Project Report: How Can Wastewater Testing be Used to Monitor Drug Consumption?

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DATA 601: **Working with Data and Visualization**

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Introduction

Monitoring drug consumption within the population is imperative for assessing drug use and its impact on the public health system. Markedly, such monitoring enables officials to address ongoing drug-related crises while also forecasting future surges. The European Union Drug Agency has described wastewater analysis to be "*a rapidly developing scientific discipline with the potential for monitoring real-time data on geographical and temporal trends in illicit drug use."* Considering that overdoses from the use of illicit drugs generally goes unreported, an effective method can be used to monitor the concentration of drug metabolites within the wastewater (EUDA, 2024). Drug metabolites are the breakdown products of the parent drug formed following metabolization, which are then typically excreted out of the body (DNA Legal, 2021). Therefore, its presence in wastewater can predict parent drug use within the population (Yi et al., 2023).

The aim of this project is to investigate if wastewater analysis can be used to support drug consumption monitoring in cities. Given the potency of using drug metabolites to monitor drug usage, this project will investigate a dataset, produced by Statistics Canada (2024), that measures the detection of drug metabolites in wastewater within seven selected Canadian cities. The ability to monitor drug consumption is a significant and necessary step towards addressing unseen drug issues (EUDA, 2024). The drugs measured in the dataset will be categorized into two categories: Prescribed and Unprescribed. Drugs that constitute as Prescribed will include Cannabis, Codeine, Fentanyl, Methadone, Morphine, and Oxycodone, as these are all classes of drugs that are typically prescribed as high-power painkillers (CCSA, 2024). Drugs that constitute as Unprescribed will include Amphetamine, Cocaine, Ecstasy, and Methamphetamine, as these are classified as illegal substances **(**RCMP, 2024). These categorizations will shed light on whether overall drug consumption is mostly composed of illegal or legal drug usage. It is important to note that this dataset can only be used as a prediction, which is a limitation of this research (Perez-Iracheta & Oliver, 2024). In simpler terms, although there is a correlation between the level of drug detection in the wastewater and the consumption of the parent drug within the city, it would be inappropriate to deduce causation between the two. Other factors that can alter these results must also be considered, such as the dumping of drugs (Perez-Iracheta & Oliver, 2024). This project will provide valuable support to other initiatives led by Statistics Canada, particularly to those focused on the city's economic and social statistics including public health and lifestyle conditions (Statistics Canada, 2024).

Dataset & Guiding Questions

The data on "Drug Metabolites in Wastewater in select Canadian Cities, by month, 2022 to 2023" focuses on the detection amounts of different drug metabolites in the wastewater of several cities in Canada (Statistics Canada, 2024). The seven cities included in this study are Halifax, Montreal, Toronto, Prince Albert, Saskatoon, Edmonton, and Vancouver. This data will be used to estimate the levels of drug consumption by detecting various drug metabolites found in wastewaters. It is important to note that the

values presented in the dataset are estimates of the amount of drug metabolites excreted into the wastewater, so it does not directly create a causal link to the total consumption levels of the specific drug. However, inferences and predictions of consumption levels can still be made. The dataset is structured and in tabular format consisting of 1111 rows and 13 columns (Statistics Canada, 2024).

The dataset was completed by collecting wastewater samples from wastewater treatment plants in each city. The number of treatment plants in each city is as follows: Halifax (3), Montreal (2), Toronto (4), Prince Albert (1), Saskatoon (1), Edmonton (1) and Vancouver (5) (Statistics Canada, 2024). Samples were collected for seven consecutive days, every 24 hours, starting every second Monday of the month for the year 2022 and every second Wednesday for the year 2023. The collected water samples were then analyzed by mass spectrometry at the Health Canada's Regulatory Operations Enforcement Branch to measure the concentrations of drug metabolites in daily loads per capita. This is done by calculating the total volume of influent arriving at each treatment plant on the day of sampling and the estimated population in the sewer shed (based on 2021 Statistics Canada Census Population).

The guiding questions that were investigated using the dataset are the following:

1. Which drug metabolites are readily detected in wastewater across all seven Canadian cities?

   It is important to be aware of the magnitude of the level of drugs detected in the wastewaters for many reasons. Observing the magnitude helps city officials and federal agencies plan financially, as well as forecast the demand for social services and resources.

2. What are the top three cities that have the highest total overall detection of drug metabolites?

   Determining the top three cities with the highest level of drug metabolites can shed light onto communities that are most vulnerable to drug use. In doing so, analyzing monthly patterns can help cities identify periods of increased drug activity and understand seasonal variations in drug usage. Investigating a correlation between the seasons and drug consumption could potentially help the city to prepare for increases in drug use by incorporating more resources and care during specific times of the year.

3. In the top three selected cities, is the estimated drug consumption primarily driven by prescribed or unprescribed substances? Additionally, which drug is the leading contributor to the overall detection levels?

   Differentiating between prescribed and unprescribed drug metabolites is extremely important to avoid making assumptions regarding illicit drug use within the observed data. Dividing the data into prescribed and unprescribed drug use can assist city officials in identifying underlying drug-related issues. That can help determine whether overprescribing by healthcare providers is

contributing to the problem or inform law enforcement of the presence of potential illicit drug distributors within the city.

4. Is there a correlation between Unprescribed and Prescribed drugs? Additionally, is there a correlation between prescribed drug metabolites themselves, as well as between unprescribed drug metabolites?

   Determining whether a correlation exists between drugs is important in investigating if a pattern of potential consumption appears within that population of interest. If a correlation occurs between an unprescribed and prescribed drug, then this may indicate that certain prescribed medications are being illegally distributed for illicit use. It may also indicate whether certain combination of drugs is leading to increased dependency. This can help city officials and law enforcement to control prescription practices, focus on certain interventions efforts, and target specific drugs contributing to health issues.

Data Exploration

The dataset had 16 columns out of which four were selected: Ref Date, Geo, Measure, and Value. The rest of the columns had the same values for all the rows therefore they were left untouched. The column 'Ref Date' represents the date on which samples were collected, 'Geo' contains the city name in which samples were collected, 'Measure' portrays the type of drug detected, and 'Value' being the amount of drug detected in milligrams/1000/per day.

Data wrangling was performed on the Ref Date column and the values were fixed to a proper format, as it initially had values like 'Jan 22', 'Feb 22' and so on. When converted to Datetime, Ref Date values were showing '2024 Jan 22'. This was incorrect as '22' was representing the year 2022 and not the day in the dataset. Regular expressions were used to fix this problem, and it added 20 before the 22 and 23 in the Ref Date column. The values were finally fixed to the correct format i.e. 'Jan 2022', and 'Mar 2023', representing the true months and year.

The second hurdle was to handle the missing values. Data was missing for the first two months (January 2022 and February 2022) for Prince Albert, Saskatchewan and six months of data was missing for Saskatoon, Saskatchewan. Upon doing exploratory data analysis, it was observed that Prince Alberta had the highest drug detection rate among all cities. To make the analysis consistent, the data from January 2022 and February 2022 were removed for all drugs in all cities, and Saskatoon was removed from the analysis to ensure consistency and reliability. Since this data was retrieved from a scientific experiment, it was not appropriate to replace the missing values in both cities with means. This would have had no meaning in analyzing the data, thus decreasing the credibility of the final analysis.

Finally, a Prescribed column has been added to the dataset, which contains two categorical values describing if the drug is “Prescribed” or “Unprescribed”. This categorization is based on drug information given in the introduction. This column is used to determine drug concentration driven by prescribed and unprescribed compounds in top 3 cities and to perform linear regression.

Analysis

Guiding Question #1 Analysis: Which drug metabolites are readily detected in wastewater across all seven Canadian cities?

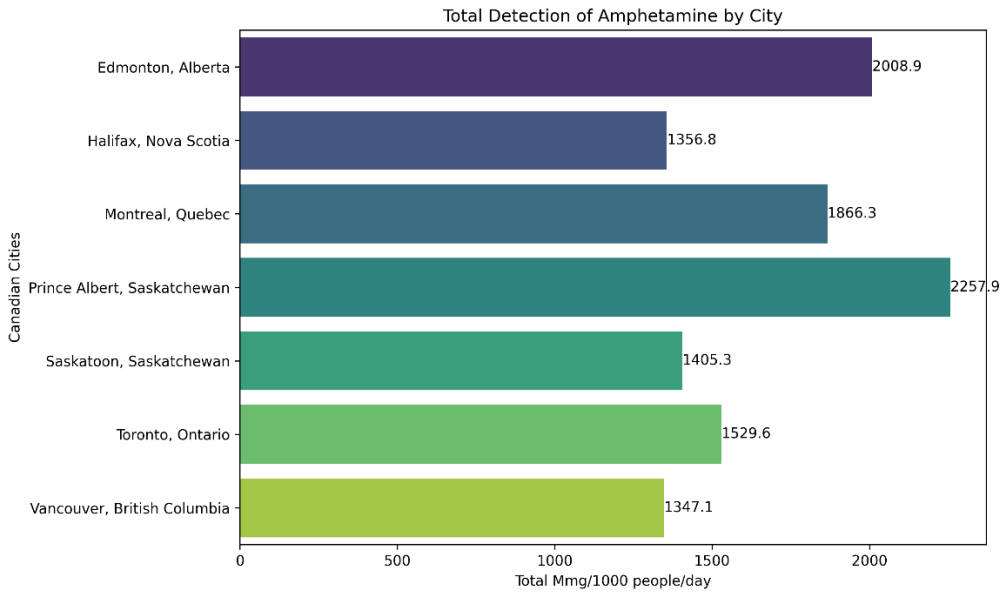

Figure 1: Total Detection of Amphetamine in different cities of Canada.

