 | 3.3788 | 2.2608 | 1.5706 | 1.5800 | 1.8908 | 1.9397 | 1.5926 | 1.2435 | 1.7902 | 2.5318 |
| Std. Deviation | 0.1555 | 0.0393 | 0.2852 | 0.2451 | 0.0003 | 0.7758 | 0.1810 | 0.1312 | 0.1388 | 0.1433 | 0.1096 | 0.1472 | 0.0906 | 0.0967 | 0.2719 |

## Table A6

Cleveland sample site cancer exposure risk values broken down by yearly quarter

| | Cleveland Source Cancer exposure risk Values | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 | Mean | Stat Dev |
| DS201 | 1.3206 | 0.9303 | 0.8550 | 0.9987 | 0.4036 | 0.4048 | 1.1483 | 0.9630 | 0.6425 | 0.9691 | 0.9972 | 0.6825 | 0.5666 | 0.9363 | 0.8340 | 0.8435 | 0.2596 |
| DS202 | 1.2869 | 1.1471 | 0.7680 | 1.1104 | 0.5743 | 1.0424 | 0.9346 | 0.9255 | 0.7617 | 0.7324 | 0.9856 | 0.6406 | 0.4562 | 0.7915 | 0.7938 | 0.8634 | 0.2272 |
| DS203 | 1.3888 | 1.1132 | 0.8503 | 1.0286 | 0.5997 | 1.0117 | 1.1176 | 0.7317 | 0.6760 | 0.7463 | 0.9320 | 0.6188 | 0.4612 | 0.8032 | 0.7553 | 0.8556 | 0.2433 |
| DS204 | 1.0069 | 0.9823 | 0.8315 | 0.9224 | 0.6189 | 1.0772 | 1.1351 | 0.9212 | 0.5473 | 0.6694 | 0.9477 | 0.6999 | 0.6012 | 0.8149 | 0.8833 | 0.8439 | 0.1811 |
| DS205 | 1.1346 | 1.0385 | 0.9888 | 1.2144 | 0.6937 | 1.0989 | 1.2632 | 0.8700 | 0.5328 | 0.8664 | 1.0396 | 0.7095 | 0.5080 | 0.8907 | 0.7924 | 0.9094 | 0.2317 |
| DS206 | 0.9626 | 1.1249 | 0.8206 | 0.9811 | 0.7380 | 1.1626 | 1.0618 | 0.7598 | 0.6353 | 0.7878 | 0.9862 | 0.7256 | 0.5248 | 0.9506 | 0.8206 | 0.8695 | 0.1822 |
| DS207 | 0.8500 | 0.8999 | 0.6610 | 0.9433 | 0.5192 | 0.9993 | 0.7392 | 0.5734 | 0.4305 | 0.6751 | 0.7329 | 0.5406 | 0.5098 | 0.6156 | 0.6828 | 0.6915 | 0.1701 |
| DS208 | 1.0280 | 0.9418 | 0.7452 | 1.0156 | 0.5208 | 0.9233 | 1.1873 | 0.6515 | 0.3930 | 0.6092 | 0.7907 | 0.6374 | 0.3965 | 0.7099 | 0.7308 | 0.7521 | 0.2325 |
| DS209 | 1.0040 | 1.0057 | 0.9767 | 1.0296 | 0.6186 | 1.1036 | 0.9859 | 0.7956 | 0.5224 | 0.5729 | 1.0210 | 0.5974 | 0.4984 | 0.9443 | 0.7573 | 0.8289 | 0.2150 |
| DS210 | 1.1593 | 1.0074 | 0.8734 | 1.1246 | 0.6798 | 1.2055 | 1.0188 | 1.1024 | 0.7270 | 0.9447 | 1.2416 | 0.8923 | 0.5748 | 0.9508 | 0.9161 | 0.9612 | 0.1942 |
| DS211 | 1.0947 | 1.0738 | 0.7203 | 1.0735 | 0.5514 | 1.0789 | 0.9832 | 0.5995 | 0.4152 | 0.9624 | 0.8757 | 0.5539 | 0.4551 | 0.6822 | 0.6794 | 0.7866 | 0.2452 |
| DS212 | 1.4472 | 1.0502 | 1.2019 | 1.0435 | 0.6479 | 1.0699 | 1.2207 | 0.8319 | 0.5326 | 0.8953 | 1.0630 | 0.7635 | 0.5326 | 0.9323 | 0.7586 | 0.9327 | 0.2610 |
| DS213 | 1.0369 | 0.9295 | 0.7642 | 1.0586 | 0.5771 | 1.1076 | 0.9363 | 0.5927 | 0.5245 | 0.7495 | 0.9407 | 0.6861 | 0.5203 | 0.6603 | 0.8246 | 0.7939 | 0.1993 |
| DS214 | 1.0794 | 1.0919 | 0.7315 | 0.9891 | 0.6045 | 1.0800 | 0.8571 | 0.7643 | 0.5299 | 0.7181 | 0.9756 | 0.6906 | 0.5240 | 0.7666 | 0.8192 | 0.8148 | 0.1930 |
| DS215 | 1.2058 | 0.9228 | 0.5964 | 0.8932 | 0.5288 | 0.8497 | 0.8439 | 0.6310 | 0.4715 | 0.5086 | 0.9013 | 0.5830 | 0.4408 | 0.7110 | 0.6432 | 0.7154 | 0.2139 |
| DS216 | 0.9610 | 1.0649 | 0.7634 | 1.0595 | 0.6384 | 0.7935 | 0.8341 | 0.7425 | 0.4524 | 0.6112 | 1.0146 | 0.8151 | 0.4225 | 0.8874 | 0.7467 | 0.7871 | 0.1980 |

