Electronic Cigarettes: Conducting vapor analysis for heavy metals from two different types of e-cigarettes

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Abstract

Background: Since 2011, the popularity of electronic cigarettes in North America has increased dramatically. However, with a lack of scientific data performed on long term health effects and the limited number of short term studies, it is difficult for Environmental Health Officers to effectively educate the public on concerns relating to the health and safety of the general public. The increase of teenage users demonstrates the need for better government legislation and enforcement, in order to prevent the re-glamorization of smoking in younger generations. Therefore, the following study conducted a chemical analysis on artificially inhaled vapor from two different types of e-cigarettes (disposable and rechargeable), to determine if any heavy metal concentrations; specifically cadmium, chromium, lead and arsenic, are detectable.

Methods: The vapor from one of two e-cigarette types was artificially inhaled through a cellulose filter cassette by a personal sampling pump. A two tailed t-test was performed to determine if there were any differences between the heavy metals and the type of e-cigarette used in the study.

Results: There was no statistical significant difference in heavy metal concentration by the type of e-cigarette used (for cadmium the p-value was 0.00, and power was 0.00, for chromium the p-value was 0.181220, and power was 0.008976342, for lead the p-value was 0.333711, and power was 0.001825742, for arsenic the p-value was 0.00, and power was 0.00).

Conclusion: Based on the results, it was determined that there was no statistical significance between disposable e-cigarettes and rechargeable e-cigarettes with respect to concentration of the four heavy metals of interest (eg. cadmium, chromium, lead and arsenic). Although there was no statistical significance between the types of e-cigarettes used, the average concentration of chromium (IV) from the rechargeable e-cigarette was 0.13mg/m3, which is ten times the recommended 8-hour time weighted average (TWA) set by the BC Occupational Health and Safety Regulations. Hence, further studies must be conducted to determine if the average concentration found in this study truly reflects the concentration found in inhaled vapor from rechargeable e-cigarettes. Furthermore, environmental health officers can provide the public with the concentration found in this study and warn of potential health risks associated with e-cigarettes until further studies are released.

Keywords: Electronic cigarette, e-cigarette, vapor, disposable, rechargeable, heavy metals, inhaled, alternative, concentration, e-juice, smoking, Environmental Health Officer

Introduction

An electronic cigarette, also known as an e-cigarette, is an electronic vaporizing system that is intended to replace traditional tobacco cigarettes. As the World Health Organization (WHO) (2014, June 3) states, e-cigarettes are devices that do not burn or produce tobacco combustion but rather vaporize or aerosolize a solution the user then inhales. This feature has allowed many users of tobacco cigarettes an alternative to quitting. Since the first disposable e-cigarette arrived in Canada in 2007 (Canadian Living, 2014, January), their use has increase dramatically, especially with their presence of online stores. By providing consumers with a smoking cessation product that mimics real tobacco cigarettes, but without the dangerous health hazards that are associated, it is no wonder their use has been seen in areas that have been commonly avoided such as in open public spaces.

The safety of e-cigarettes is a topic that some health professionals and organizations are voicing their concerns over. Although there are short-term studies that have been done on the associated health effects of e-cigarettes to indoor air quality, such as in the study conducted by McAuley, Hopke, Zhao, and Babaian (2012), and the secondhand exposure to vapor study performed by Czogala, J., Goniewicz, M.L., Fidelus, B., Zielinska-Danch, W., Travers, M.J., and Sobczak, A. (2013), researchers still recommend that long-term studies are needed in order to successfully label e-cigarettes as "safe". The risk of hazards that may arise from other ingredients of the liquid such as solvents, flavors, additives and contaminants (Hahn, Henkler, Hutzler, et al., 2014) that are inhaled into the human body is unknown, and requires further testing on products and equipment. For the purpose of this study, chemical analysis will be performed on the inhaled vapor artificially produced by a sampling train to determine if heavy metal such as cadmium, lead, chromium, and arsenic are found at any concentration.