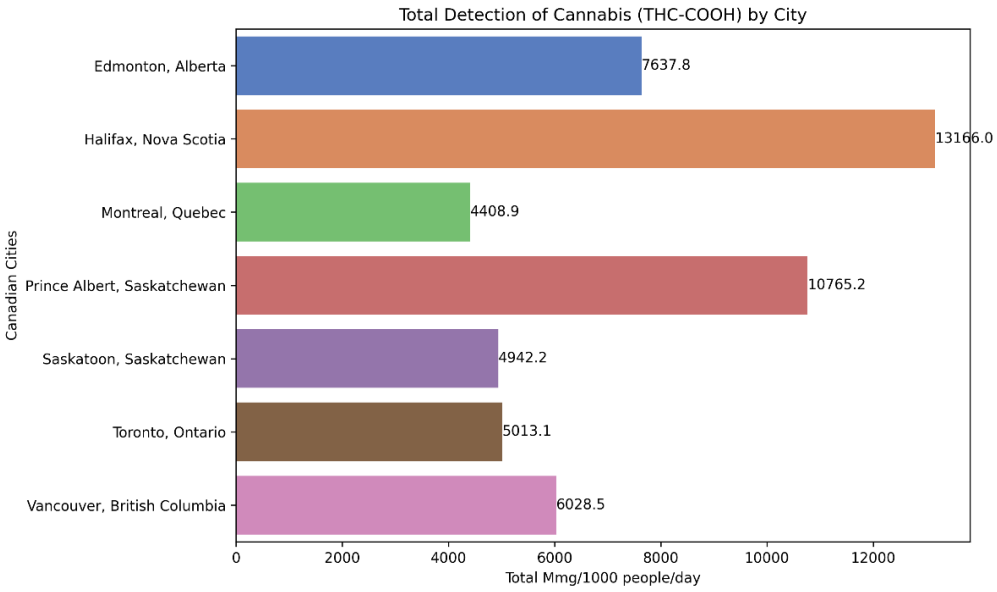

Figure 2: Total Detection of Cannabis in different cities of Canada.

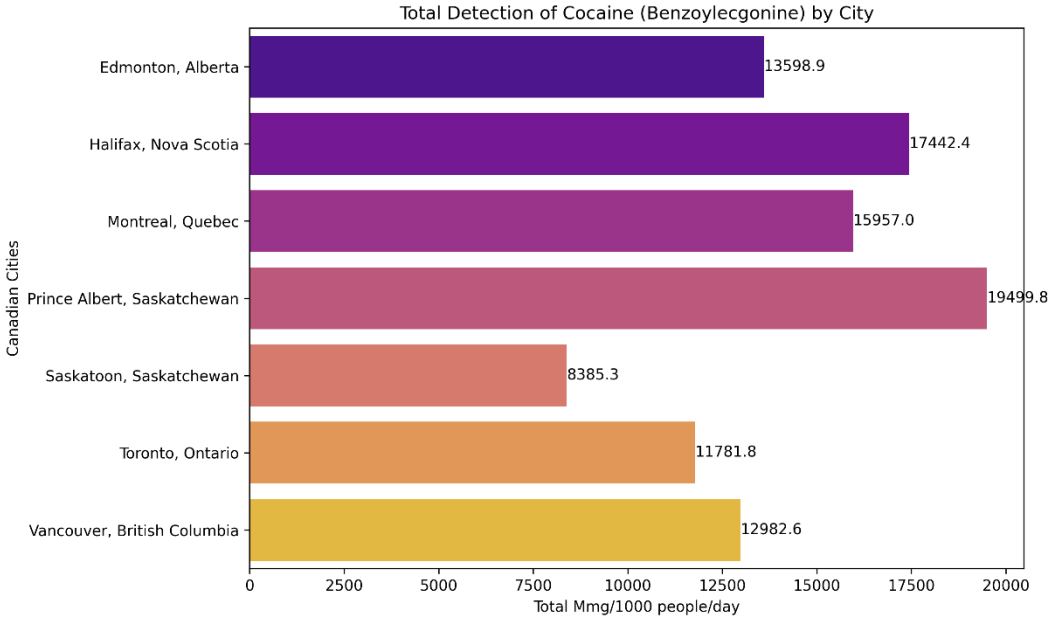

Figure 3: Total Detection of Cocaine in different cities of Canada.

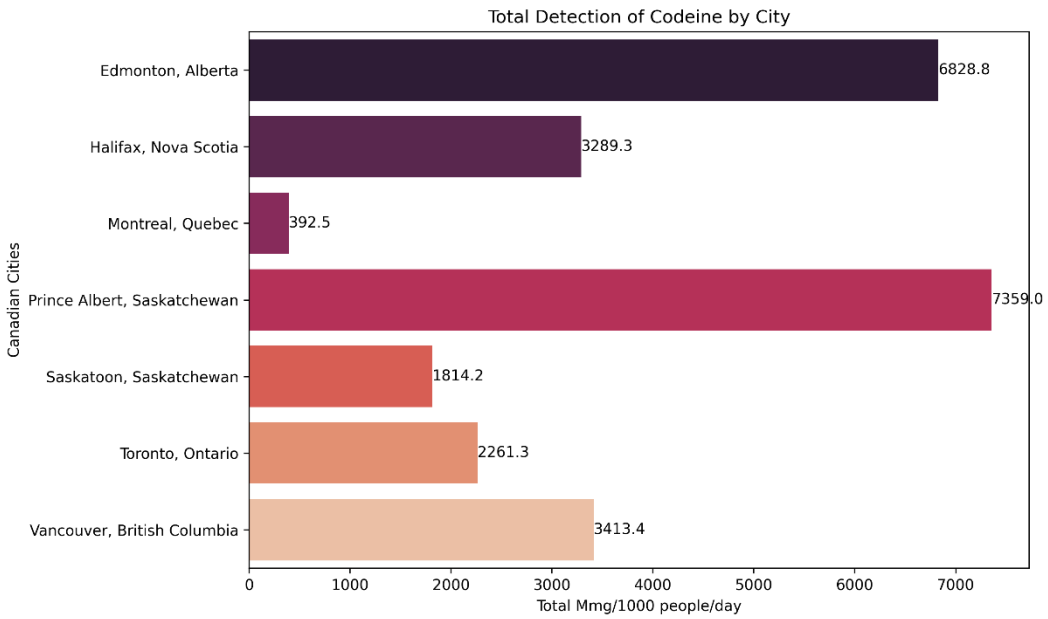

Figure 4: Total Detection of Codeine in different cities of Canada.

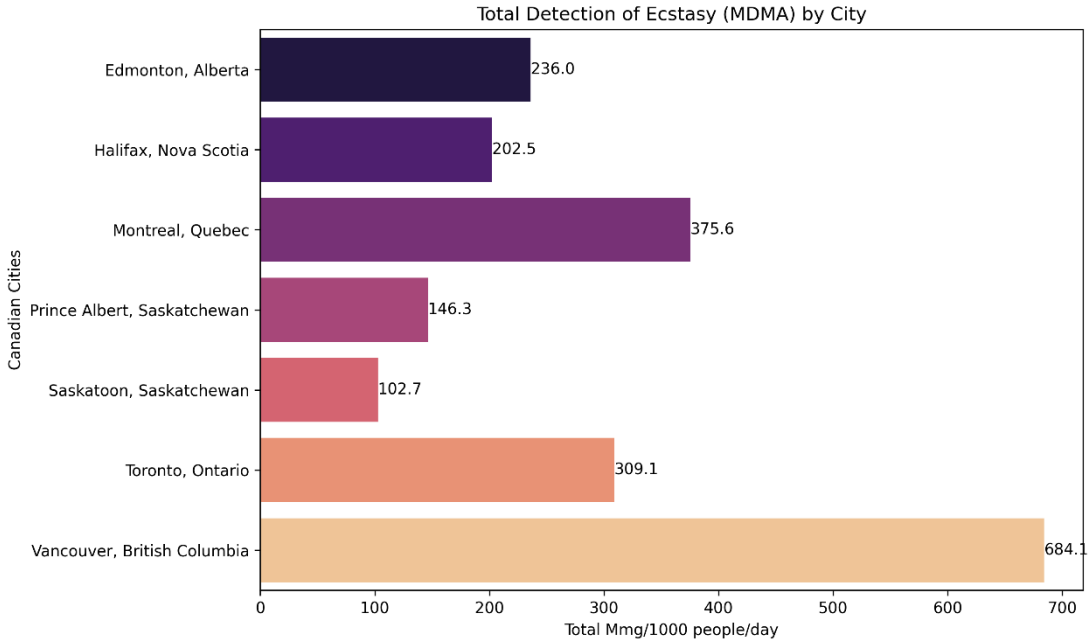

Figure 5: Total Detection of Ecstasy in different cities of Canada.

