OFFICE OF THE CITY CLERK

COUNCIL MINUTES

December 5, 2019

The City Council of the City of Mesa met in a Study Session in the lower level meeting room of the Council Chambers, 57 East 1st Street, on December 5, 2019 at 7:51 a.m.

COUNCIL PRESENT	COUNCIL ABSENT	OFFICERS PRESENT
John Giles	Mark Freeman	Christopher Brady
Jennifer Duff	Jeremy Whittaker	Dee Ann Mickelsen
Francisco Heredia		Jim Smith
David Luna		
Kevin Thompson		

Mayor Giles excused Vice Mayor Freeman and Councilmember Whittaker from the entire meeting.

1. Review and discuss items on the agenda for the December 9, 2019 Regular Council meeting.

All of the items on the agenda were reviewed among Council and staff and the following was noted:

Conflict of interest: None

Items removed from the consent agenda: 6-c

In response to a question posed by Councilmember Thompson regarding agenda item 4-d, **(One-Year Term Contract with Two Years of Renewal Options for Streetlight Parts and Electrical Supplies for the Transportation Department (Citywide),** on the Regular Council meeting agenda, Assistant City Manager Kari Kent stated damaged streetlights will be replaced with light-emitting diodes (LED).

In response to a question from Councilmember Luna regarding agenda item 4-o, **(Jefferson Park Playground Improvements (District 5))**, on the Regular Council meeting agenda, Parks, Recreation and Community Facilities Department Director Marc Heirshberg stated funding is coming from the Community Development Block Grant (CDBG) and staff is working with Playworld and other manufacturers to create a Dave Bang memorial playground.

In regard to agenda item 6-c, **(Amending Title 6, Chapter 11, Sections 1 through 8, 10 through 14, and 21 through 23 of the Mesa City Code relating to smoking regulations and healthier smoke-free environments by adding vaping. The amendment adds the prohibition of vaping and the use of vaping products in public facilities, public places, and certain places of employment. (Citywide))**, on the Regular Council meeting agenda, Amanda Wheeler, Executive Director of the Arizona Smoke-Free Business Alliance (ASFA), explained ASFA represents the local small business owners in the vaping industry. She reported there are five ASFA member businesses located in Mesa. She stated the main concern is the exemption in the ordinance for vape shops and the ventilation clause and how the cost will impact small businesses.

Ms. Wheeler explained the importance of allowing vaping on the premises because of working with customers on product safety, instructing them how to properly use the device and letting them try products to determine what is best suited for the customer.

Ms. Wheeler presented a 2015 study by the International Journal of Environmental Research and Public Health and a 2017 study by the Centers for Disease Control and Prevention (CDC) which tested the air quality inside retail vape shops. She highlighted both studies found the air samples from vape shops did not show any significant difference in the air quality of a vape shop versus a standard workplace. She requested Council consider taking out the ventilation requirement because it would be burdensome on vape shop business owners. **(See Attachments 1 and 2)**

In response to a question posed by Councilmember Thompson, Ms. Wheeler stated she works with dozens of municipalities throughout Arizona and Colorado and ASFA has sponsored legislation to prevent youth vaping. She highlighted ASFA is supportive of raising the legal age to 21 for purchasing vaping products and imposing strict fines for businesses that sell to minors.

In response to a question from Councilmember Duff regarding whether there are filters that can be installed to filter the air passing between stores, Ms. Wheeler stated that is outside of her area of expertise, but she is willing to look into the issue and report back. She added ASFA is willing to consider other mitigation options rather than having to install new ventilation systems.

Mayor Giles commented if carcinogens are present in vape, as they are in tobacco, the two should be treated the same. He continued by saying that implementation of the ordinance is being delayed by six months to allow retailers to make any necessary changes but suggested possibly increasing the delay.

In response to a question from Councilmember Duff, Ms. Wheeler stated the isolated ventilation requirement has not come up in other cities.

City Manager Christopher Brady pointed out staff was attempting to make the change simple by including vaping to the existing ordinance, adding the ventilation section can be re-evaluated.

In response to a question from Councilmember Luna regarding whether there is more current data available, Ms. Wheeler stated the CDC study from 2017 showed there were no harmful levels of vapor emissions in the air. She added she is not aware of the CDC posting new information on their website.

2-a. Hear a presentation and discuss the West World War II Hangar at Falcon Field Airport including its history and current utilization, and a proposed Master Tenant Lease with the Falcon Warbirds Foundation, Inc. and the Wings of Flight Foundation, Inc.

Falcon Field Airport Director Corinne Nystrom displayed a PowerPoint presentation and provided background on the Master Tenant Lease for the West World War II (WWII) Hangar at Falcon Field Airport. (**See Attachment 3)**

Ms. Nystrom stated the U.S. Government opened Falcon Field in 1941 with two hangars used for training the British Royal Air Force and U.S. Army Air Corps pilots during WWII. She reported after the war Mesa agreed to run the airport as a municipal airport. (See Page 2 of Attachment 3)

Ms. Nystrom explained since that time, the West WWII hangar has primarily been used as aircraft storage. She remarked the West and East WWII hangars are listed on the National Register of Historic Places. (See Page 3 of Attachment 3)

Ms. Nystrom stated since 2014 the West WWII hangar has been leased by Falcon Warbirds to store vintage aircraft, and as part of the lease they have agreed to assist the City in educating the community about Falcon Field's WWII history by providing tours. (See Page 4 of Attachment 3)

Ms. Nystrom explained the City would like to set apart the West WWII hangar to continue to acknowledge and educate the community about Falcon Field's history. She added a Notice of Intent to Lease was published and proposals were solicited from non-profit organizations to promote Falcon Field's WWII history. (See Pages 5 and 6 of Attachment 3)

Ms. Nystrom verified proposals were received from Falcon Warbirds and Wings of Flight Foundation and both agreed to conduct airport tours and participate in airport events. She reported both organizations would share 20,000 square feet (sf) of hangar space and over 6,000 sf of office space. (See Page 7 of Attachment 3)

Ms. Nystrom added the partnership with Falcon Warbirds and Wings of Flight Foundation will provide an opportunity to continue educating the community, especially the younger generation, on WWII and the role Falcon Field played.