Product Design

In the current market there are hundreds of different kinds of e-cigarettes that are available through retail stores and online sources. In Canada, e-cigarettes fall under the Food and Drugs Act, making the sale of nicotine illegal without a prescription. The sale, advertising and importing of electronic devices that use nicotine must get authorization before any retailer can receive it in the country. (Health Canada, 2009) The overall basic design of any e-cigarette is that they are 'composed of three essential parts: the battery, the heating element or atomizer, and a cartridge or tank that holds a nicotine solution' (Czogala, et al., 2013) or flavored liquid. The majority of these e-cigarettes will be in one of two broad categories: one-piece or two-piece. There used to be a three-piece design as the Electronic Cigarette Consumer Reviews (2014) states, however, this type has become obsolete, and is becoming less and less frequently used because they are not as convenient, reliable, or remotely satisfying as a two-piece e-cigarette.

One-piece e-cigarettes are typically known as 'disposables'. Their cheap, lightweight design looks very similar to an actual tobacco cigarette as seen in Figure 1, and is typically purchased by first-time users converting over from tobacco cigarettes. The one-piece design is not recommended for heavy smokers due to the lack of smoke intensity it can create and their short battery life.

The two-piece design has become more popular with regular e-cigarette smokers due to its sleek, modern designs and its convenience. As McAuley, et al. (2012) explains, in two piece e-cigarettes the atomizer and cartridge are combined and called a cartomizer. Cartomizers will have a material called 'polyfill' which is wrapped around a heating coil located inside a cylindrical tank and soaked in e-cigarette liquid. The cylindrical tank will have a separate mouth piece attached or one built in that users can then inhale from (Misthub, 2013) .The two-piece design is also known commercially as 'midsize models' or 'advanced personal vaporizers'. Another feature allows for the two-piece design to be manual or automatic. With a manual button, users cannot inhale until the bottom is pushed, whereas the automatic design is battery activated with every inhale.

The heating element inside disposable and rechargeable e-cigarettes is made from one of two different kinds of resistance wire; nichrome or kanthal. The nichrome wire can be found in many household items such as flat irons, toaster ovens, and water heaters. It is made of a non-metallic alloy, with nickel as its primary metal (TEMCo, 2015). The percentage of nickel inside the wire can vary and it is represented by a number next to the name, for example, Nichrome60, this wire will contain 60% nickel in its composition. The other 40% is made of 16% chromium and 24% iron (TEMCo, 2015). Kanthal wire can be found under two different names; 'Kanthal A-1', or 'Kanthal D' (TEMCo, 2015). The difference between the two types of kanthal wires is minimal.

Reduction of Tobacco Use

According to the World Health Organization (WHO, 2014, May), approximately one person dies every six seconds due to tobacco, accounting for one in 10 adult deaths in the world. Of 6 million smokers who die annually, the most common associated diseases are lung cancer, coronary heart disease, stroke, and chronic obstructive lung disease (Doll, Peto, Boreham, and Sutherland, 2004). Canada became an industry leader by becoming one of the first countries to introduce graphic health warming pictures onto tobacco products (WHO, 2011). This action was taken to help reduce the number of Canadians who die every year from smoking tobacco, which the Canadian Lung Association (2012) estimates to be roughly 37,000 people.

The popularity of e-cigarettes has allowed many smokers the chance to reduce their tobacco usage to the point where they can quit altogether. Although various organizations have stated that e-cigarettes are not proven to be nicotine replacement therapy devices, due to the lack of long term data for their safety and efficacy, (Goniewicz, Knysak, Gawron, et al., 2014) the WHO does not dismiss their potential to be utilized as a certified smoking cessation aid. There are various studies that have been performed that can demonstrate that short term usage of nicotine delivery devices are safer than burning tobacco cigarettes. (Williams, Villarreal, Bozhilvor, et al., 2013) In a 2012 study published by Inhalation Toxicology (McAuley, et al., 2012), various brands of e-cigarettes and tobacco cigarettes were used for analysis. The researchers connected these products to smoking devices and analyzed the 'inhaled' smoke or vapor for pollutants such as nicotine, volatile organic compounds (VOCs), carbonyls (formaldehyde), polyaromatic hydrocarbons (PAHs), tobacco specific nitrosamines (TSNs) and glycols (diethylene glycol and propylene glycol). Some contaminants were found to have below limit detection, such as for the majority of VOCs. However, for some other contaminants such as formaldehyde, the results were above detection limits. The overall analysis of all contaminants from the study provided researchers with the conclusion that the e-cigarettes vapor showed significantly lower risk when compared to tobacco cigarettes. Similar studies have given doctors and public health officials a better understanding of the health effects of this new product. E-cigarettes have now been effectively used to eliminate tobacco smoking habits that have been aided by the hand-mouth motion that most smokers become accustomed to. E-cigarettes can make the transition much smoother by providing users a common behavior, unlike other smoking alternatives such as nicotine patches and gum (Williams, et al., 2013) A study looked at by the 'Quit Now' campaign, organized through the BC Lung Association, found that "57% who used e-cigarettes with nicotine reduced by half or more the number of cigarettes they smoked per day, versus 41% of patch users" (QuitNow, 2013, October).