## Table A7

Columbus sample site cancer exposure risk values broken down by yearly quarter

| | Columbus Source Cancer exposure risk Values | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 | Mean | Stat Dev |
| DS201 | 1.4820 | 2.0201 | 2.3271 | 1.5794 | 1.8362 | 1.9187 | 2.4783 | 2.1262 | 1.6825 | 2.0108 | 1.8659 | 1.5640 | 1.1653 | 1.4172 | 1.8954 | 1.8246 | 0.3511 |
| DS202 | 1.1837 | 1.7326 | 1.9042 | 1.1707 | 1.4064 | 1.5299 | 1.5947 | 1.6150 | 1.3091 | 1.4513 | 1.3670 | 0.9921 | 0.7287 | 1.1419 | 1.5503 | 1.3785 | 0.3020 |
| DS203 | 1.5554 | 1.7509 | 2.0938 | 1.4719 | 1.6243 | 1.8285 | 1.9835 | 1.8717 | 1.6066 | 1.6047 | 1.5283 | 1.3225 | 0.9600 | 1.3394 | 1.6775 | 1.6146 | 0.2830 |
| DS204 | 1.2335 | 2.1163 | 2.3266 | 1.3190 | 1.8617 | 1.9230 | 2.3990 | 1.6709 | 1.5991 | 1.8537 | 1.7658 | 1.0164 | 1.0965 | 1.5613 | 1.9721 | 1.7143 | 0.4187 |
| DS205 | 0.7105 | 1.9889 | 2.2554 | 1.4031 | 1.7669 | 1.8091 | 1.6764 | 1.8923 | 1.6340 | 1.9666 | 1.7397 | 1.4953 | 1.0337 | 1.4441 | 1.3427 | 1.6106 | 0.3918 |
| DS206 | 1.6655 | 1.7312 | 2.1667 | 1.6058 | 1.9303 | 1.8414 | 2.2768 | 2.0768 | 1.4766 | 1.6131 | 1.6766 | 1.2474 | 1.1125 | 1.3742 | 1.6630 | 1.6972 | 0.3264 |
| DS207 | 1.3385 | 1.8115 | 2.2520 | 1.3073 | 1.5135 | 1.8284 | 2.0418 | 2.0155 | 1.5303 | 1.9789 | 1.5366 | 1.5495 | 1.0048 | 1.5316 | 1.5140 | 1.6503 | 0.3311 |
| DS208 | 1.0501 | 1.8127 | 1.6311 | 1.2809 | 1.1191 | 1.4860 | 1.7850 | 1.6219 | 1.1984 | 1.0377 | 1.0426 | 0.7800 | 0.5364 | 1.1432 | 1.0285 | 1.2369 | 0.3663 |
| DS209 | 1.2754 | 2.3248 | 1.7906 | 1.4620 | 1.2665 | 1.6081 | 0.5965 | 1.8310 | 1.1630 | 1.0413 | 1.1274 | 0.9406 | 0.6291 | 1.4158 | 1.1830 | 1.3103 | 0.4560 |
| DS210 | 1.4269 | 1.9279 | 1.8228 | 1.4127 | 1.1069 | 1.5249 | 1.4836 | 1.8317 | 1.2707 | 1.2113 | 1.4660 | 1.1459 | 0.8284 | 1.3338 | 1.4941 | 1.4192 | 0.2939 |
| DS211 | 1.0143 | 2.3362 | 1.9996 | 2.0750 | 1.6102 | 1.7756 | 1.3886 | 1.7570 | 1.3236 | 1.0108 | 0.8809 | 0.5862 | 0.7762 | 1.4309 | 0.9212 | 1.3924 | 0.5251 |
| DS212 | 1.0842 | 2.0823 | 1.7163 | 1.2292 | 1.2534 | 1.3063 | 2.2041 | 1.3499 | 1.1640 | 1.0753 | 0.9735 | 0.6401 | 0.4809 | 1.0571 | 1.0076 | 1.2416 | 0.4656 |
| DS213 | 1.4352 | 2.1108 | 1.7769 | 1.4577 | 1.3143 | 1.5525 | 1.6212 | 1.8191 | 1.3462 | 1.1531 | 1.1675 | 0.8704 | 0.6732 | 1.2971 | 1.2162 | 1.3874 | 0.3660 |
| DS214 | 1.1101 | 1.6167 | 1.9155 | 1.1096 | 1.5025 | 1.5324 | 1.6710 | 1.5424 | 1.2885 | 1.4802 | 1.3434 | 1.0302 | 0.7551 | 1.1809 | 1.4597 | 1.3692 | 0.2946 |
| DS215 | 1.3086 | 1.8179 | 1.9300 | 1.1408 | 1.4440 | 1.5241 | 1.7537 | 1.5267 | 1.3593 | 1.2582 | 1.3442 | 1.0468 | 0.6534 | 1.1537 | 1.6491 | 1.3940 | 0.3294 |
| DS216 | 0.3355 | 0.3705 | 0.5537 | 0.4370 | 0.3149 | 0.4175 | 0.5026 | 0.6142 | 0.4995 | 0.3445 | 0.6025 | 0.7012 | 0.5054 | 0.7498 | 0.6483 | 0.5065 | 0.1373 |