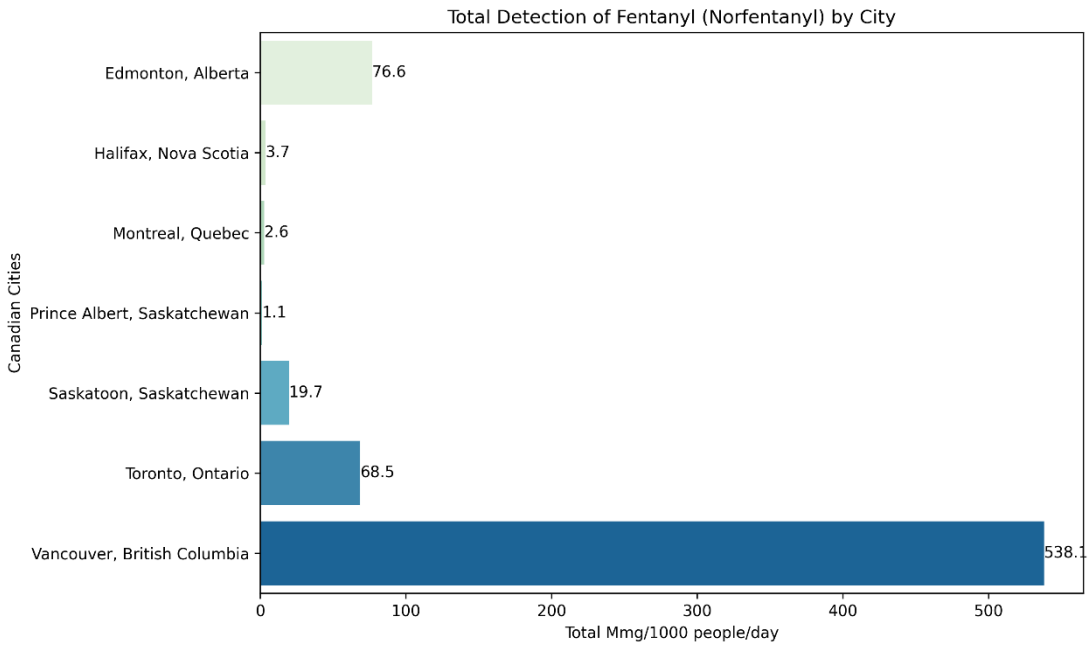

Figure 6: Total Detection of Fentanyl in different cities of Canada.

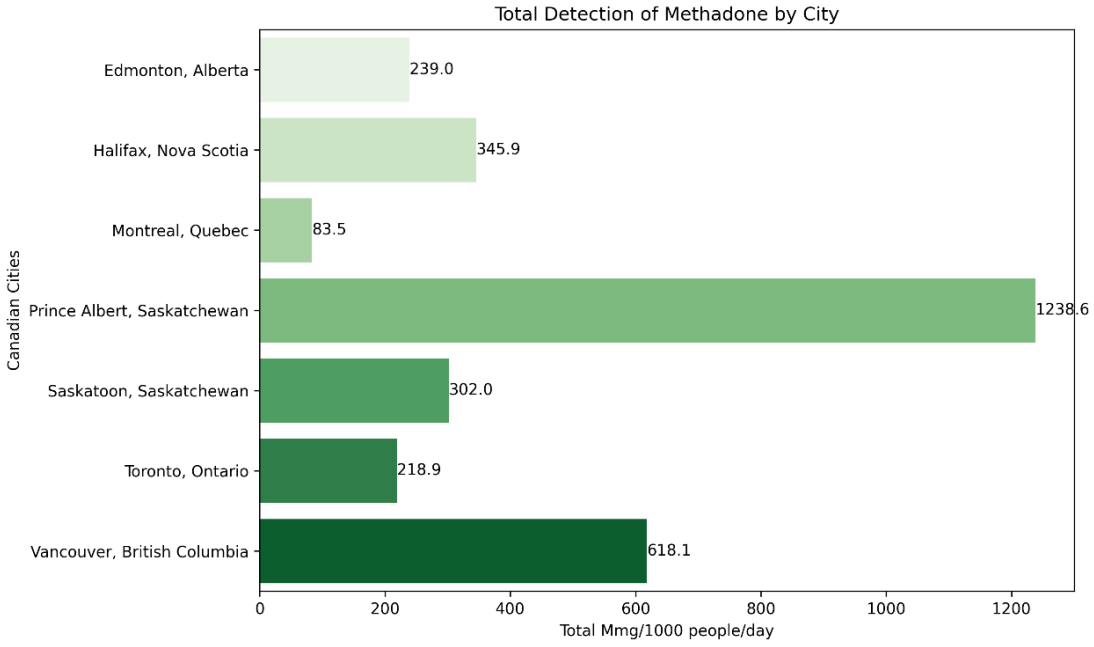

Figure 7: Total Detection of Methadone in different cities of Canada.

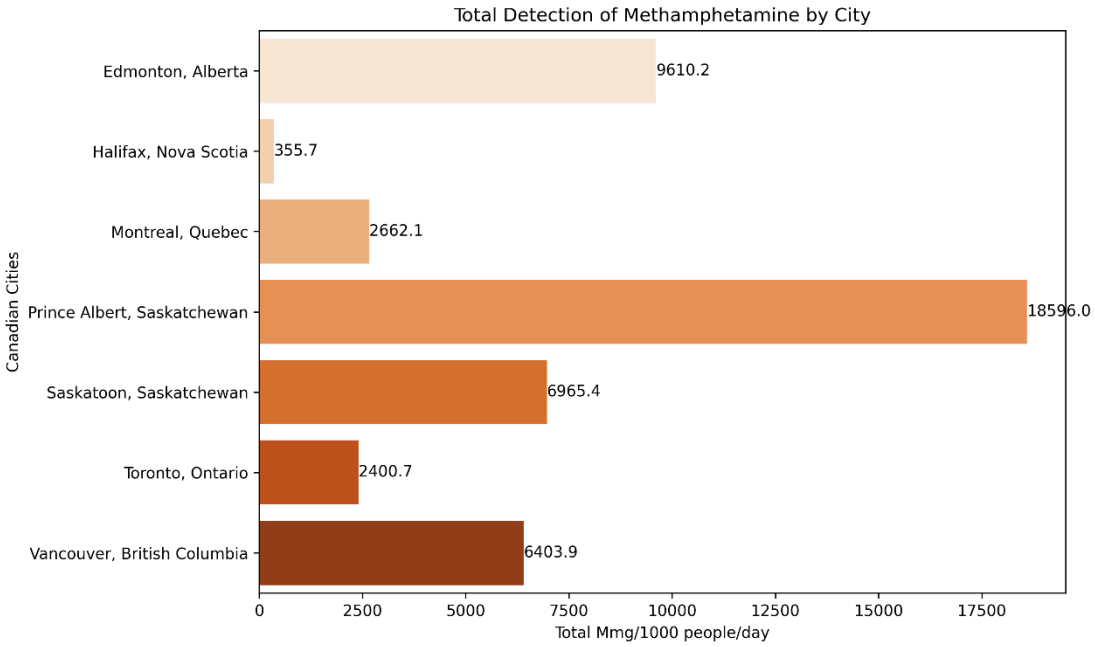

Figure 8: Total Detection of Methamphetamine in different cities of Canada.

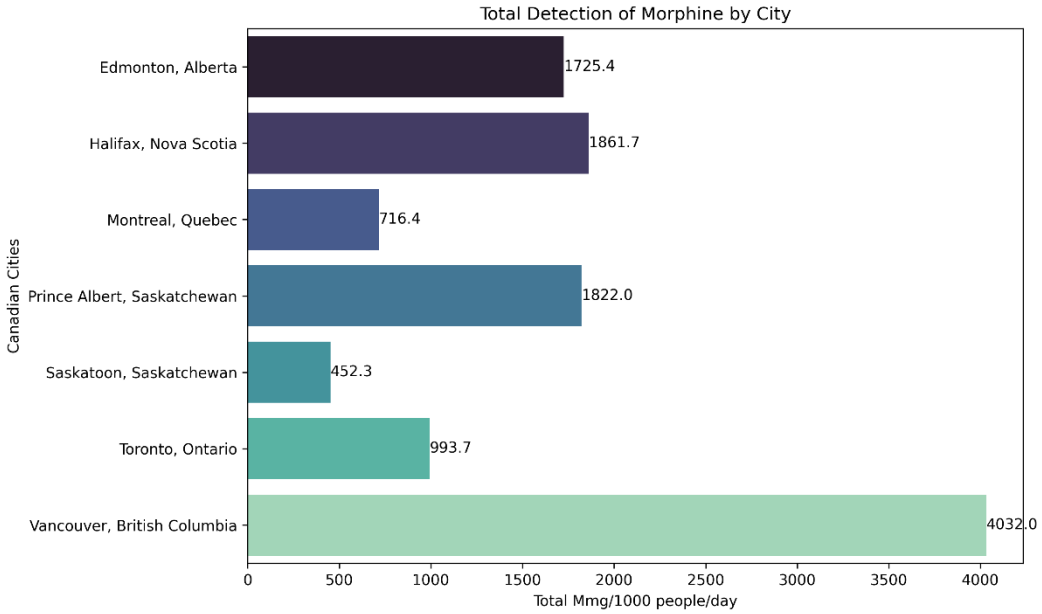

Figure 9: Total Detection of Morphine in different cities of Canada.