Re-glamorizing Smoking

Since the Tobacco Act in Canada passed in 1997, there has been a steady decline in the use of tobacco cigarettes, especially among youth. (Health Canada, 2013, October 1st) The lack of advertising has allowed individuals not to be subliminally subjected to false marketing strategies tobacco companies were known to use throughout the 1900's. In North American, smoking tobacco cigarettes has been associated with health risks, a negative social stigma and other inconveniences. (Bloomberg Businessweek, 2014) It has become a social norm to view the use of tobacco cigarettes negatively. This has created a hostile environment if individuals do not appropriately respect other individual's personal space. However, with the introduction of e-cigarettes used as a 'healthier' alternative, their use is being seen in areas that people were known to avoid such as indoor spaces. E-cigarettes can still provide smokers with their nicotine delivery without the known carcinogens and toxins that is produced with the combustion of tobacco. (Czogala, Goniewicz, Fidelus, et al., 2013) To know that e-cigarettes can be used indoors, around others without producing dangerous secondhand vapor is a key selling feature. It is that habit of smoking e-cigarettes indoors and more openly in public spaces that has some health professionals concerned. Dr. Tom Frieden, the Director of Centers for Disease Control and Prevention, recently stated he was "worried that e-cigarettes will re-glamorize smoking" (Partnership for Drug Free Kids, 2014). There is a whole generation that grew up learning about the dangers associated with smoking tobacco and created a social norm to discourage smoking around others who were non-smokers. It would be as if our society went back 50 years if smoking became seen as an allowable habit to perform in places where we have denied regular tobacco use currently. A report released by the Center for Disease Control and Prevention looked at national representative youth surveys, and found that in 2013 more than a quarter million adolescents and teens who were non-smokers had tried an e-cigarette (CDC, 2014). A study in the journal Nicotine and Tobacco Research noted that youth who had tried e-cigarettes were twice as likely to try regular tobacco cigarettes the following year. (Reuters, 2014)

Creating a new generation of smokers in today's youth may be the reason many large tobacco companies such as Altria Group, Reynolds American, and Lorillard have begun to buy smaller e-cigarette companies such as Blu and Green Smoke. The e-cigarette industry is estimated to make $3 billion annually around the world and has over 450 different brands (CBS News, 2014). Some analysts predict that the sales of e-cigarettes will surpass the sales of tobacco cigarettes within the next decade (Etter and Bullen, 2013). E-cigarette companies have little regulation to abide by and virtually nothing in legislation. Most of their products are allowed in kid-friendly flavors such as chocolate, bubble gum, and gummy bear (Scientific American, 2014). In Canada, the ban of flavored tobacco products such as cigarettes, little cigars and blunt wraps has been in enforcement since 2010 (Health Canada, 2010). However, e-cigarettes are not considered a tobacco product in Canada and fall under the Food and Drug Act allowing the use of flavoring agents in the 'e-juice' or flavor liquid that becomes vaporized.

Absence of Legislation

There is currently nothing in the Tobacco Act in Canada referring to e-cigarettes that can be used as enforcement (Tobacco Act, 2015). Health Canada has placed e-cigarettes under the Food and Drugs Act from which they are regulated (Food and Drugs Act, 2015). Although Health Canada prohibits the sale of nicotine in e-cigarettes, the purchase of various liquid flavors can still pose a health concern to the user and surrounding bystanders. Lesley James, a senior health policy analyst for the Heart and Stroke Foundation recently stated, "We are asking all levels of government, federal, provincial and municipal to act quickly to adopt regulations to protect Canadians similar to what Vancouver has done." (CBC News, 2014). The City of Vancouver has become one of the very few cities in Canada to take the necessary steps of putting e-cigarettes in their bylaws. The City of Vancouver has banned the use of e-cigarettes in public places and the sale to minors (CBC News, 2014). Another group in Canada, the Non-Smokers' Rights Association, has be voicing their concerns about e-cigarettes and is asking the federal government to make nicotine-based e-cigarettes legal for purchase (Globe and Mail, 2014). The group's main concern is that the chemical levels inside the 'e-juice' or flavored liquid is not being properly monitored or tested, therefore some values could be dangerous over time with use. If nicotine was properly regulated in e-cigarettes, then there would be clear rules and better monitoring systems in place to assure these companies meet standard compliance. Eric Morrissette, a spokesman for Health Canada, said "the department has no plans to do anything about e-cigarettes" (Globe and Mail, 2014).