## Table A8

Cincinnati sample site cancer exposure risk values broken down by yearly quarter

| | Cincinnati Source Cancer exposure risk Values | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 | Mean | Stat Dev |
| DS201 | 0.5204 | 0.7838 | 0.5312 | 0.6354 | 0.7505 | 0.8215 | 0.7280 | 0.5284 | 0.7279 | 0.7585 | 0.5265 | 0.5136 | 0.7466 | 0.6525 | 0.6507 | 0.6584 | 0.1100 |
| DS202 | 0.5415 | 0.8113 | 0.4449 | 0.7316 | 0.6188 | 0.6241 | 0.8279 | 0.5752 | 0.6962 | 0.8130 | 0.5317 | 0.5844 | 0.8294 | 0.8137 | 0.6429 | 0.6724 | 0.1264 |
| DS203 | 0.6338 | 0.9043 | 0.7529 | 0.7351 | 0.8942 | 0.8313 | 0.8311 | 0.6227 | 0.9601 | 0.8720 | 0.7073 | 0.5629 | 0.9870 | 0.9450 | 0.8521 | 0.8061 | 0.1312 |
| DS204 | 0.5395 | 0.8057 | 0.7196 | 0.7320 | 0.7335 | 0.7620 | 0.7081 | 0.6890 | 0.7696 | 0.8209 | 0.6158 | 0.5783 | 0.7388 | 0.8346 | 0.7256 | 0.7182 | 0.0846 |
| DS205 | 0.5900 | 0.8114 | 0.7408 | 0.7293 | 0.8478 | 0.8609 | 0.7997 | 0.6307 | 0.8818 | 0.9291 | 0.7656 | 0.5784 | 0.7336 | 0.7849 | 0.6978 | 0.7588 | 0.1037 |
| DS206 | 0.3974 | 0.5194 | 0.3643 | 0.4295 | 0.6005 | 0.6649 | 0.4355 | 0.3770 | 0.5995 | 0.4706 | 0.3979 | 0.3646 | 0.5349 | 0.5029 | 0.5175 | 0.4784 | 0.0945 |
| DS207 | 0.4555 | 0.6792 | 0.8493 | 0.7986 | 0.6115 | 0.8064 | 0.9581 | 0.8904 | 0.5971 | 0.5992 | 0.7218 | 0.7177 | 0.6748 | 0.6786 | 0.8392 | 0.7252 | 0.1327 |
| DS208 | 0.3840 | 0.5727 | 0.3830 | 0.6089 | 0.5581 | 0.6198 | 0.4025 | 0.3691 | 0.5767 | 0.5081 | 0.4078 | 0.3938 | 0.5416 | 0.5144 | 0.4982 | 0.4892 | 0.0905 |
| DS209 | 0.5128 | 0.7677 | 0.8963 | 0.8493 | 0.6535 | 0.9589 | 1.0787 | 0.8732 | 0.6648 | 0.6016 | 0.7855 | 0.7188 | 0.7611 | 0.7903 | 0.8056 | 0.7812 | 0.1429 |
| DS210 | 0.4967 | 0.6193 | 0.5960 | 0.5570 | 0.7236 | 0.6614 | 0.6765 | 0.4628 | 0.7202 | 0.5923 | 0.5830 | 0.5109 | 0.7456 | 0.5973 | 0.6552 | 0.6132 | 0.0849 |
| DS211 | 0.3238 | 0.5433 | 0.3012 | 0.3269 | 0.4475 | 0.5036 | 0.3078 | 0.3003 | 0.4664 | 0.4038 | 0.2795 | 0.3116 | 0.4476 | 0.4445 | 0.4058 | 0.3876 | 0.0852 |
| DS212 | 0.3976 | 0.5201 | 0.3614 | 0.4561 | 0.5930 | 0.6526 | 0.4337 | 0.4242 | 0.5774 | 0.5440 | 0.3517 | 0.3868 | 0.5439 | 0.5492 | 0.5151 | 0.4871 | 0.0922 |