In response to a question from Mayor Giles, Ms. Nystrom stated the West WWII hangar is leased at market rate, but if the organizations conduct a certain number of events promoting the airport over a 12-month period a discount will be provided. She advised the ability to draw on both organizations for marketing benefits the City's budget.

Councilmember Luna commented Falcon Warbirds and Wings of Flight Foundation provide community support for Falcon Field and he invited the public to visit Falcon Field.

Councilmember Duff confirmed her great-uncle was instrumental in Falcon Field and contributed to documenting the history. She described the importance of keeping the history preserved for the community.

Mayor Giles thanked staff for the presentation.

3. <u>Acknowledge receipt of minutes of various boards and committees</u>.

3-a. Museum & Cultural Advisory Board meeting held on September 26, 2019.

It was moved by Councilmember Thompson, seconded by Councilmember Luna, that receipt of the above-listed minutes be acknowledged.

Upon tabulation of votes, it showed:

AYES – Giles-Duff-Heredia-Luna-Thompson
NAYS – None
ABSENT – Freeman-Whittaker

Mayor Giles declared the motion carried unanimously by those present.

4. Current events summary including meetings and conferences attended.

Mayor Giles –	East Valley Partnership Thought Leader Forum – Berge Family and Whiteman Family Honored Mayor's Youth Committee Event
Councilmember Duff –	Meeting with Jorge Mendoz Yescas, Consul General of Mexico Maricopa Association of Governments Human Services Conference East Valley Partnership Thought Leader Forum
Councilmember Luna –	Meeting with Jorge Mendoz Yescas, Consul General of Mexico
Councilmember Heredia –	Mesa Police Department 911 Dispatch Center Tour

5. Scheduling of meetings.

City Manager Christopher Brady stated that the schedule of meetings is as follows:

Monday, December 9, 2019, 4:30 p.m. – Study Session

Monday, December 9, 2019, 5:45 p.m. – Regular Council Meeting

6. Adjournment.

Without objection, the Study Session adjourned at 8:24 a.m.

JOHN GILES, MAYOR

CITY OF MESA CORPORATE SEAL MARICOPA COUNTY, AZ

ATTEST:

DEE ANN MICKELSEN, CITY CLERK

I hereby certify that the foregoing minutes are a true and correct copy of the minutes of the Study Session of the City Council of Mesa, Arizona, held on the 5th day of December 2019. I further certify that the meeting was duly called and held and that a quorum was present.

DEE ANN MICKELSEN, CITY CLERK

la (Attachments – 3)

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Article

An Assessment of Indoor Air Quality before, during and after Unrestricted Use of E-Cigarettes in a Small Room

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Abstract: Airbome chemicals in the indoor environment arise from a wide variety of sources such as burning fuels and cooking, construction materials and furniture, environmental tobacco smoke as well as outdoor sources. To understand the contribution of exhaled e-cigarette aerosol to the pre-existing chemicals in the ambient air, an indoor air quality study was conducted to measure volatile organic compounds (including nicotine and low molecular weight carbonyls), polycyclic aromatic hydrocarbons, tobacco-specific nitrosamines and trace metal levels in the air before, during and after e-cigarette use in a typical small office meeting room. Measurements were compared with human Health Criteria Values, such as indoor air quality guidelines or workplace exposure limits where established, to provide a context for potential bystander exposures. In this study, the data suggest that any additional chemicals present in indoor air from the exhaled e-cigarette aerosol, are unlikely to present an air quality issue to bystanders at the levels measured when compared to the regulatory standards that are used for workplaces or general indoor air quality.

Keywords: e-cigarette; indoor air quality; bystander exposure; exhaled aerosol; ambient air

1. Introduction

In recent years, the use of electronic cigarettes (also termed "vaping") has increased significantly worldwide with such products gaining acceptance with consumers as an alternative to traditional tobacco products. A report published in July 2014 by Action on Smoking and Health estimated as many as 2.1 million adults in the UK currently use electronic cigarettes (e-cigarettes) [1]. E-cigarettes are battery-powered devices that deliver vaporized nicotine, propylene glycol and/or glycerol and flavorings to users from an "e-liquid" [2,3]. They do not contain tobacco or require combustion [2,3]. E-cigarettes are available in many different configurations; the two principal distinctions being "open" systems which can be refilled by the consumer (e.g., tank systems) or "closed" systems (e.g., replaceable cartridges pre-filled by manufacturers) [3]. When the user takes a puff on the product, a heating element is activated converting the e-liquid in the cartridge into an aerosol that the user holds in the mouth or inhales.

With the increasing prevalence of e-cigarettes, there is growing discussion amongst public health organizations and the scientific community as to whether the aerosol exhaled following use of such products has implications for the quality of air breathed by bystanders through so-called "passive vaping", akin to that reported for environmental tobacco smoke from combusted tobacco products [2–6]. In recent years, there has been conflicting and, at times, confusing information presented to the public regarding the potential risks to bystanders from exhaled e-cigarette aerosol [5,7]. There are calls, including by some government bodies, to prohibit the use of e-cigarettes in workplaces and enclosed public spaces [5,7]. Equally, other organizations and researchers have stated that any regulation on using such products in enclosed public spaces requires an established evidence base, which is limited at this time [2,8].