Role of Environmental Health Officer

As Environmental Health Officer's (EHO's) in the field, it will be very difficult to enforce any regulations with regards to the use of e-cigarettes without proper guidelines or policies in place. The recent banning of e-cigarette usage in public places in the City of Vancouver will hopefully be a stepping stone for other municipalities or Health Authorities to create and develop their own set of guidelines. Although most current research suggests there are no levels of potentially toxic compounds observed from e-cigarette vapor, almost all research has been done in short term studies. The need for more research is clearly evident with trace amounts of metals and other toxic compounds being observed. Further research may also provide the opportunity for vapor companies or manufacturers to change product design with better technology and human health in mind. Without the full picture, it is difficult for EHO's in the field to provide accurate information to the public.

Purpose

It is important to perform research on topics that may pose a threat to human health. As governments and community leaders encourage healthy, the need to assure that citizens are protected and properly informed about e-cigarettes and 'healthy alternatives' should be at the top of the list. With the lack of regulations and legislation available for EHO's to use for enforcement, the need for accurate and up-to-date educational material is necessary. The purpose of this research project was to chemically analyze inhaled vapor artificially produced by a sampling train from an e-cigarette to determine if heavy metals such as cadmium, lead, chromium, and arsenic are found at any concentration. The results provided by this study will help develop a better understanding of e-cigarettes and any potential health hazards associated.

Methods

Calibrated each personal sampling pump with a representative sampler in line and recorded the average. Tygon tubing was connected from the personal sampling pump to a new, un-used PVC filter cassette. From the PVC filter cassette, used tygon tubing was connected to the e-cigarette. Sampling occurred for 5 seconds every 5 seconds over 1 minute, at 1 L/min. After 1 minute, the sampling pump was turned off. The PVC filter cassette serial number was recorded. The tubing from the PVC filter cassette was removed and the top and bottom plugs were inserted. Once all samples collected, the end calibration was performed for each sampling pump with a representative sampler in line.

Currently, there is no standard method of sampling for e-cigarettes used in the field or analytical laboratories. Most professionals who perform chemical analysis and sampling use the ISO Standard 3308:2012. However, as studies are being performed researchers are finding problems with e-cigarette users as they do not inhale the same as regular tobacco users. In order to aid in the development of standard methods for sampling of e-cigarettes, the research performed through this project contained created elements and procedures not specified in current methods.

The cost of the rechargeable e-cigarette, Kangertech e-smart, was $44.88. The cost included the e-smart kit (two rechargeable e-cigarettes, charger and instructions) and one 10ml vial of no nicotine, tobacco flavor e-juice. The cost of the disposable e-cigarette, Smoke NV tobacco flavor, was $10.49 and two were purchased for testing purposes. The analytical testing for metals was performed through the BCIT Chemistry department. The use of the Chemistry department did not have any cost associated.

The total time involved with sampling for metals took approximately six hours and was performed between January 14, 2015 and January 26, 2015. Each sample was sampled for five seconds, every five seconds for a one minute period. There were a total of 30 samples taken for the rechargeable e-cigarette and 30 samples taken for the disposable e-cigarette.

All calibration and sampling procedures were completed by Kelsey Hynes, BCIT Environmental Health student, and the metals analysis was performed by three second year students from the Chemical and Environmental Technology diploma program at BCIT; Jaymar Bisente, Fiona Cen, and Ambrose Chung. All three are training chemical technologist who performed metals analysis following the NIOSH Manual of Analytical Methods (NIMAM), Elements by ICP (Aqua Regina Ashing): Method 7301.

Reliability and Validity of Measures

In order to increase the reliability and validity of the sampling equipment, the following methods were used; the use of the following proven instruments such as Dry Cal., SKC personal sampling pump and analytical equipment such as Agilent 4200 MP-AES to analyze the samples, the calibration methods used before and after samples were taken and analyzed to assure the equipment was consistent and accurate and the users of the instruments were well trained and familiar with the equipment.