## Table A9

Canton sample site cancer exposure risk values broken down by yearly quarter

| | Canton Source Cancer exposure risk Values | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 | Mean | Stat Dev |
| DS201 | 0.5010 | 0.5291 | 0.9863 | 0.7701 | 0.5425 | 0.5791 | 0.7239 | 0.7963 | 0.6002 | 0.6043 | 0.7346 | 0.8349 | 0.6220 | 0.6162 | 0.8545 | 0.6863 | 0.1408 |
| DS202 | 0.4357 | 0.3334 | 1.0179 | 0.6858 | 0.4365 | 0.5303 | 0.4772 | 0.6155 | 0.4412 | 0.5081 | 0.7342 | 0.7649 | 0.5182 | 0.4102 | 0.6132 | 0.5682 | 0.1760 |
| DS203 | 0.5106 | 0.2681 | 0.5818 | 0.4346 | 0.3540 | 0.5772 | 0.3289 | 0.4417 | 0.3329 | 0.2922 | 0.5821 | - | - | - | - | 0.4276 | 0.1204 |
| DS204 | 0.4831 | 0.4744 | 0.8485 | 0.7469 | 0.5394 | 0.5251 | 0.5757 | 0.7433 | 0.6862 | 0.7043 | 0.7862 | - | - | - | - | 0.6466 | 0.1312 |
| DS205 | 0.5498 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.5498 | - |
| DS206 | 0.2680 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.2680 | - |