Airborne chemicals in the ambient air which can impact indoor air quality arise from a wide variety of sources such as those infiltrating from outdoor sources (e.g., vehicle fumes), cooking, burning fuels and tobacco, and (scented) candles [9]. Other sources include emissions from construction materials and furniture, use of air fresheners and cleaning products as well as other consumer goods products like personal care products [9]. To date, there is limited data on the impact of exhaled e-cigarette aerosol on indoor air quality.

Of the few studies that have been undertaken to investigate the impact of e-cigarette emissions on indoor air quality, it has been reported that nicotine, propylene glycol, glycerol (the components of e-liquids), amongst other chemical compounds including volatile organic compounds, low molecular weight carbonyls, polycyclic aromatic hydrocarbons and trace metals, may be released into the air during use of e-cigarettes [10–15]. As no validated, standardized protocol is available for measuring exhaled e-cigarette emissions, the limited number of analytical investigations published above differ in environmental conditions and experimental set-up making it difficult to compare their findings and to determine the impact of e-cigarette use on the indoor ambient air. It is also questionable to compare results from smoking machine generated aerosol released into a room [12] with aerosol generated from human subjects [13] due to the changed chemistry and physical properties of the aerosol upon exhalation. Other factors include differences in the type of e-cigarette device used ("closed" *vs.* "open" system), the e-liquid composition, and the e-cigarette consumers' individual puffing topography, *i.e.*, number of puffs, interval between puffs, puff duration, inhalation volume and depth of inhalation.

It has been reported there is wide variations in the quality of e-cigarettes which may also impact measured emission values [16]. Taken as a whole, there is a clear need for studies evaluating indoor air quality before, during and after e-cigarette use to provide important information on the impact of e-cigarettes on indoor air quality and therefore bystander exposures under real-life conditions [17].

In this study, we performed an assessment of indoor air quality before, during and after *ad libitum* use of a disposable 'closed' system e-cigarette (Puritane™; manufacturer, Fontem Ventures B.V., Amsterdam, The Netherlands) by human subjects in a naturally ventilated meeting room. Within this study, we analyzed the airborne concentrations of volatile organic compounds (VOCs) including nicotine and low molecular weight carbonyls, polycyclic aromatic hydrocarbons (PAHs), tobacco-specific nitrosamines (TSNAs) and trace metals. To assess indoor air quality and to provide a context for potential bystander exposures, we compared these findings with Human Criteria Values including UK and other general indoor air quality guidelines or workplace exposure limits (WELs), where available. The experimental approach presented here may also be useful to compare the chemicals released into the ambient air from different e-cigarettes used in different indoor environments.

2. Experimental Section

2.1. Study Design

To assess indoor air quality in a real-life environment, a business meeting was conducted in a small meeting room (12.8 m^2) with five male adult volunteers (three experienced, regular e-cigarette users and two non-users) who had provided written, informed consent. The purpose of this was to create a realistic environment to encourage normal behavior by volunteers, without undue focus on vaping behavior. Smoking or vaping had not occurred in the room previously which was under natural ventilation conditions (*i.e.*, no air conditioning and all windows/doors were kept closed during the study). The air exchange rate of the office was confirmed using a standard tracer gas method as described previously by Upton and Kukadia [18]. The internal volume of the room was 38.5 m^3 and was furnished with a central table and five chairs; a video camera was placed in one corner of the room to record the study and number of puffs taken by the volunteers. Filter assemblies and sampling lines were suspended above the meeting table using metal struts; this served to reduce interference with volunteer behavior. To mitigate potential confounding from operators entering the test space, air samples were drawn using sampling lines into an adjacent room for collection onto tubes or sorbent cartridges specific for the respective chemical parameter being monitored. Samples for metals analysis were taken within the office using filter arrangements. A schematic representation of the room layout, with details of the two independent sampling locations and the positions of the e-cigarette users and non-users is shown in Figure 1. To investigate potential changes in indoor air quality, the ambient air was analyzed before, during and after a 165 min vaping session. Sampling times are shown in Figure 2. During the vaping session, three of the five participants used Puritane™ 16 mg/g disposable Original flavored e-cigarettes ("closed" system; battery capacity, 240 mAh) purchased over-the counter from a number of UK retail outlets. The base e-liquid (1 mL) used in the product consists of mixture of propylene glycol (67% (w/w)) and glycerol (30% (w/w)) in which pharmaceutical grade nicotine (1.6% (w/w); 16 mg/g per product) and small amounts of flavorings are dissolved; a typical e-liquid conformation in the UK. Products were consumed *ad libitum* (*i.e.*, with no restrictions on how to consume the product during the study period) with multiple products available to enable continual vaping during the study period as required; two participants did not use an e-cigarette during the meeting. The study was developed in collaboration with and conducted by an independent, leading UKAS accredited laboratory in the UK with expertise in indoor air quality.