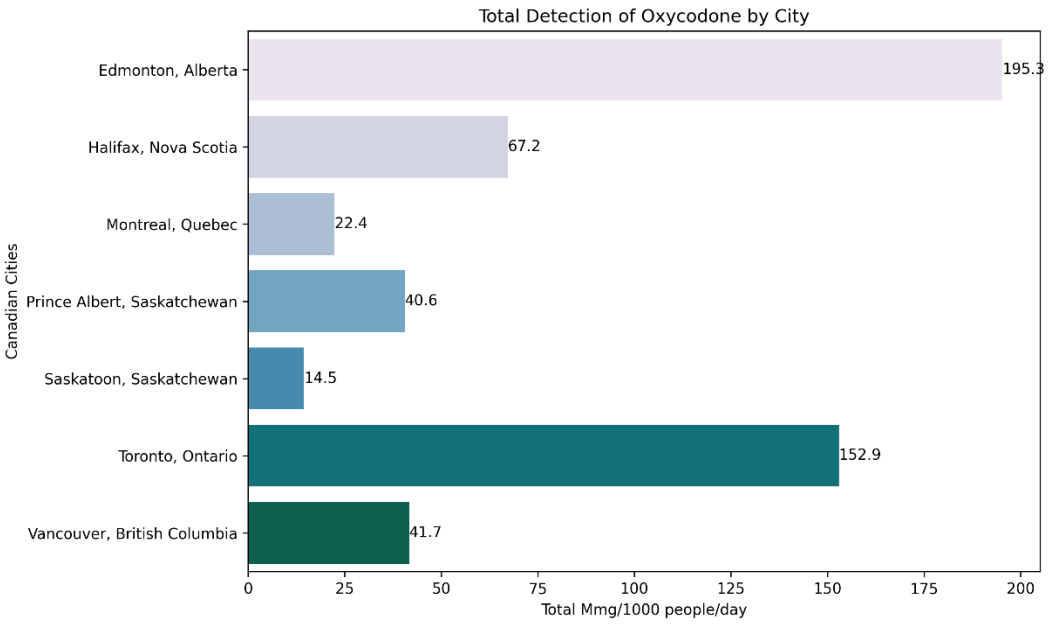

Figure 10: Total Detection of Oxycodone in different cities of Canada.

To see the comparison of the drug metabolites detected in the wastewater across all seven cities, a bar chart was plotted for each drug. The concentration in mg/1000 people/day was on the x-axis and the list of cities on the y-axis. Figures 1-10 displays the bar charts for the 10 drugs that were detected within this study.

Analysis revealed that Cocaine had the highest detection amount of 19,499.8 mg/1000 people/day, in comparison to the other drugs (Figure 3). This occurred in the city of Prince Albert. The second highest was Methamphetamine with a concentration of 18,596.0 in Prince Albert as well (Figure 8). The third highest was Cannabis with a concentration of 13,166.0 in Halifax (Figure 2). Out of the 10 drugs that were detected throughout Canada, Prince Albert took the lead in 5 drugs in the following order: Cocaine, Methamphetamine, Cannabis, Codeine, Amphetamine and Methadone. Vancouver led in 3 drugs, all categorized as unprescribed drugs: Morphine, Ecstasy and Fentanyl. Looking at Canada, overall, Cocaine had the highest detection in all cities with Cannabis and Methamphetamine interchanging for second place, except for in Halifax. In Halifax the second most detected drug is Cannabis followed by Codeine.

Guiding Question #2 Analysis: What are the top three cities that have the highest total overall detection of drug metabolites?

Average Drugs Detected in each City

City	Mean
Edmonton, Alberta	324.28
Halifax, Nova Scotia	293.01
Montreal, Quebec	203.75
Prince Albert, Saskatchewan	474.82
Toronto, Ontario	190.23
Vancouver, British Columbia	277.61

Table 1: Total Detection of all Drug Metabolites Across Seven Canadian Cities Over 13 Months

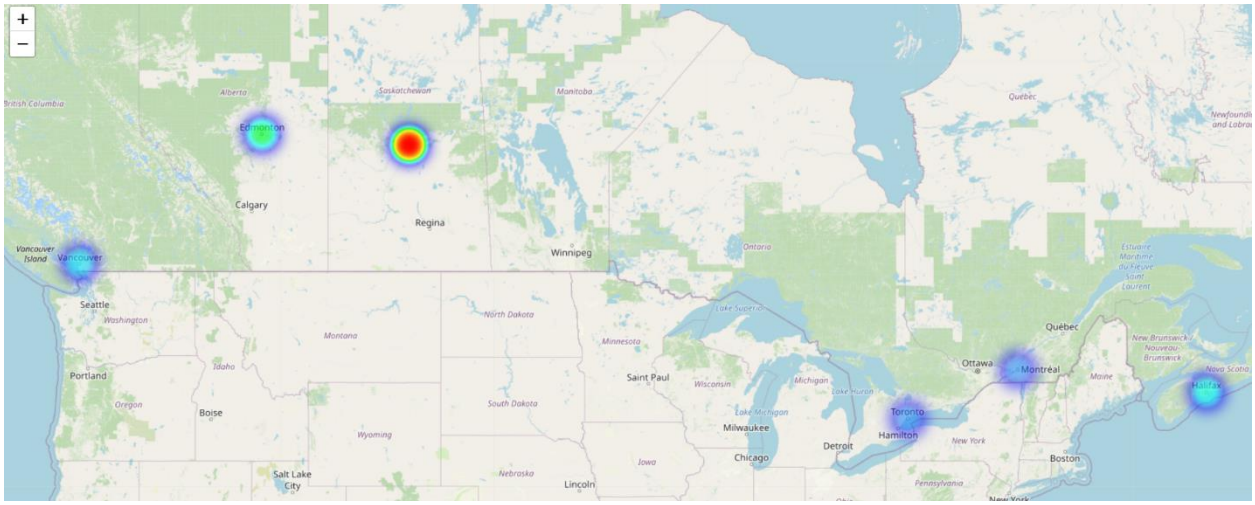

Figure 11: Folium map indicating the total detected amounts in all seven Canadian cities being analyzed.

Table 1 was created to summarize the mean amount of drug metabolites detected per month across the seven Canadian cities over the course of 13 months. The units used were mg/1000 people/day. This was done to identify the top three cities that had the most drug metabolite detection in the study. Based on Table 1, the top three cities with the highest overall detection of drug metabolites were Prince Albert, Edmonton and Halifax, with concentrations of 474.81 mg/1000 people/day, 324.28 mg/1000 people/day and 293.01 mg/1000 people/day, respectively. Figure 11 shows the monthly trend of drug detection in the top three cities: Prince Albert, Edmonton and Halifax.

Folium, a python library to create interactive visualizations is used here to plot the heat map that represents the geospatial data. Folium provides markers and shapes to represent the location. Here, Latitude and Longitude points are used to specify markers at each location. Folium allows to create and save its visualizations in .html file. So, it can be explored in depth opening it on a web page.

Click here Explore the Heat Map to view the Interactive Heat map.

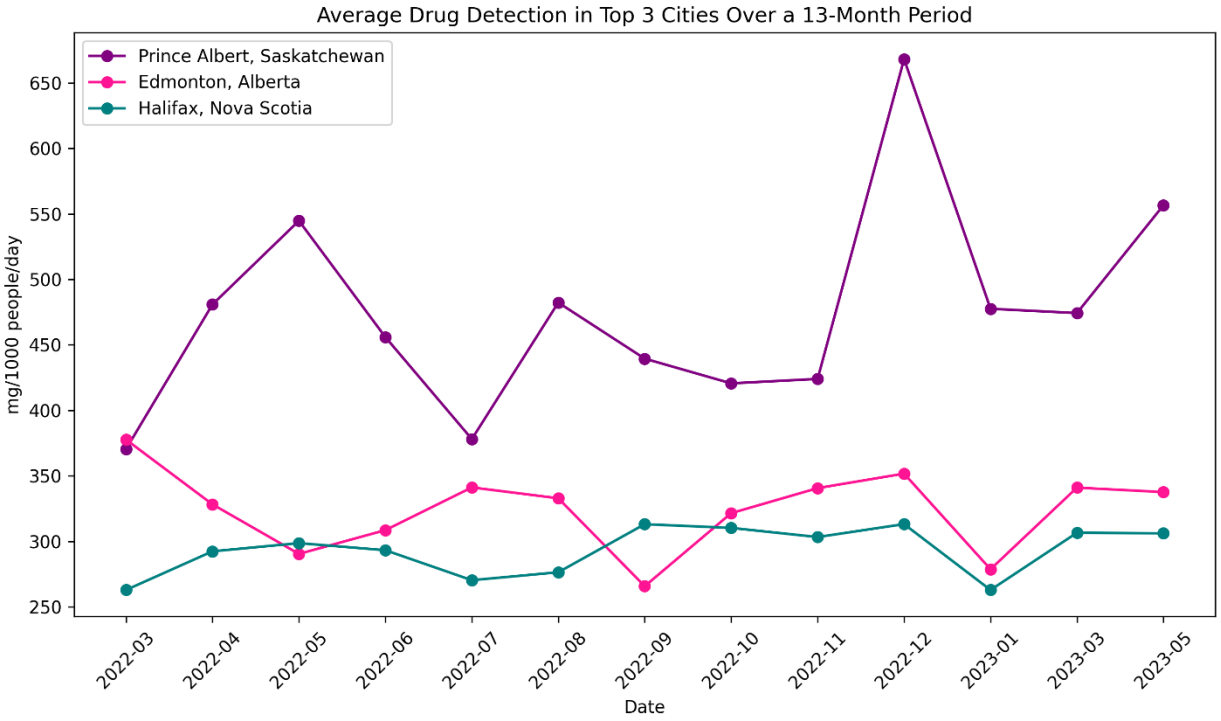

Figure 11*1*: Line graph displaying the monthly trend of the average detection of drugs in the top three cities.