## Table A10

Akron sample site cancer exposure risk values broken down by yearly quarter

| | Akron Source Cancer exposure risk Values | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 Q1 | 2014 Q2 | 2014 Q3 | 2014 Q4 | 2015 Q1 | 2015 Q2 | 2015 Q3 | 2015 Q4 | 2016 Q1 | 2016 Q2 | 2016 Q3 | 2016 Q4 | 2017 Q1 | 2017 Q2 | 2017 Q3 | Mean | Stat Dev |
| DS201 | 1.0309 | 1.1158 | 3.6325 | 2.6511 | 0.0013 | 2.0656 | 1.9790 | 1.4890 | 1.0019 | 1.7652 | 1.6846 | 1.3069 | 0.9257 | 1.7902 | 2.1917 | 1.6421 | 0.8458 |
| DS202 | 0.8169 | 1.1402 | 3.1607 | 2.4896 | 0.0012 | 1.8925 | 1.7142 | 1.3467 | 1.3613 | 1.6077 | 1.6097 | 1.1333 | 1.1016 | 1.5793 | 1.9577 | 1.5275 | 0.7242 |
| DS203 | 0.8295 | 1.1505 | 3.6690 | 2.3672 | 0.0013 | 1.8551 | 1.8587 | 1.1717 | 1.3180 | 1.6592 | 1.6682 | 1.2389 | 1.1170 | 1.6632 | 1.7918 | 1.5573 | 0.8018 |
| DS204 | 1.1960 | 1.1067 | 2.9954 | 2.8855 | 0.0014 | 1.0706 | 2.2608 | 1.5706 | 1.3711 | 1.8908 | 1.7444 | 1.4429 | 1.0456 | 1.5216 | 2.4314 | 1.6357 | 0.7768 |
| DS205 | 1.0128 | 1.1385 | 3.7728 | 2.8703 | 0.0019 | 1.0813 | 1.9293 | 1.3738 | 1.3786 | 1.6808 | 1.6777 | 1.3646 | 1.1916 | 1.7115 | 2.0874 | 1.6182 | 0.8621 |
| DS206 | 0.7881 | 1.2175 | 3.5306 | 2.5560 | 0.0009 | 0.7224 | 1.8278 | 1.2187 | 1.2112 | 1.6188 | 1.6156 | 1.2197 | 1.1234 | 1.5856 | 2.2132 | 1.4966 | 0.8328 |
| DS207 | 0.8799 | 1.1907 | 3.7889 | 2.6832 | 0.0010 | 2.0582 | 2.2532 | 1.3656 | 1.3063 | 1.7709 | 1.7968 | 1.3433 | 1.1784 | 1.7082 | 2.1131 | 1.6958 | 0.8633 |
| DS208 | 0.9135 | 1.1892 | 3.6045 | 2.6858 | 0.0014 | 2.0627 | 2.0503 | 1.2935 | 1.2606 | 1.6524 | 1.7735 | 1.2558 | 1.1611 | 1.5938 | 1.7958 | 1.6196 | 0.8192 |
| DS209 | 0.8425 | 1.1903 | 3.5763 | 2.2413 | 0.0009 | 0.8001 | 2.2248 | 1.2160 | 1.3405 | 1.5311 | 1.5951 | 1.2023 | 1.0950 | 1.7071 | 1.8005 | 1.4909 | 0.8085 |
| DS210 | 1.1210 | 1.2350 | 3.0506 | 2.1205 | 0.0014 | 0.9724 | 2.0651 | 1.5140 | 1.5800 | 1.3977 | 1.7758 | 1.5869 | 1.2435 | 1.5406 | 1.7118 | 1.5278 | 0.6573 |
| DS211 | 0.7275 | 1.1588 | 3.4878 | 2.2679 | 0.0011 | 3.3788 | 2.0603 | 1.3363 | 1.2810 | 1.4094 | 1.9397 | 1.2421 | 1.2170 | 1.7761 | 2.5318 | 1.7210 | 0.9326 |
| DS212 | 1.1520 | 1.1584 | 3.1390 | 2.6202 | 0.0014 | 1.0379 | 2.2161 | 1.5137 | 1.1663 | 1.6927 | 1.5445 | 1.5926 | 1.0145 | 1.5202 | 2.3289 | 1.5799 | 0.7624 |