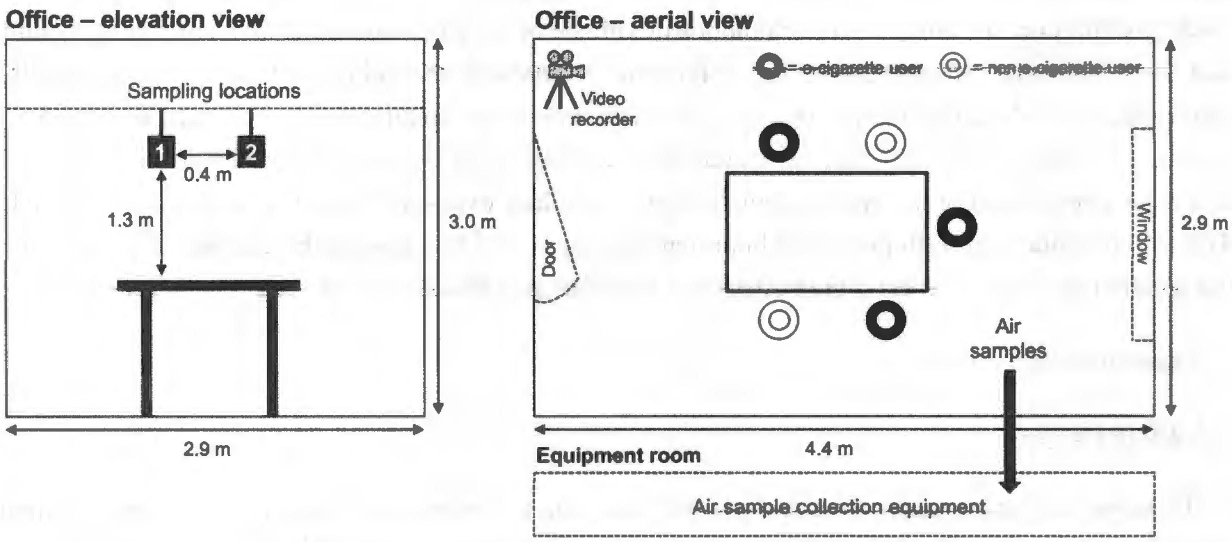

Figure 1. The layout of the meeting room used in this study (not drawn to scale). Sampling locations and positions of the e-cigarette users and non-users during the meeting are highlighted.

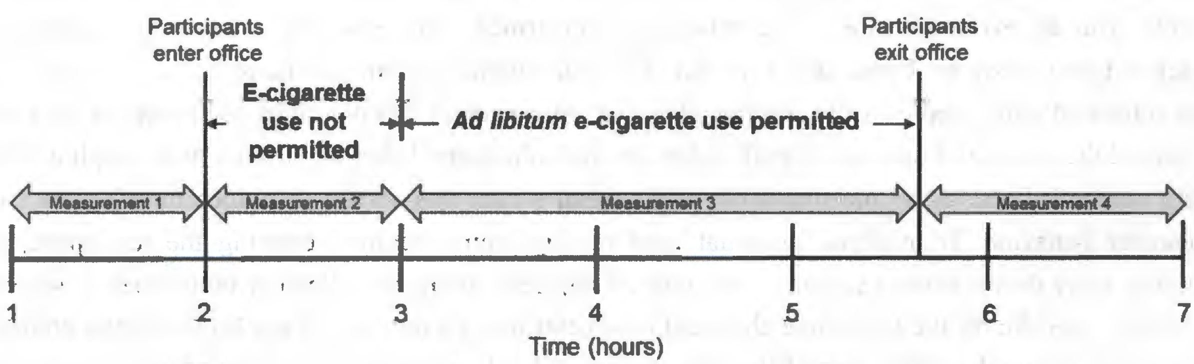

Figure 2. Timeline illustrating when participants entered and exited the office, when e-cigarettes were used and sampling times.

2.2. Analysis of Indoor Air Parameters

2.2.1. Indoor Climate

Carbon dioxide was measured continuously using a non-dispersive infrared detector (Q-Trak IAQ monitor, TSI Inc., Shoreview, MN, USA; limit of detection, 9 mg/m³). Carbon monoxide was measured continuously using an electro-chemical sensor (Q-Trak IAQ monitor, TSI Inc.; LOD, 1.2 mg/m^3). Ozone was measured continuously using a UV based photometric analyzer (Ozone Analyzer Model 49C; LOD, 0.002 mg/m^3 Thermo Environmental Systems, Franklin, MA, USA). Nitric oxide and nitrogen dioxide were measured continuously using a NO_x Analyzer (Thermo Environmental Systems Model 42C; LOD, 1.25 mg/m^3 for nitric oxide and 1.9 mg/m^3 for nitrogen dioxide). Indoor humidity and temperature were continuously monitored (Q-Trak IAQ monitor, TSI Inc.).

2.2.2. Nicotine

Nicotine was measured in the air by pump sampling maintained at a flow rate of 1 L/min throughout the sampling period through PTFE tubing into XAD2 sorbent tubes (Ref. 226-30-06, SKC Ltd, Dorset, UK). Analysis of exposed tubes was performed by solvent extraction and GC-MS. The LOD for nicotine in air was 7.0 μg/m^3. Travel blanks were also collected and analyzed.

2.2.3. Volatile Organic Compounds (VOCs)

Sampling and analysis of VOCs was carried out according to the ISO 16000-6 international standard [19]. Pump sampling was maintained at a flow rate of 0.15 L/min throughout the sampling period through PTFE tubing. Travel blanks were also collected and analyzed. The total volatile organic compounds (TVOC) concentration, as used in many indoor air quality guidelines, was calculated as the area of all compounds eluting between, and including, hexane and hexadecane. This is quantified as toluene equivalents, and so the TVOC concentration may be less or more than the sum of the individual VOCs reported. The LODs for each individual VOC were in the range 0.5–1.0 μg/m^3.

2.2.4. Glycerol

Glycerol was measured in the air by pump sampling maintained at a flow rate of 1 L/min throughout the sampling period through PTFE tubing into XAD7 sorbent tubes (SKC Ltd Ref. 226-57). Analysis of exposed tubes was performed using a thermodesorption unit coupled to by solvent extraction and GC-MS. The LOD for glycerol in air was 150–350 μg/m^3; this range represents differences in sample durations and therefore sampling volumes. Travel blanks were also collected and analyzed.

2.2.5. Low Molecular Weight Carbonyls

Formaldehyde (methanal), acetaldehyde (ethanal) and acrolein (propenal) were measured in the air by pump sampling maintained at a flow rate of 1.5 L/min throughout the sampling period through PTFE tubing into commercially available purpose-built tubes which contained silica coated with 2,4-dinitrophenyl hydrazine (DNPH). Sampling and analysis of exposed tubes was performed according to ISO 16000-3 international standard [20]. The LOD for carbonyls in air was 2.0 μg/m^3. Travel blanks were also collected and analyzed.