Guiding Question #3 Analysis: In the top three selected cities with highest overall drug detection, is the estimated drug presence primarily driven by prescribed or unprescribed substances? Additionally, which drug is the leading contributor to the overall detection levels?

Figure 12*2*: A tree map comparing the detection of Unprescribed drug metabolites with Prescribed Drug detection in the top three cities with highest overall drug metabolite detection.

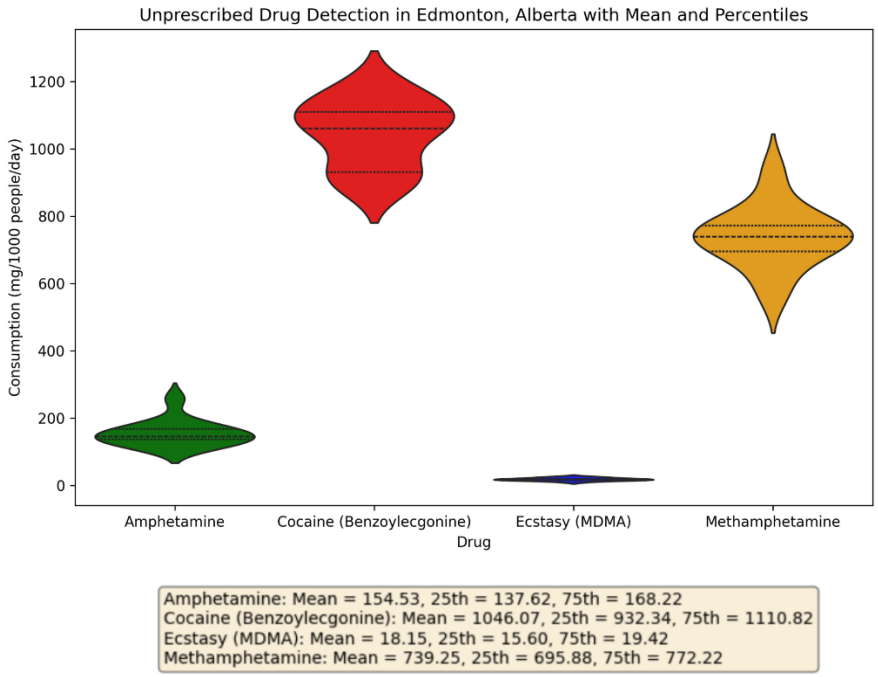

Figure 13*3*: Violin plot of Unprescribed drug detection in Edmonton, Alberta with mean and percentiles.

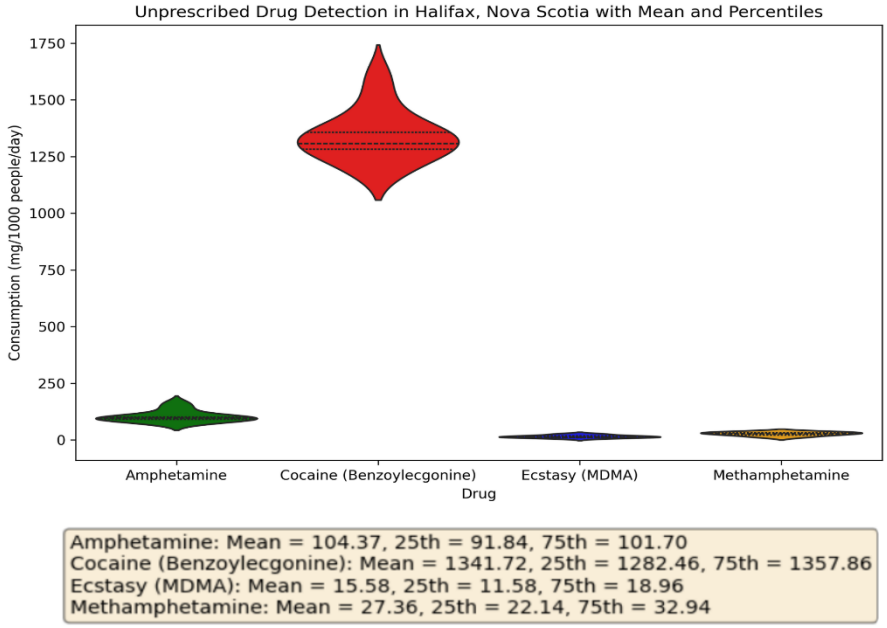

Figure 14*4*: Violin plot of Unprescribed drug detection in Halifax, Nova Scotia with mean and percentiles.

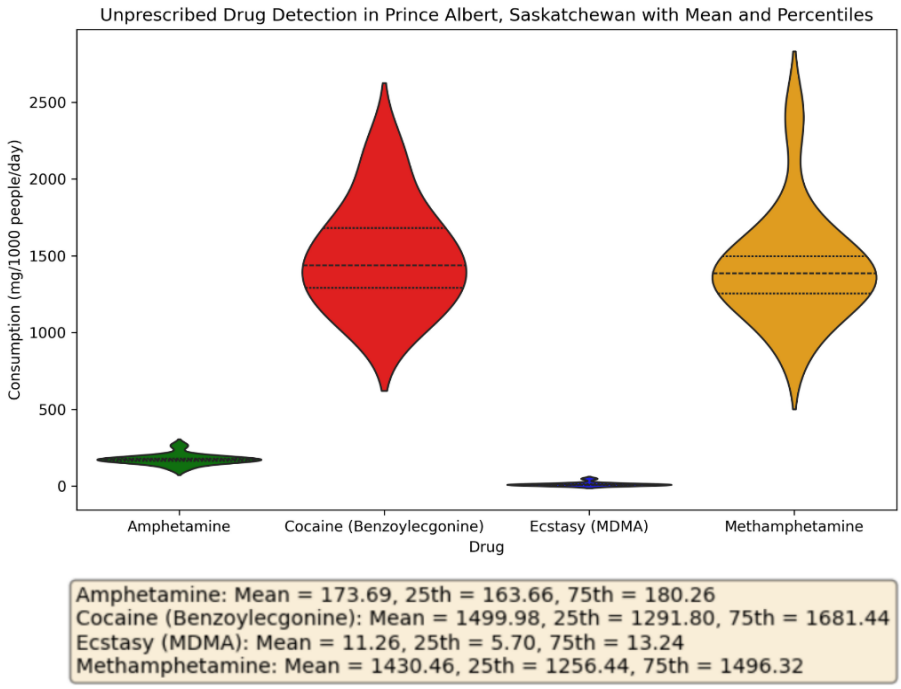

Figure 15*5*: Violin plot of Unprescribed drug detection in Prince Albert. Saskatchewan with mean and percentiles.

Unprescribed to Prescribed Ratios by City

City	Unprescribed to Prescribed Ratio
Edmonton, Alberta	1.52
Halifax, Nova Scotia	1.03
Montreal, Quebec	3.71
Prince Albert, Saskatchewan	1.91
Toronto, Ontario	1.84
Vancouver, British Columbia	1.46

Table 2 *1*: The ratio of detected Unprescribed to detected Prescribed drugs across six Canadian cities.

Given the results obtained from Guiding Question 2, the top three cities that had the highest overall drug metabolite detection were Prince Albert, Edmonton, and Halifax. To ascertain whether drug detection within the top three cities is influenced more by Unprescribed drug detection and Prescribed drug detection, a tree map was created to properly visualize these relationships in Figure 12. The use of a tree map was chosen because it allows for comparison between drug-type detection between the three cities, as well as subdividing the detection into the specific Unprescribed and Prescribed drugs that make up the entire category. Figure 12 reveals that overall drug metabolite detection in the top three cities was primarily driven by Unprescribed drug metabolite presence; Cocaine and Methamphetamine were the two of the most frequently detected Unprescribed drugs in each of the top three cities. In terms of Prescribed drugs metabolite concentration, Cannabis and Codeine were the two most frequently detected Prescribed drug in each of the top three cities.