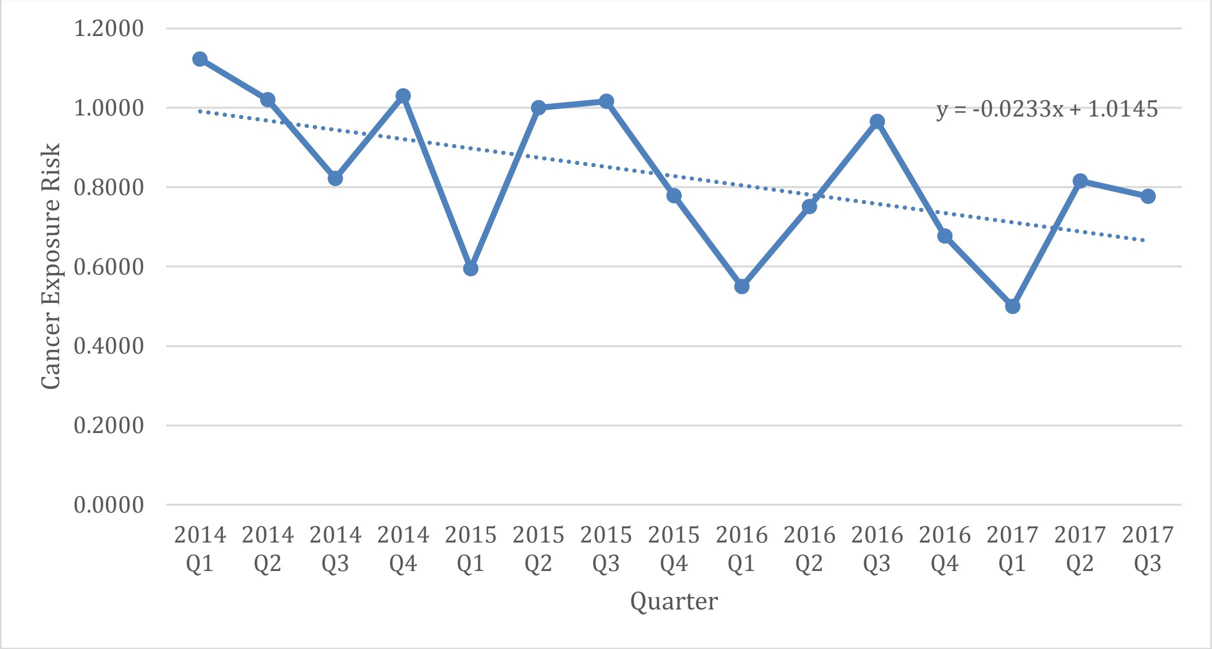


**Figure 1A** Graph of the mean cancer exposure risk over time for Cleveland with a trendline

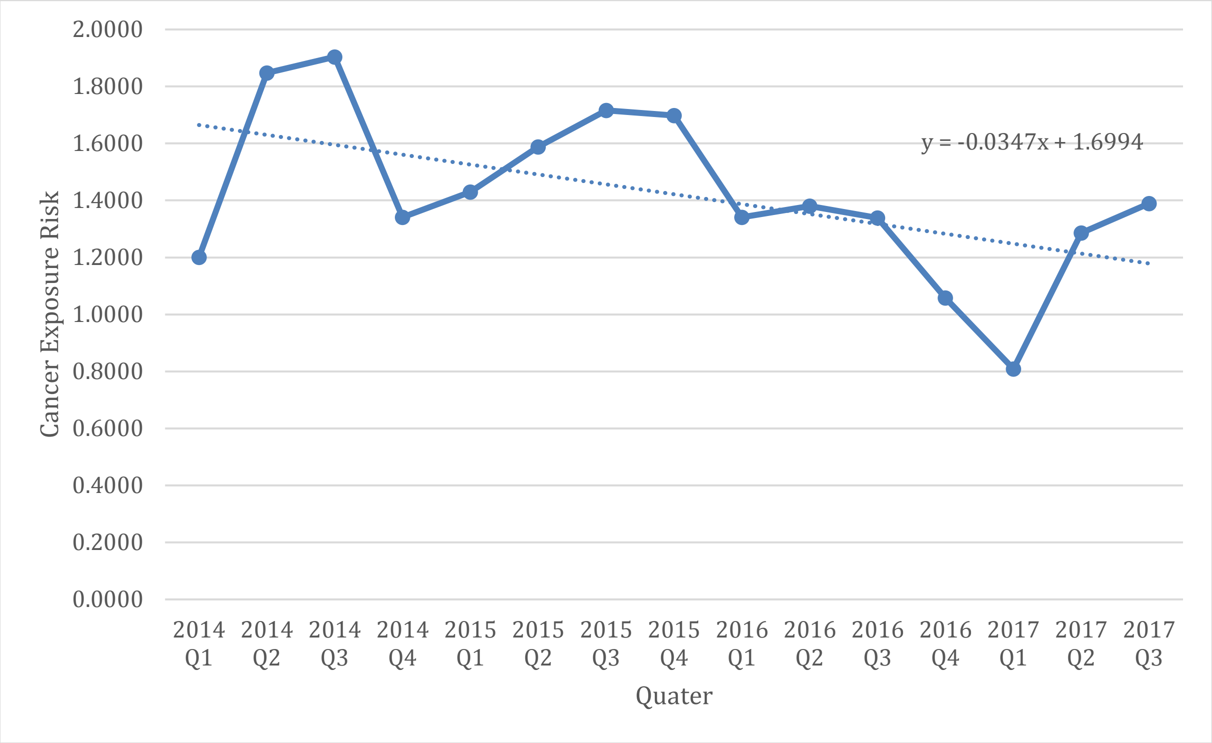


**Figure 2A** Graph of the mean cancer exposure