2.2.6. Polycyclic Aromatic Hydrocarbons (PAHs)

The US Environmental Protection Agency (US EPA) 'priority list' of 16 PAHs [21] were measured in the air by pump sampling maintained at a flow rate of 2 L/min throughout the sampling period through PTFE tubing into XAD2 sorbent tubes (SKC Ltd Ref. 226-30-06). Analysis of exposed tubes was performed by solvent extraction and high resolution GC-MS. The LOD for each PAH in air was 1.25 μg/m³. Travel blanks were also collected and analyzed.

2.2.7. Trace Metals

The US EPA "Method 29" metals [22], aluminium and phosphorus were measured in the air by pump sampling operating maintained at a flow rate of 6.5 L/min throughout the sampling period into pre-prepared 25 mm filter assemblies (using mixed cellulose ester "MCE" membrane filters). The filters were acid-extracted by digestion in boiling *aqua regia* and the extract analyzed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The LOD for each metal in air ranged from 1.0 to 2.0 μg/m³, depending on the metal analyzed. Travel blanks were also collected and analyzed.

2.2.8. Tobacco-Specific Nitrosamines (TSNAs)

TSNAs were measured in the air by pump sampling maintained at a flow rate of 1.5 L/min throughout the sampling period through PTFE tubing into Cambridge filter pads (44 mm diameter) impregnated with potassium bisulphate. Analysis of exposed tubes was performed by solvent extraction and HPLC-MS. The LOD for each TSNA in air was 0.5 μg/m³. Travel blanks were also collected and analyzed.

2.3. Analysis of Outdoor Air Parameters

Temperature, relative humidity, and levels of ozone and NO_x were also monitored outside the building.

3. Results and Discussion

Across Europe and North America, consumer interest in electronic vapour (e-vapour) products, including e-cigarettes, continues to grow [1]. While there are some parallels between e-vapour products and conventional tobacco products in terms of product conformation and consumer behaviors, the products themselves are radically different in their design, composition, and the resultant inhaled and exhaled aerosol. As such, product standards and other regulatory measures must take account of this although as a comparatively recent product category, the evidence base on which to establish such regulation is still developing. While e-cigarettes do not combust or generate side-stream emissions, there is currently a debate on whether exhaled e-cigarette aerosols pose a potential exposure risk to bystanders akin to that reported for environmental tobacco smoke from conventional tobacco products [2–6]. In designing the present study, the key aims were to conduct a study under realistic conditions and to examine findings reported previously by other researchers.

3.1. Product Use: Puff Rate

From the video footage, the average puff rate across the three e-cigarette users during the 165 min vaping session was calculated to be 3.2 puffs per minute.

3.2. Indoor Climate Parameters

The measured room ventilation rate showed a low level of natural ventilation for the size of the office and number of occupants, with an average air exchange rate of 0.8 air changes per hour. The UK Chartered Institute of Building Services Engineers (CIBSE) recommends a ventilation rate of 1.0 air change per hour [23]. However, this level of ventilation is comparable to that previously reported for living rooms in residential properties [24].

The temperature and relative humidity (RH) in the office over the course of the study were in the ranges 22–28 °C and 43%–57% respectively, with both parameters showing a marked increase as a consequence of the room occupation, as would be expected in a small space with limited natural ventilation and no recourse to cooling. The temperature and RH nevertheless remained within the UK Health and Safety Executive (HSE) ranges for acceptable human comfort in an office space [25].

Carbon monoxide was not detected during any of the test periods (vaping or non-vaping). Carbon dioxide (CO_2) levels increased to a mean level of 5813 mg/m^3 from a background level of 969 mg/m^3 during the non-vaping session, with the concentration peaking at nearly 6800 mg/m^3 during the vaping session. With the windows and door closed, and continuous occupation by five people, this rise in CO_2 concentrations is to be expected from normal respiration. There were small differences in the concentrations of nitric oxide (NO), nitrogen dioxide (NO_2) and ozone (O_3) during the periods of vaping and non-vaping in the meeting room (data not shown). The small variations in the concentrations of these gases were considered to be as a result of the usual changes that occur in the outside atmosphere, which migrate into the building through infiltration.

3.3. Volatile Organic Compounds (VOCs; Including Nicotine, Propylene Glycol and Glycerol) and Low Molecular Weight Carbonyls

Table 1 summarizes the results for VOCs, including nicotine, propylene glycol and glycerol (the three principal components of e-cigarette base liquid) and low molecular weight carbonyls. Nicotine is present in most e-liquids and e-cigarettes, and several studies have investigated its presence in the ambient air following product use. After the generation and release of e-cigarette aerosol using a smoking machine into an exposure chamber, McAuley *et al.* [11] reported airborne nicotine concentrations ranging from 0.725 to 8.77 μg/m^3 following use of rechargeable e-cigarettes with refillable cartomisers containing 24 mg/mL or 26 mg/mL nicotine. Similarly, Czogala *et al.* [12] used three different e-cigarette products containing 16 mg/mL or 18 mg/mL nicotine and found airborne concentrations in an exposure chamber ranging from 0.82 to 6.23 μg/m^3. Both these studies (and others) used a machine approach to simulate the use of e-cigarettes for estimating potential bystander exposures to exhaled e-cigarette aerosol [11,12,26]. Such an approach does not account for consumer behavior nor the retention of nicotine by the e-cigarette user and so is likely to overestimate airborne nicotine concentrations and potential bystander exposures. In a volunteer study conducted by Schober *et al.* [13], it was found that the nicotine concentration in the ambient air ranged from 0.6 to 4.6 μg/m^3 during a 2 h vaping session using a rechargeable e-cigarette with refillable tank ("open" system).

Table 1. Average indoor air concentrations of VOCs (including nicotine, propylene glycol and glycerol (principle components of the e-liquid)) and low molecular weight carbonyls (μg/m^3) measured before, during and after use of e-cigarettes from two independent sampling sites.