Inclusion and Exclusion Criteria

This study included the e-cigarette brands Kangertech e-smart and Smoke NV. All other e-cigarette brands were excluded from this study. The results obtained through the chemical analysis of e-cigarette vapor was analyzed for specific elements; cadmium, chromium, lead and arsenic. All other elements that were analyzed but not previously stated were excluded from this study.

Ethical Consideration

No animals or humans were directly influenced or used in the testing of the rechargeable e-cigarette and disposable e-cigarette for analytical purposes. Therefore, there is no ethical consideration needed for the purpose of this study. All sampling techniques were performed in a fume hood in order to avoid any potential exposure risk during the testing procedures.

Statistical Analysis

The following statistical analysis was performed using the statistical software NCSS with numerical data points that were chemically analyzed by three second year students from the Chemical and Environmental Technology diploma program at BCIT. The analysis was performed using a two tail t-test, which compared the data results for a particular heavy metal such as cadmium from one of the two types of e-cigarettes (eg. rechargeable and disposable). Table 1 presents the numeric data collected after performing the statistical analysis for heavy metals through the software program Microsoft Excel.

Inferential Statistic- Hypothesis

Cadmium:

Ho: Disposable [Cd] = Rechargeable [Cd]

HA: Disposable [Cd] ≠ Rechargeable [Cd]

Chromium:

Ho: Disposable [Cr] = Rechargeable [Cr]

HA: Disposable [Cr] ≠ Rechargeable [Cr]

Lead:

Ho: Disposable [Pb] = Rechargeable [Pb]

HA: Disposable [Pb] ≠ Rechargeable [Pb]

Arsenic:

Ho: Disposable [Ar] = Rechargeable [Ar]

HA: Disposable [Ar] ≠ Rechargeable [Ar]

Results

Statistical

Based on the inferential statistical results for cadmium, the p-value was 0.00000, and power was 0.00000, hence do not reject the null hypothesis and conclude that there is no statistically significant difference between the concentration of cadmium in disposable e-cigarettes compared to rechargeable e-cigarettes.

The inferential statistical results for chromium is the p-value was 0.18122, and power was 0.00898, hence do not reject the null hypothesis and conclude that there is no statistically significant difference between the concentration of chromium in disposable e-cigarettes compared to rechargeable e-cigarettes.

The inferential statistical results for lead is the p-value was 0.33371, and power was 0.00183, hence do not reject the null hypothesis and conclude that there is no statistically significant difference between the concentration of lead in disposable e-cigarettes compared to rechargeable e-cigarettes.

The inferential statistical results for arsenic is the p-value was 0.00000, and power was 0.00000, hence do not reject the null hypothesis and conclude that there is no statistically significant difference between the concentration of arsenic in disposable e-cigarettes compared to rechargeable e-cigarettes.

Discussion

As stated earlier there is no standard method of sampling for e-cigarettes used in the field or analytical laboratories. The way in which scientists perform their procedure is strictly based on the best way to confidently analyze these instruments to determine whether or not high concentrations of various chemicals or metals may be found. Through the numerous journals evaluations with e-cigarettes there were two that closely incorporated the similar sampling procedure and metal results that this study was able to find.

In a 2012 study published by Inhalation Toxicology (McAuley, et al., 2012), the inhaled vapor from various e-cigarettes was compared against vapor produced by various tobacco cigarettes. Although metals were not a product of interest in this particular study, it was determined that the amount of all the contaminants produced from the e-cigarettes was significantly lower than the contaminants produced by the tobacco cigarettes (eg. nicotine, volatile organic compounds (VOCs), carbonyls (formaldehyde), polyaromatic hydrocarbons (PAHs), tobacco specific nitrosamines (TSNs) and glycols). These results are consistent with the study described in this paper, as there were no statistical significance to indicate that e-cigarettes produce elevated concentrations of heavy metals between the two types of e-cigarettes that may pose a risk to its users.

In a study performed in 2013 (Williams, Villarreal, Bozhilvor, et al., 2013), 22 different brands of e-cigarettes were taken apart and their cartomizers were analyzed. It was found that the fibers inside had significant amounts of black debris and green discoloration. Although the matrix of interest does not match the matrix analyzed in the study described in this paper, the study performed by Williams, Villarreal, et al., 2013, did find traces of various metals from the inner and outer fibers.