risk over time for Columbus with a trendline

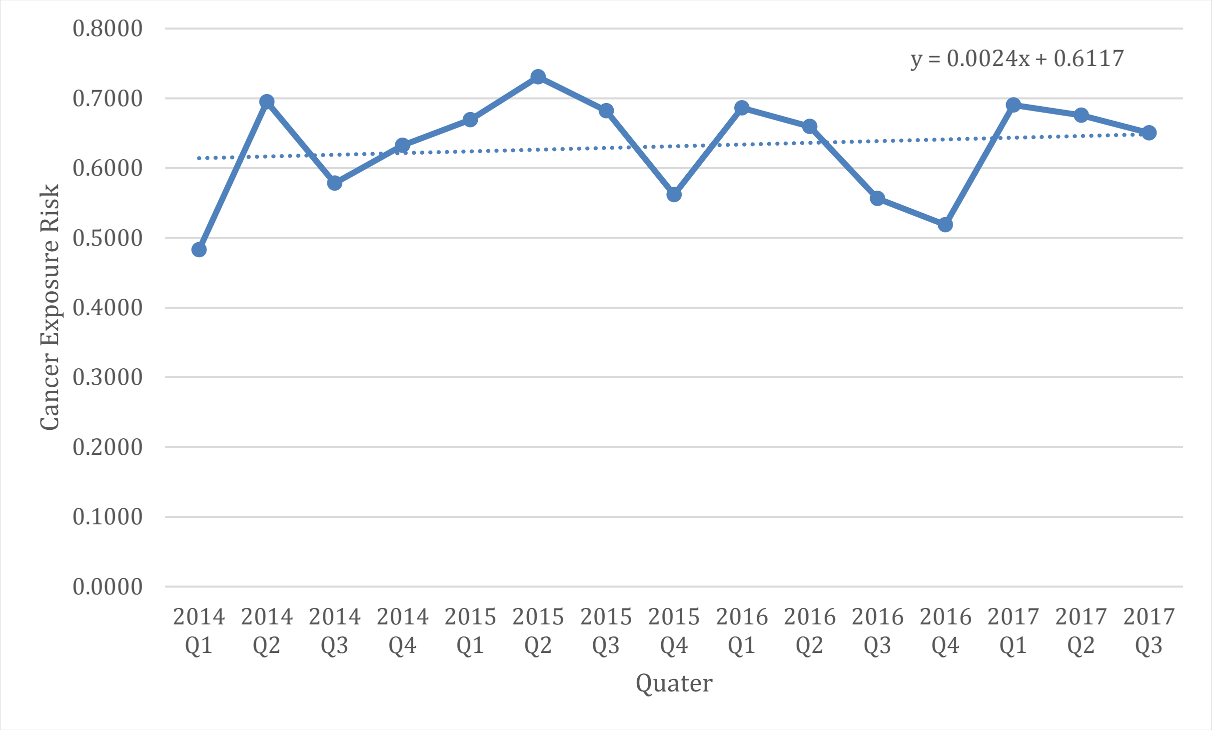


**Figure 3A** Graph of the mean cancer exposure risk over time for Cincinnati with a trendline

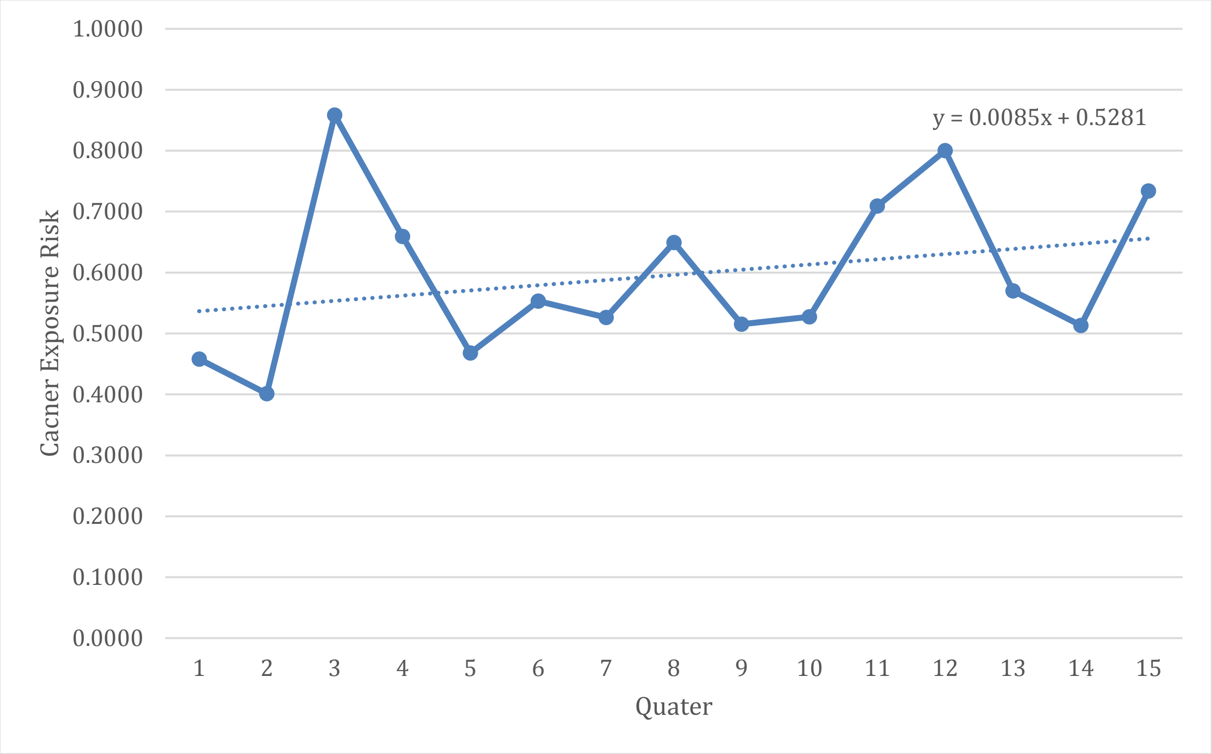