Chemical Compound	Background (before Participants Enter Room)	Room Occupied (No Vaping)	Room Occupied (Vaping Permitted)	Room Unoccupied (after Participants Leave Room)	Air Quality Guidelines or UK Workplace Exposure Limit as Published (WEL; 8 h Average) (mg/m^3)	Air Quality Guidelines or UK Workplace Exposure Limit * (WEL; 8 h Average) (μg/m^3)
	Measurement 1 (μg/m^3)	Measurement 2 (μg/m^3)	Measurement 3 (μg/m^3)	Measurement 4 (μg/m^3)		
Propylene glycol	<0.5	<0.5	203.6	10.2	UK WEL: 474	474,000
Glycerol	<150	<225	<250	<200	UK WEL: 10	10,000
Nicotine	<7.0	<7.0	<7.0	<7.0	UK WEL: 0.5	500
Isoprene	<0.5	6.2	9.5	<0.5	Not established	Not established
Acetone	1.3	9.2	10.7	1.2	UK WEL: 1210	1,210,000
Propan-2-ol	55.3	13.6	8.0	29.2	UK WEL: 999	999,000
Hexamethylenecyclotri-siloxane	5.3	29.1	13.3	4.4	Not established	Not established
Octamethylcyclotetra-siloxane	<0.5	14.2	3.6	0.9	Not established	Not established
Limonene	2.2	2.1	2.9	1.5	Not established	Not established
Octanal	2.1	3.5	5.4	4.6	Not established	Not established
Decamethylcyclo-pentanesiloxane	6.3	307	460.8	107.5	Not established	Not established
Nonanal	6.3	7.9	10.6	11.0	Not established	Not established
Decanal	2.8	5.7	9.5	11.6	Not established	Not established
2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate	7.7	16.1	17.3	18.0	Not established	Not established

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Table 1. *Cont.*

Chemical Compound	Background (before Participants Enter Room)	Room Occupied (No Vaping)	Room Occupied (Vaping Permitted)	Room Unoccupied (after Participants Leave Room)	Air Quality Guidelines or UK Workplace Exposure Limit as Published (WEL; 8 h Average) (mg/m³)	Air Quality Guidelines or UK Workplace Exposure Limit * (WEL; 8 h Average) (μg/m³)
	Measurement 1 (μg/m³)	Measurement 2 (μg/m³)	Measurement 3 (μg/m³)	Measurement 4 (μg/m³)		
2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	<0.5	<0.5	1.5	2.2	Not established	Not established
Di-isobutyl phthalate	3.5	4.4	2.3	2.8	UK WEL: 5	5000
Formaldehyde	32.0	31.0	37.6	21.0	WHO: 0.1	100
Acetaldehyde	9.0	6.5	12.4	6.0	EU Indoor Air Quality: 0.2	200
Acrolein	<2.0	<2.0	<2.0	<2.0	UK WEL: 0.23	230
Total VOC	65.0	237.0	379.8	129.0	UK Building Regulations: 0.3 (8 h average)	300

* converted to μg/m³ to facilitate comparison with analytical findings in this study.

These levels are in general agreement with the theoretical maximum level determined in a recent publication which used a mathematical model to assess the concentration of nicotine in the indoor air following e-cigarette use [27]. However in our volunteer study presented here, there was no measurable increase in nicotine airborne concentrations with vaping when compared with either the no vaping control session or background measurements *i.e.*, all measurements were found to be <7.0 μg/m^3. By way of context, the published UK WEL for nicotine is 500 μg/m^3 [28]. The low level measured in this study may be attributable to the high retention rate of nicotine in the body, which has previously been reported following inhalation of tobacco smoke [29], as well as some potential loss by deposition [30]. Further research in these areas will be informative.

Propylene glycol and glycerol are principal components of e-liquids and their presence in exhaled e-cigarette aerosol is expected. Concentrations of propylene glycol in the range of 110–215 μg/m^3 and glycerol in the range of 59–81 μg/m^3 in the gas phase of emissions have been reported previously [13]. In other studies, McAuley *et al.* [11] observed airborne concentrations of propylene glycol that ranged from 2.25 to 120 μg/m^3 and Romagna *et al.* [15] reported airborne glycerol concentrations of 72 μg/m^3.

In our study, during *ad libitum* use of the 'closed' system e-cigarettes, propylene glycol in the air of the meeting room increased from <0.5 μg/m^3 during the no vaping control session to 203.6 μg/m^3 during vaping. At the end of the vaping session, there was a substantial and rapid decrease in the levels detected (down to 10.2 μg/m^3). The levels of propylene glycol determined within our study design were below the UK WEL of 474,000 μg/m^3 set for this chemical [28]. Glycerol, while also expected to be present in the indoor air during the vaping session, could not be detected with satisfactory precision due to the limit of detection (LOD) for this compound (<350 μg/m^3). Further methodological refinement is required in future work. Nonetheless, it can be established that glycerol in the indoor air did not exceed 350 μg/m^3 during consumption of the e-cigarettes which is below the UK WEL of 10,000 μg/m^3 set for this chemical [28].

Total volatile organic compounds (TVOCs) is an analytically based classification for a range of organic chemical compounds present in ambient air or emissions and is used for reporting purposes. In evaluating TVOCs, consideration of the individual compounds is also necessary (Table 1). The background concentration of TVOCs observed in the meeting room ambient air in our study rose from 65 μg/m^3 to 237 μg/m^3 upon occupation of the room. While not components of e-liquids, this increase was likely due to the contribution of siloxane compounds arising from the five volunteers. It is well known that siloxanes are widely used in toiletries, deodorants and other personal care products [31]; with increasing room temperature during the study session, release of these and other cosmetic components would likely to have increased. A number of other commonly used aroma compounds (e.g., octanal, nonanal) were also detected at lower levels during the study period. During the vaping phase the TVOC concentrations rose to 379.8 μg/m^3, conceivably due to further release of siloxanes and exhalation of propylene glycol from the active consumption of the e-cigarettes (see above). Following participant exit from the office, the TVOC concentrations returned to pre-vaping levels. While a WEL has not been established, UK Building Regulations recommend an 8 h average TVOC level of 300 μg/m^3 [32].