In regards to the raw data collected, the averaged concentration of chromium (III & IV) was found to be 0.13 mg/m3. This value is 10x above the BC Occupational Health & Safety (BC OHS) regulations for an 8 Hour-time weighted average (TWA) of 0.01 mg/m3 of chromium (IV) (WorkSafeBC, 2015). Therefore, if an individual were to use a rechargeable e-cigarette over a 2 minute period and inhale the vapor for 5 seconds, every 5 seconds, then technically the concentration of chromium (IV) inhaled would be above the exposure limit set out by BC OHS regulations. However, more studies are required to analyze the concentration of chromium (IV) over an 8 hour time period to confirm whether they truly do exceed the chromium (IV) exposure limit or not.

Recommendations

Based on the results received from the study, it would be recommended that further short term studies be conducted. Chemical parameters such as nicotine, volatile organic compounds (VOCs), carbonyls (formaldehyde), polyaromatic hydrocarbons (PAHs), tobacco specific nitrosamines (TSNs) and glycols should be focused based on their associated health risks to the human body. Long term studies involving various heavy metals and other transition metals should be focused upon to evaluate their bioaccumulation in the human body with daily use over several years. As seen with the raw data points, especially chromium (IV), an 8 hour long term studies must be performed in order to determine if the raw data truly exceeds the exposure limits set by the BC OHS regulations. Furthermore, the analytical testing of various e-juice used with e-cigarettes should be tested to determine manufacturers quality control and quality assurance.

As with any product of concern, conducting the necessary research before allowing consumers to purchase the items should be a high priority. By thoroughly understanding the possible risk that items such as e-cigarettes may pose on an individual's health, regulators and health professionals can provide the general public with the necessary information to allow them to make informed decisions. Hence, the new Vancouver by-law passed in late 2014 prohibiting the sale of e-cigarettes to individuals under the age of 19 and the display of e-cigarette advertising in public can provide the initial steps towards educating a vulnerable age group and limiting access as done with tobacco products.

Limitations

Although 30 samples were successfully taken from both the disposable and rechargeable e-cigarette, a higher number of samples may have produced statistically significant difference with a higher power, and therefore provided the author with confidence regarding whether or not the null hypothesis should have been rejected.

For the purposes of this study, each student was given a budget of $100. The cost associated with the purchase of the disposable and rechargeable e-cigarette was $55.37. Therefore, this study was limited by the financial cost of having to purchase the e-cigarettes. If there was a larger financial budget or sponsorship to provide the e-cigarettes, the study would have been able to add several different brands to the study and determine if the manufacturer's practises place a potential role in the concentration of heavy metals that may have been found in the vapour.

Although sampling occurred in a brief time period, January 14 to 26, the actual chemical analysis of the cellulose filters took over 2 months before any results were received. Due to the involvement of students performing the chemical analysis, extra time was necessary to ensure proper procedures and quality control was being followed and achieved. If the chemical analysis was performed through a certified private laboratory, the results would have been ready in less than seven days. However, the cost would have been too high on the student budget.

As with any chemical analysis, the risk of possible human error during the sampling procedure or chemical analysis increases, especially with the higher number of individuals involved with either steps. It can be said with confidence that all students involved have been appropriately trained in their field of expertise, and that the equipment used for both the sampling procedure and laboratory analysis were calibrated to the manufacturers requirements and records of service maintenance were available for review.As a training Environmental Health Officer, there is a natural bias in regards to the public's usage of electronic cigarettes and any associated health risk or migration to tobacco cigarettes. However, for the purposes of this study, the null and alternative hypothesis were chosen to eliminate that bias and strictly focus on determining whether or not two different types of e-cigarettes would produce heavy metals in the inhaled vapour or not. Therefore, there should be no bias involved with the research presented in this study.