The tree map in Figure 12 revealed that overall drug metabolite presence is driven by the detection of Unprescribed drug metabolites in the top three cities with the highest overall drug metabolite presence in the wastewater. To investigate this matter further, violin plots were created to quantify which specific Unprescribed drug metabolite was found at the highest concentration within these three cities; these plots were chosen due to its ability to allow for comparison between discrete factors, while also shedding light on information pertaining to percentiles. Figure 13 portrays the mean detection of Unprescribed drugs within Edmonton, Alberta over the course of 13 months, and reveals that Cocaine had the highest mean, with a value of 1046.07 mg/1000 people/day. This is followed by Methamphetamine, Amphetamine and Ecstasy, which had values of 739.25 mg/1000 people/day, 154.53 mg/1000 people/day and 18.15 mg/1000 people/day, respectively. Figure 14 displays the mean detection of Unprescribed drugs within Halifax, Nova Scotia over the course of 13 months, and exhibits that Cocaine had the highest mean, with a value of 1341.72 mg/1000 people/day. This is followed by Amphetamine, Methamphetamine and Ecstasy, which had values of 104.37 mg/1000 people/day, 27.36 mg/1000 people/day and 15.58 mg/1000 people/day, respectively. Figure 15 visualizes the mean detection of Unprescribed drugs within Prince Albert, Saskatchewan over the course of 13 months, and reports that Cocaine had the highest mean, with a value of 1499.98 mg/1000 people/day. This is followed by Methamphetamine, Amphetamine and Ecstasy, which had values of 1430.46 mg/1000 people/day, 173.69 mg/1000 people/day and 11.26 mg/1000 people/day, respectively.

Table 2 was created to visualize the ratio between Unprescribed drug detection and Prescribed drug detection across all seven cities. The values were obtained by taking the mean concentration of detected Unprescribed drug metabolites and dividing it by the mean concentration of detected Prescribed drug metabolites for each city. The question of which drug type, Unprescribed or Prescribed, is the leading contributor to overall drug detection levels across the seven cities, can be answered from the table, as values greater than one depict Unprescribed drug metabolites being present in greater quantities than Prescribed drugs metabolites, and values less than one reveal Prescribed drug metabolites being found in larger quantities than Unprescribed drugs. From Table 2, cities organized from highest ratio to lowest is Montreal, with a ratio of 3.71, Prince Albert, with a ratio of 1.91, Toronto, with a ratio of 1.84, Edmonton, with a ratio of 1.52, Vancouver, with a ratio of 1.46 and finally Halifax, with a ratio of 1.03.

Given the results, it can be concluded that Unprescribed drug metabolites are the leading contributors to overall detection levels.

Guiding Question #4 Analysis: Is there a correlation between Unprescribed and Prescribed drugs? Additionally, is there a correlation between prescribed drug metabolites themselves, as well as between unprescribed drug metabolites?

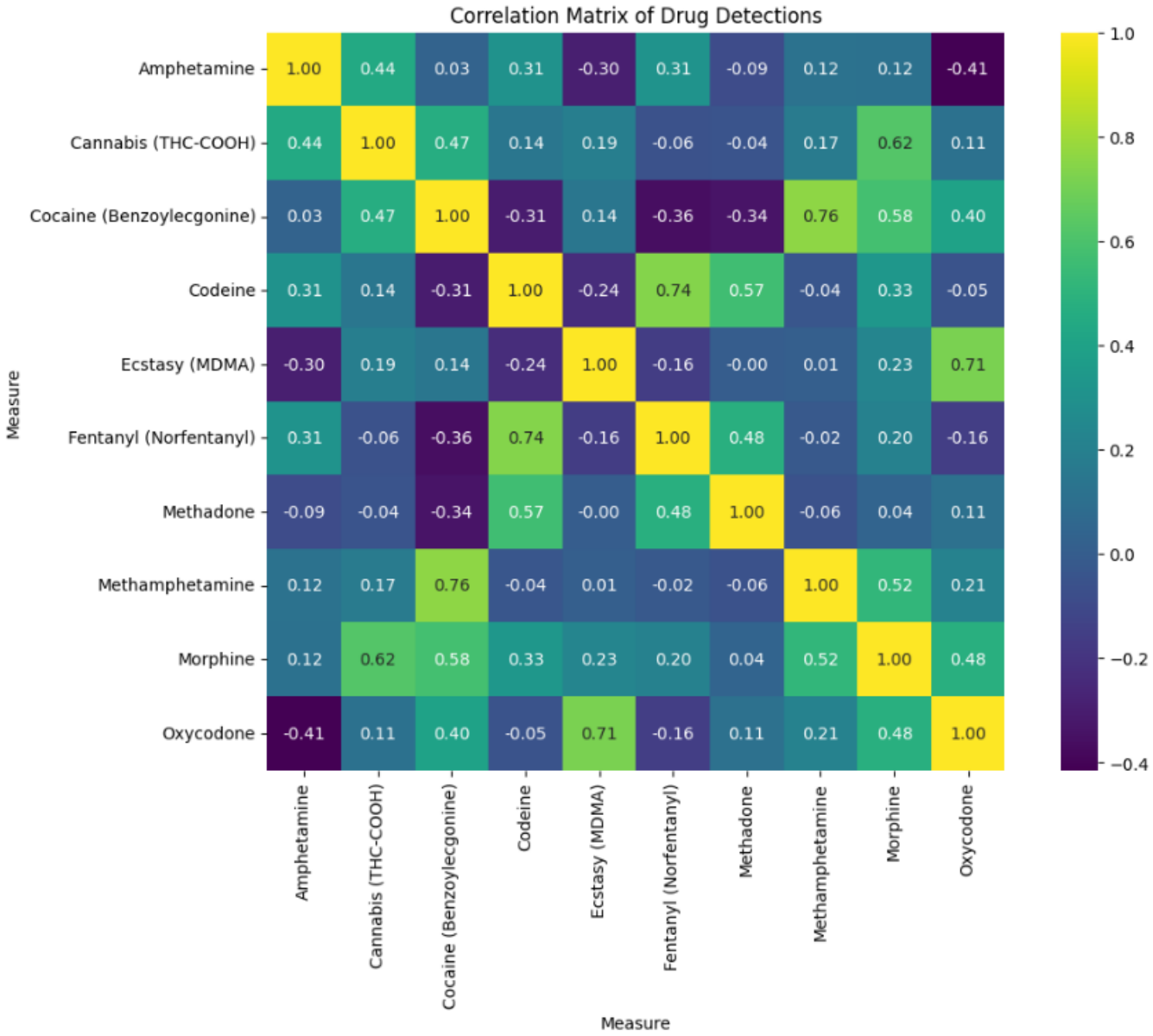

Figure 16:6 A correlation matrix representing the concentration levels of drug metabolites in wastewater (mg/1000 people/day).

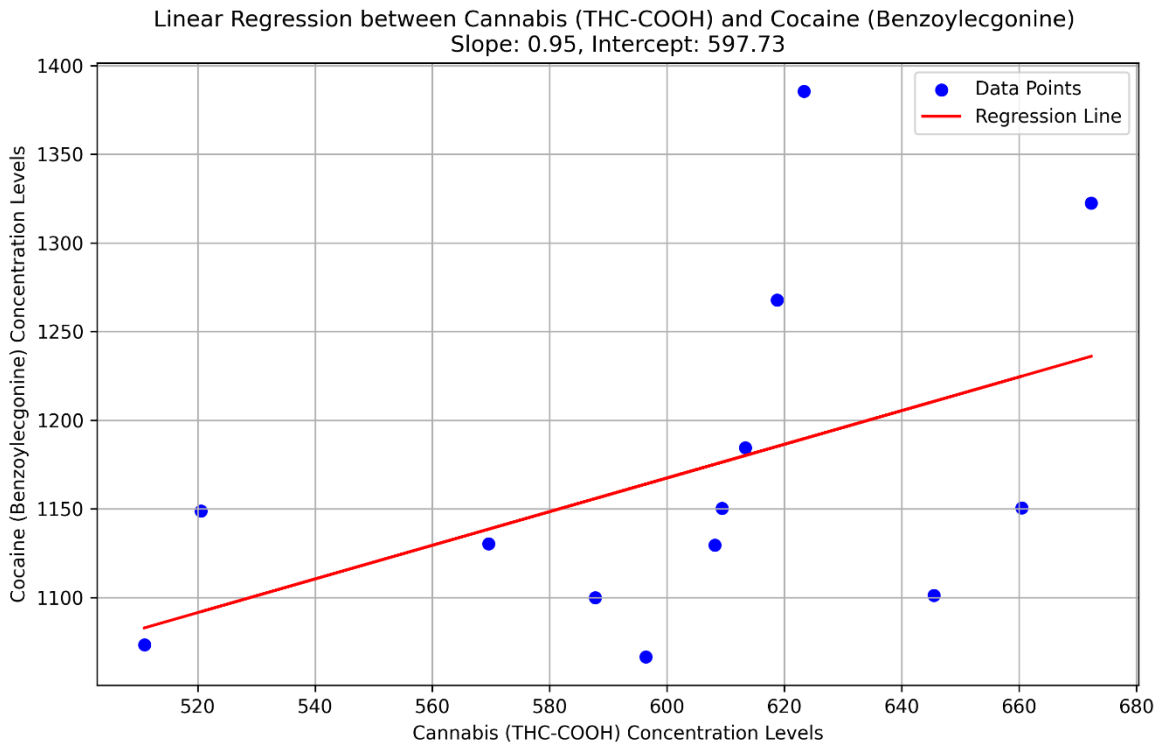

Figure 17:7 A linear regression stating a positive association between the concentration levels of Cannabis (THC-COOH) and Cocaine (Benzoylecgonine).