Previous studies have detected the presence of the low molecular weight carbonyls formaldehyde and acetaldehyde in exhaled e-cigarette aerosols [10,13]. It has been reported that potential sources of these compounds in e-cigarette aerosol may arise from the heating or pyrolysis of propylene glycol [33].

Schripp *et al.* [10] evaluated emissions from e-cigarettes after asking a volunteer user to consume three different refillable "open" e-cigarette devices in a closed 8 m^3 chamber. The authors reported formaldehyde and acetaldehyde in the air of the chamber albeit at significantly lower levels than emissions from a conventional cigarette. Schripp *et al.* [10] concluded that the presence of formaldehyde in the ambient air may be explained by human contamination and not from e-cigarette emissions; it has been previously reported that low amounts of both formaldehyde and acetaldehyde of endogenous origin can be detected in exhaled breath [34]. In addition, it is widely reported that formaldehyde is released from some furniture and fittings, an effect which increases with room temperature and humidity [35]. Taken as a whole, this highlights the importance of appropriate control sampling during air quality studies.

In our study, using a 38.5 m^3 environment, we observed slight changes in formaldehyde levels from an empty meeting room background value of 32.0 μg/m^3, to 31.0 μg/m^3 with occupancy, to 37.6 μg/m^3 during e-cigarette use. The level fell rapidly to 21.0 μg/m^3 following vacation of the office by study participants. The WHO has established a guideline indoor air value of 100 μg/m^3 for formaldehyde [36]. While indicated as a short-term (30 min) guideline to prevent sensitivity or sensitization in both adults and children, WHO has stated that this value is sufficient to prevent long-term health effects, including cancer, since two distinct long term risk assessment models in the review arrived at proposed guideline values of around 210 and 250 μg/m^3 [36]. The levels of formaldehyde determined within our study design were below WHO Indoor Air Quality guideline value of 100 μg/m^3 set for this chemical and comparable to range of values typically found in domestic or public spaces [36,37]. Schripp *et al.* [10] and Schober *et al.* [13] both reported formaldehyde levels below the WHO Indoor Air Quality Guideline.

When compared with the non-vaping session, we found acetaldehyde levels changed from a background of 9.0 μg/m^3 to 6.5 μg/m^3 after occupation to 12.4 μg/m^3 during the vaping session. These values and those reported by Schripp *et al.* [10] and Schober *et al.* [13] were well within the EU Indoor Air Quality guideline for acetaldehyde which is set at 200 μg/m^3 [38].

A further finding in our study was the absence of a measurable increase in acrolein, the pyrolysis product of glycerol [33], in the office air with use of e-cigarettes when compared to control measurements (<2.0 μg/m^3). This finding is consistent with those findings from Romagna *et al.* [15], who did not detect acrolein in air quality measurements in a 60 m^3 room during *ad libitum* use of e-cigarettes.

By way of context, it has been reported by the US Environmental Protection Agency (EPA) and others that the burning of candles indoors resulted in a measureable increase of benzene, toluene, formaldehyde, acetaldehyde and acrolein [39]. In air quality measurement studies following their use, formaldehyde levels in the air ranged from 1.0–323.5 μg/m^3 and acetaldehyde from 1.0 to 74.95 μg/m^3; reported levels of these two carbonyls measured in our study were substantially less than the maximal values in these studies [9].

For acetone and isoprene, both exhaled breath components [40], there was an increase from baseline during the occupied non-vaping session and active vaping sessions. Isoprene increased from a baseline measurement of <0.5 μg/m^3 to 6.2 μg/m^3 during room occupation to 9.5 μg/m^3 during active vaping.

Acetone increased from a baseline measurement of 1.3 μg/m³ to 9.2 μg/m³ during room occupation to 10.7 μg/m³ during active vaping. Following participant exit from the room, the concentrations of both compounds returned to background levels. This indicates that the occupants were the primary source of isoprene and acetone. A UK WEL has not been established for isoprene; acetone levels in all measurements were substantially lower than the UK WEL which is currently 1,210,000 μg/m³ [28].

3.4. Polycyclic Aromatic Hydrocarbons (PAHs)

Table 2 summarizes the results for the PAHs. Schober *et al.* [13] recently reported airborne concentrations of PAHs increased following e-cigarette use by volunteers, but were still substantially lower than the USA Occupational Safety and Health Administration's (OSHA) Permissible Exposure Level (PEL) for PAHs in the workplace of 200 μg/m³ [41]. In a commentary on this work, Farsalinos and Voudris [42] noted several study limitations including measuring baseline values on different days from the vaping sessions thus changes in airborne PAHs levels may reflect variations in environmental PAH levels and not e-cigarette use. In our study, there was no measurable increase in the airborne concentration of any of the US EPA 'priority list' of 16 PAHs during the vaping period (all <1.25 μg/m³), which includes seven PAHs classified as probable carcinogens by International Agency for Research on Cancer (IARC) [43,44]. Differences between the current work presented here and the low levels detected by Schober *et al.* [13] may reflect differences in the sensitivity of the methodologies employed, study design and/or differences between products used in the respective studies.

Table 2. Average indoor air concentrations of US EPA "priority list" of 16 PAHs (μg/m³) measured before, during and after use of e-cigarettes from two independent sampling sites.