Future Research Suggestions

Performing analysis on “home-made” e-juice, compared to store bought, and determining if any levels of nicotine, volatile organic compounds (VOCs), carbonyls (formaldehyde), polyaromatic hydrocarbons (PAHs), tobacco specific nitrosamines (TSNs), glycols or heavy metals are present at any concentration.
Determining if any levels of particulate matter (PM10 or PM2.5) or ultrafine particulates are produced during the inhaling of vapor from e-cigarettes.
Performing a survey of individuals of who have tried an e-cigarette, who have not tried an e-cigarette, or who currently uses e-cigarettes.
Testing the air concentration inside electronic cigarette smoke shops for various chemical parameters such as nicotine, volatile organic compounds (VOCs), carbonyls (formaldehyde), polyaromatic hydrocarbons (PAHs), tobacco specific nitrosamines (TSNs), glycols and heavy metals over several different time periods of the day.
Testing 3-4 different brands of rechargeable e-cigarettes or disposable e-cigarettes for heavy metals to determine if there is any statistical difference between the inhaled vapour produced and any concentrations found.

Conclusion

Upon completing the sampling and chemical analysis for all 60 samples in total, the inferential statistical analysis performed by the software NCSS produced the following results in table 4.
Based on the results produced through the statistical software NCSS, it was determined that the null hypothesis could not be rejected and that there were no statistically significant difference between the e-cigarette types used and the concentration of the four metals tested.

Acknowledgement

I would like to acknowledge my supervisor Helen Heacock, who provided me with many hours of her time to review my drafts and gave me the encouragement I needed during stressful times. A special thank you to Fred Shaw, who worked with me to help set up my sampling train during my sampling procedures. Thank you Elaine Woo and Dr. Lynn Erickson, for allowing their students to work in collaboration with me and the Environmental Health Department at BCIT. And finally, to Jaymar Bisente, Fiona Cen, and Ambrose Chung, with out your help performing the chemical analysis this project would of never began. I am very grateful for your time, energy and cooperation during this project. Thank you.

Table 1: Descriptive Statistics

Statistical Analysis for Metals					
	Mean	Median	Standard Deviation	Max	Min
[Cadmium] Rechargeable	0.00000	0.00000	0.00000	0.00000	0.00000
[Cadmium] Disposable	0.00000	0.00000	0.00000	0.00000	0.00000
[Chromium] Rechargeable	0.01000	0.01000	0.01044	0.05000	0.00000
[Chromium] Disposable	0.01000	0.00000	0.00896	0.03000	0.00000
[Lead] Rechargeable	0.00000	0.00000	0.00000	0.00000	0.00000
[Lead] Disposable	0.00000	0.00000	0.00197	0.01000	0.00000
[Arsenic] Rechargeable	0.00000	0.00000	0.00000	0.00000	0.00000
[Arsenic] Disposable	0.00000	0.00000	0.00000	0.00000	0.00000

Table 2: Inferential Statistics

Inferential Statistics for Metals					
	P Value	**Power (α=0.05)**	**Alpha**	**Beta**	**Reject HO (α=0.05)**
[Cadmium] Disposable vs. Rechargeable	0.00	0.00	N/A	N/A	Do not reject
[Chromium] Disposable vs.	0.181220	0.008976342	N/A	Yes, possible beta error. Need to	Do not reject

Rechargeable				increase sample size.	
[Lead] Disposable vs. Rechargeable	0.333711	0.001825742	N/A	Unlikely	Do not reject
[Arsenic] Disposable vs. Rechargeable	0.00	0.00	N/A	N/A	Do not reject

Table 3: Raw data (averaged) based on 30 samples for both rechargeable and disposable e-cigarettes

Element	**Average Concentration (ppb or ug/L or mg/m^3)**	
	Rechargeable e-cigarette	**Disposable e-cigarette**
Silver (Ag)	-----	-----
Arsenic (As)	-----	-----
Barium (Ba)	-----	-----
Beryllium (Be)	-----	-----
Cadmium (Cd)	-----	-----
Cobalt (Co)	-----	-----
Chromium (Cr) (III & VI)	0.13	-----
Copper (Cu)	0.38	-----
Manganese (Mn)	-----	0.04
Nickel (Ni)	-----	-----
Lead (Pb)	-----	-----
Selenium	0.04	0.02
Strontium (Sr)	-----	-----
Titanium (Ti)	0.09	0.03

* The detection limit was 0.01 ppm for the solutions.

** In the analytical procedure (NIOSH 7301) the equation converts the solution concentration to the concentration of the original sampled vapor collected in (mg/m^3 = ug/L = ppb) per 1L vapor inhaled.

Table 4: Inferential Statistical Results

Heavy Metal	P-value	Power
Cadmium	0.00000	0.00000
Chromium	0.18122	0.00898
Lead	0.33371	0.00186
Arsenic	0.00000	0.00000

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