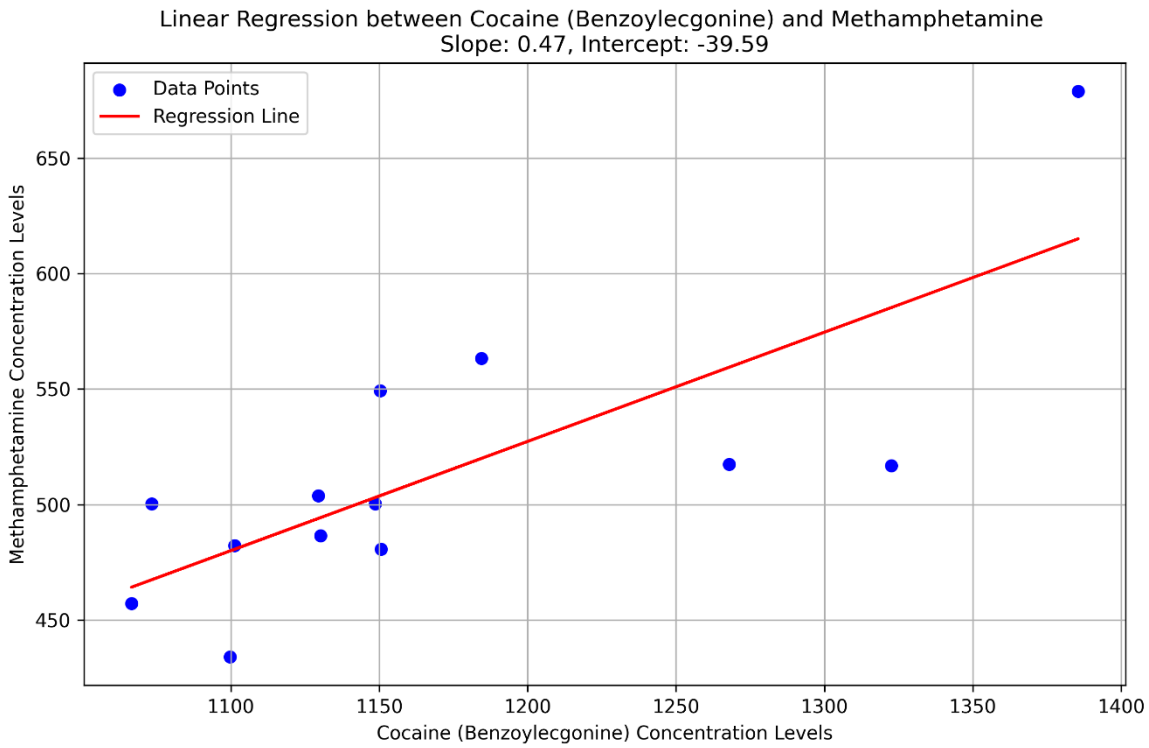

Figure 18:*8* A linear regression stating a positive association between the concentration levels of Cocaine (Benzoylecgonine) and Methamphetamine.

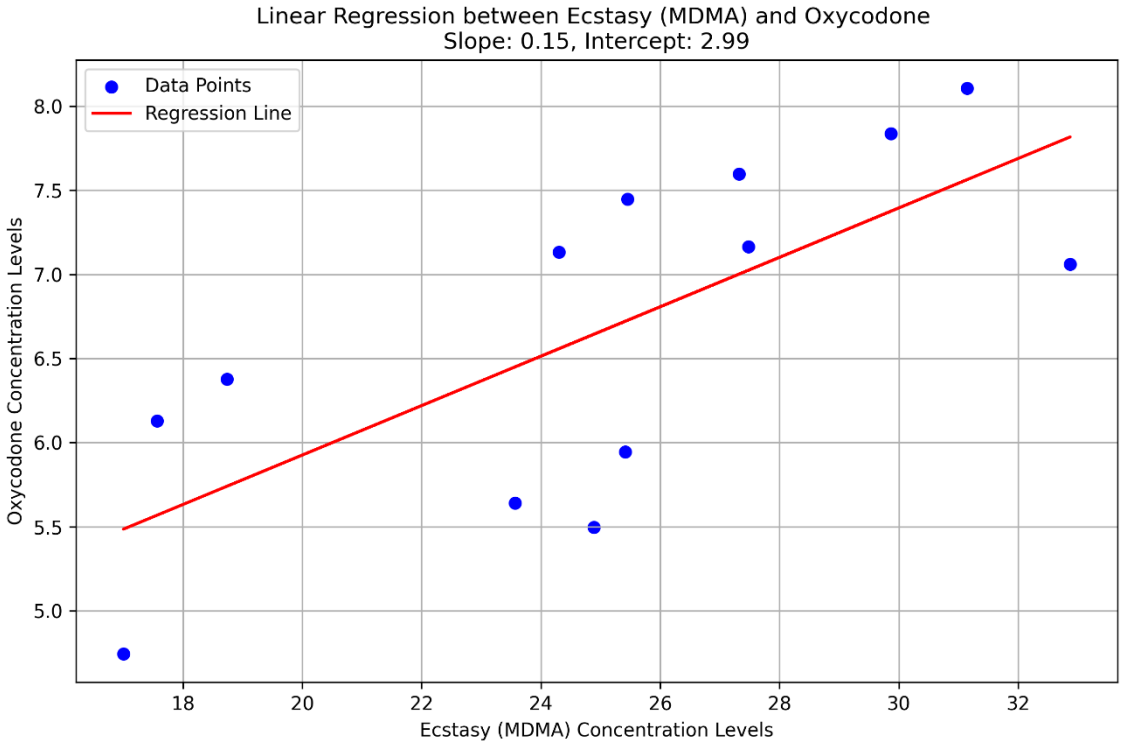

Figure 19:*9* A linear regression stating a positive association between the concentration levels of Ecstasy (MDMA) and Oxycodone.

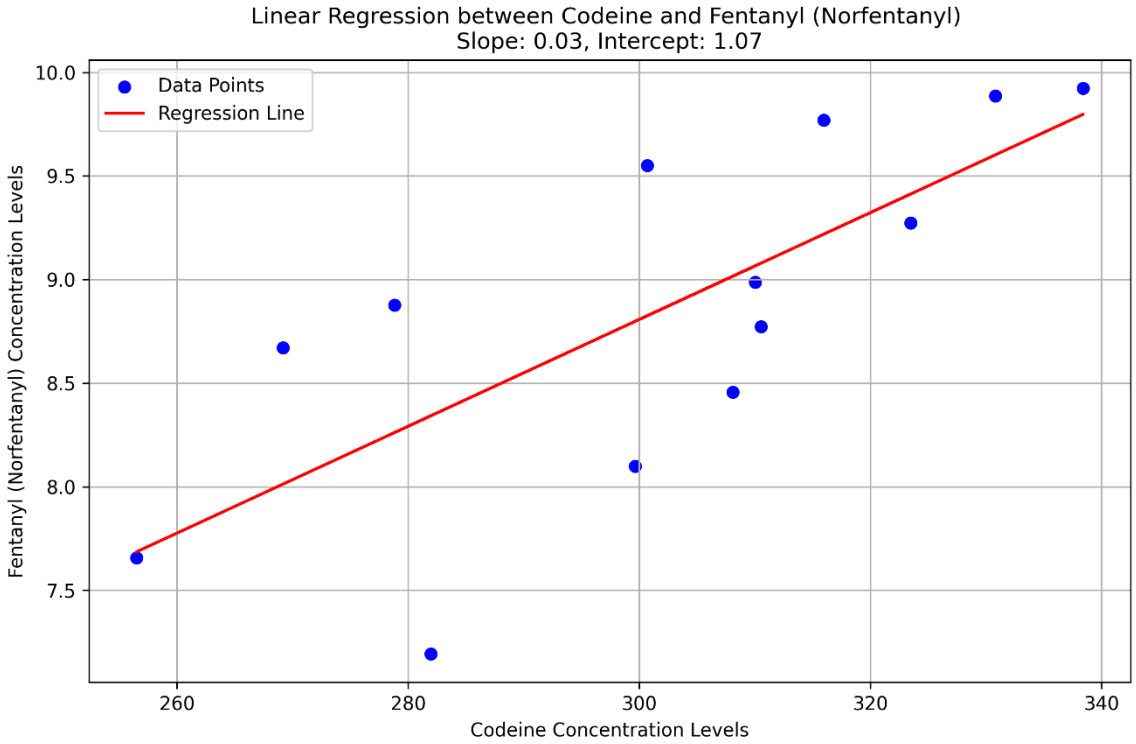

Figure 20:*10* A linear regression stating a positive association between the concentration levels of Codeine and Fentanyl (Norfentanyl).