**Figure 1A** Graph of the mean cancer exposure risk over time for Canton with a trendline

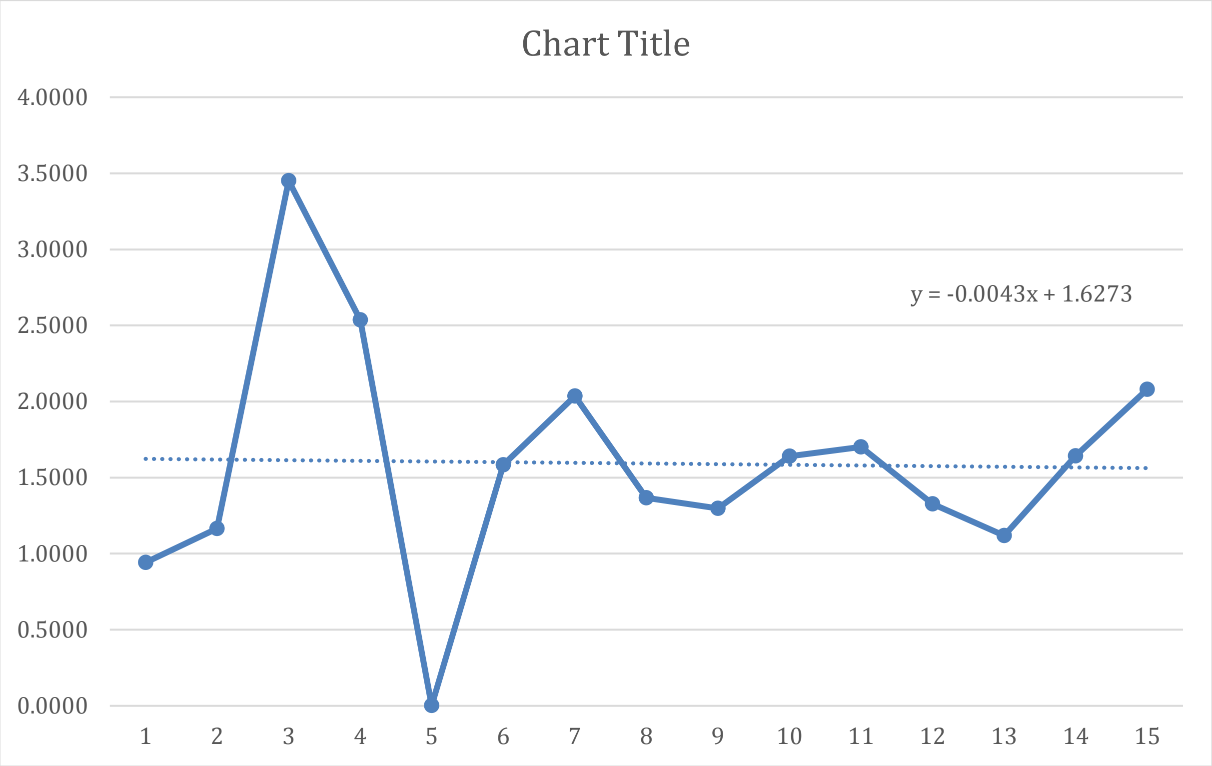


**Figure 5A** Graph of the mean cancer exposure risk over time for Akron with a trendline