Analysis revealed in Figure 16 shows the correlations between the detection of different drugs concentrations (in mg/1000 people/day) found in wastewater. Two significant positive correlations for drugs that are in separate categories were analyzed: Cannabis and Cocaine with a modest value of 0.47, Methadone and Fentanyl with 0.48, and finally, Cocaine and Morphine with a value of 0.58. Ecstasy and Oxycodone with 0.71 had the highest correlation between an Unprescribed and Prescribed drug. The strongest correlation overall was observed between two Unprescribed drugs: Cocaine and Methamphetamine with a value of 0.76. The overall weakest (positive) correlation was also found between Unprescribed drugs was 0.01 for Ecstasy and Methamphetamine. Furthermore, another significant relationship was found between Codeine and Fentanyl with a 0.74 correlation, which is the strongest correlation between Prescribed drugs in this study. Additionally, the Prescribed drugs, Morphine and Cannabis, resulted a significant value of 0.62.

Linear regression was performed for further analysis which confirmed a positive association between the following: Cannabis and Cocaine, Cocaine and Methamphetamine, Codeine and Fentanyl, and finally, Ecstasy and Oxycodone. As shown in Figure 17, Cannabis and Cocaine resulted the steepest slope value of 0.95 which suggests the largest rate of change in this analysis. In other words, for every 1 mg/1000 people/day increase in Cocaine concentration, the Cannabis concentration increases by 95%. Figure 17 also derived an intercept of 597.73 stating that Cocaine is predicted to be 596 mg/1000/per day

when the Cannabis concentration is zero. when From Figure 18, Cocaine and Methamphetamine suggested a slope of 0.47 indicating that for every 1 mg/1000 people/day increase in Cocaine concentration, the Methamphetamine concentration increases by 47% with an intercept value of –39.59. This intercept suggests that when Cocaine concentrations are zero, the predicted concentration level of Methamphetamine is –39.59. In Figure 19, Ecstasy and Oxycodone, an Unprescribed and Prescribed drug, have a positive association with a slope value of 0.15 and an intercept value of 2.99. Lastly, in Figure 20, Codeine and Fentanyl were confirmed to have a positive association with a slope of 0.03 and an intercept value of 1.07. This suggests for every 1 mg/1000 people/day increase in Codeine concentration, the Fentanyl concentration increases by 3%.

Discussion

The objective of the first guiding question, "*which drug metabolites are readily detected in wastewater across all seven Canadian cities",* it was revealed that out of all Unprescribed and Prescribed Drugs that were investigated in this study, Cocaine had the highest detection across all seven Canadian cities. This result highlights two notions: firstly, it suggests that Cocaine is a drug in which its metabolites are readily found in large quantities, suggesting that the drug is used in the city; secondly, this result is not particularly surprising, as Cocaine is known to be metabolized quickly in comparison to the other drugs (Jones, 1997). Cocaine is unique due to its short half-life of one hour, which also allows it to be quickly metabolized into its breakdown products (Jones, 1997). For reference, Cannabis, which is legalized and therefore expected to have high usage due to its accessibility, has a half-life ranging from 1 to 13 days, causing it to remain in the body up to weeks after usage (Moeller *et al.*, 2017). Furthermore, Ecstasy, whose metabolites were among the lowest in detection compared to other drugs in the study, coincidentally also has a much longer half-life compared to Cocaine, as it could take up to 34 hours before any metabolites are created (Hahn, 2023). Given these caveats, it's imperative to avoid the fallacy of quantifying drug usage using drug metabolite presence. Verily, wastewater analysis is best suited for the purpose of detecting drug usage, as opposed to measuring how much it is used.

The purpose of investigating, *"what are the top three cities that have the highest total overall detection of drug metabolites",* was to identify the cities with the highest drug metabolite concentrations. The findings suggested that Prince Albert, Edmonton, and Halifax had the highest detection of drug metabolites. Markedly, the total detection of Prince Albert is interesting, as its total detection of 474.81mg/1000 people/day was greater than any other city by nearly 1.5-fold (Table 1). Although identifying the reason for Prince Albert's high detection of drug use is beyond the scope of this study, investigating Prince Albert's ongoing drug crisis may shed light on this. Prince Albert Now (paNOW), a local news agency, reported on March 20, 2023, that the largest drug bust in the city's history had taken place, with approximately 31.2 kilograms of Cocaine seized, along with $55,000 in cash (McNeil, 2023). Further inquiry into the potential institutional shortcomings of Prince Albert could help address the root of these ongoing drug issues, which correlates with the high presence of drug

metabolites seen in this study. Another trend observed in Figure 11 was the spike in drug detection during the month of December 2022, following a dip in detection in January. There are currently postulations connecting drug usage with seasonality, as the holiday season can lead to increased drug use due to social gatherings and stress (Izri, 2024). Given that Edmonton and Halifax were second and third, respectively, in terms of drug metabolite detection across the seven cities analyzed, it could be possible that the two cities are experiencing similar issues, but to a lesser degree. More exploration on this topic would be required.

The aim of the third guiding question, "i*n the top three selected cities with the highest overall drug detection, is the estimated drug presence primarily driven by prescribed or unprescribed substances",* was to investigate if there was a balance between Unprescribed and Prescribed drug usage. Results shown in Figure 11 state that Prince Albert, Saskatchewan had the highest detection overall with most of the amount being related to Unprescribed drugs as Table 2 confirmed a 1.91 ratio of Unprescribed to Prescribed drugs. Combining these analyses can indicate underlying issues within the population. This statement is supported by news research as Prince Albert announced an investment worth 90 million to "combat homelessness and address mental health and addictions in the province" (Dayal, 2023). In addition, a statement from Canadian Broadcast Chanel (CBC) revealed that it was concerning that "Prince Albert had higher concentrations of certain substances in its wastewater than some of Canada's largest metropolises such as Vancouver and Toronto" (Frew, 2023).

In the following question, *"additionally, which drug is the leading contributor to the overall detection levels",* the analysis revealed the leading drug to be Cocaine. Interestingly enough, Cocaine was the leading drug in all top three cities as shown in Figures 13, 14 and 15. A resource derived by CBC did claim that Canadians are using more of this stimulant and that it is contributing to a "high percentage of drug-related deaths". Methamphetamine was the second highest detection in Edmonton and Prince Albert, and this ranking is likely due to the fact that Methamphetamine is "cheap, easy to produce and readily available" (Pelley, 2023). Amphetamine was also detected and was stated to have increased throughout 2022 due to "amphetamine medications being legally prescribed to treat ADHD" (Pelley, 2023). More exploration on this topic would also be required.

In the last guiding question, "i*s there a correlation between Unprescribed and Prescribed drugs*", was analyzed by creating a correlation matrix as shown in Figure 16. The analysis revealed a high correlation between the two different types of drug concentrations. This can indicate that both tend to rise and fall together in relation to wastewater analysis which can theoretically suggest usage patterns. In other words, the drugs could be co-used, or their consumption might occur in similar population groups or city areas. Furthermore, a positive correlation between the Unprescribed and Prescribed drug may indicate that certain prescribed medication is being illegally distributed for illicit use. Although the slopes in Figures 19 and 20 are lower between the Unprescribed drugs in comparison to the Prescribed data, this hypothesis can still be inferred. In the follow up question, "a*dditionally, is there a correlation between Prescribed drug metabolites themselves, as well as between Unprescribed drug metabolites*",

the analysis revealed that there is a correlation between Prescribed and Unprescribed drugs. It is important to note that the correlation values alone do not relate to causality therefore it cannot be assumed that consumption of a particular drug can lead to another. Overall, the correlation was able to show how strongly the two drug metabolites are related in terms of their concentration patterns.

The aim behind the linear regression analysis was to determine if the drugs had a linear relationship. Investigating the slopes suggested a rate of change of the dependent variable in respect to the independent variable; whereas the intercept measured the concentration level of the dependent variables when the independent variable is zero. In other words, the linear regression described how these drug metabolite concentrations change together.

Limitations

This study encountered a few limitations. (1) Notably, data for the months of February and April 2023 were missing across all seven cities, likely due to non-sampling efforts. Thereby reducing the data coverage from 17 months to 15 months. (2) To ensure the integrity and uniformity of the dataset, Saskatoon was excluded from the study due to missing data for the months of January through July 2022. Similarly, data for Prince Albert was missing for January and February 2022. As a result, the analysis for all seven cities was modified to begin in March 2022, reducing the analysis from 17 months to 13 months, ensuring uniformity across the dataset while maximizing the data. These modifications strengthen the overall reliability of the analysis. (3) The study was completed within 17 months. This time span is short to perform any future prediction modelling of drug metabolite detection or possible drug usage patterns. (4) The variation in the number of wastewaters treatment plants between cities, and the estimated population in each sewer shed (used to calculate the concentrations of drug metabolites in daily loads per capita), pose a risk to the reliability of the study's findings. (5) Another limitation resides in the fact that different drugs metabolize at different rates, as mentioned prior. For this reason, it is critical to treat the presence of drug metabolites as a method of only identifying potential use, as opposed to quantifying use.

Conclusion

From this analysis, it can be concluded that measuring the detection of drug metabolites in wastewater can potentially help forecast the demand for social services and resources for city officials. Overall, this analysis can be improved by observing a greater number of months for better accuracy and for predicting future consumption trends. We can interpret why the selected cities had their respective detection amount by furthering this research on the city's environment such as the weather, unemployment rates, living costs, and health policy to name a few.

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