Chemical Compound	Background (before Participants Enter Room)	Room Occupied (No Vaping)	Room Occupied (Vaping Permitted)	Room Unoccupied (after Participants Leave Room)
	Measurement 1 (μg/m³)	Measurement 2 (μg/m³)	Measurement 3 (μg/m³)	Measurement 4 (μg/m³)
Acenaphthene	<1.25	<1.25	<1.25	<1.25
Acenaphthylene	<1.25	<1.25	<1.25	<1.25
Anthracene	<1.25	<1.25	<1.25	<1.25
Benz[a]anthracene	<1.25	<1.25	<1.25	<1.25
Benzo[b]fluoranthene	<1.25	<1.25	<1.25	<1.25
Benzo[k]fluoranthene	<1.25	<1.25	<1.25	<1.25
Benzo[ghi]perylene	<1.25	<1.25	<1.25	<1.25
Benzo[a]pyrene	<1.25	<1.25	<1.25	<1.25
Chrysene	<1.25	<1.25	<1.25	<1.25
Dibenz[ah]anthracene	<1.25	<1.25	<1.25	<1.25
Fluoranthene	<1.25	<1.25	<1.25	<1.25
Fluorene	<1.25	<1.25	<1.25	<1.25
Indeno[1,2,3-cd]pyrene	<1.25	<1.25	<1.25	<1.25
Naphthalene	<1.25	<1.25	<1.25	<1.25
Phenanthrene	<1.25	<1.25	<1.25	<1.25
Pyrene	<1.25	<1.25	<1.25	<1.25

3.5. Trace Metals

Table 3 summarizes the results for trace metals. It has been previously reported in the literature that e-cigarette use may result in the release of metal particles into the ambient air [13,45]. Schober *et al.* [13] reported that levels of aluminium in the ambient air increased 2.4-fold following e-cigarette use. Under the conditions employed in our study, there was no measurable increase in any of the USA "EPA Method 29" metals [22] as well as aluminium and phosphorus during the vaping period compared with the no-vaping control session and background levels. Measurements were all <1.0 μg/m^3 for antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium and zinc; <2.0 μg/m^3 for aluminium, beryllium, silver and thallium, and <10 μg/m^3 for phosphorus. Where established for those metals analyzed, all were below UK WELs as shown in Table 4 [28]. Again, the differences in these findings compared to the Schober *et al.* [13] study may be due to differences in the methods employed and/or the design and manufacture processes of the e-cigarette devices used in the respective studies.

Table 3. Average indoor air concentrations of US "EPA Method 29" metals (plus aluminium and phosphorous) (μg/m^3) measured before, during and after use of e-cigarettes from two independent sampling sites.

Chemical Compound	Background (before Participants Enter Room)	Room Occupied (No Vaping)	Room occupied (Vaping Permitted)	Room unoccupied (after Participants Leave Room)	UK Workplace Exposure Limit as Published (WEL; 8 h Average) (mg/m^3)	UK Workplace Exposure Limit * (WEL; 8 h Average) (μg/m^3)
	Measurement 1 (μg/m^3)	Measurement 2 (μg/m^3)	Measurement 3 (μg/m^3)	Measurement 4 (μg/m^3)		
Aluminium	<2.0	<2.0	<2.0	<2.0	10	10,000
Antimony	<1.0	<1.0	<1.0	<1.0	0.5	500
Arsenic	<1.0	<1.0	<1.0	<1.0	0.1	100
Barium	<1.0	<1.0	<1.0	<1.0	0.5	500
Beryllium	<2.0	<2.0	<2.0	<2.0	0.002	2.0
Cadmium	<1.0	<1.0	<1.0	<1.0	0.025	25
Chromium	<1.0	<1.0	<1.0	<1.0	0.5	500
Cobalt	<1.0	<1.0	<1.0	<1.0	0.1	100
Copper	<1.0	<1.0	<1.0	<1.0	1	1000
Lead	<1.0	<1.0	<1.0	<1.0	Not established	Not established
Manganese	<1.0	<1.0	<1.0	<1.0	0.5	500
Mercury	<1.0	<1.0	<1.0	<1.0	0.02	20
Nickel	<1.0	<1.0	<1.0	<1.0	0.1	100
Phosphorus	<10.0	<10.0	<10.0	<10.0	Not established	Not established
Selenium	<1.0	<1.0	<1.0	<1.0	0.1	100
Silver	<2.0	<2.0	<2.0	<2.0	0.1	100
Thallium	<2.0	<2.0	<2.0	<2.0	0.1	100
Zinc	<1.0	<1.0	<1.0	<1.0	Not established	Not established

* converted to μg/m^3 to facilitate comparison with analytical findings in this study.

3.6. Tobacco-Specific Nitrosamines (TSNAs)

Table 4 summarizes the results for TSNAs. Previous studies have reported the presence of TSNAs in the e-liquid or mainstream e-cigarette aerosols [46]. In our study, we sampled the ambient air for the presence of *N'*-nitrosonornicotine (NNN), 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK), *N'*-nitrosoanatabine (NAT) and *N'*-nitrosoanabasine (NAB). There was no measurable increase in the airborne concentrations of the four TSNAs analysed during active consumption of e-cigarettes when compared to control measurements (all < 0.5 μg/m^3).

Table 4. Average indoor air concentrations of TSNAs (μg/m^3) measured before, during and after use of e-cigarettes from two independent sampling sites.

Chemical Compound	Background (before Participants Enter Room)	Room Occupied (No Vaping)	Room Occupied (Vaping Permitted)	Room Unoccupied (after Participants Leave Room)
	Measurement 1 (μg/m^3)	Measurement 2 (μg/m^3)	Measurement 3 (μg/m^3)	Measurement 4 (μg/m^3)
N'-Nitrosonornicotine (NNN)	<0.5	<0.5	<0.5	<0.5
4-(Methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK)	<0.5	<0.5	<0.5	<0.5
N'-Nitrosoanatabine (NAT)	<0.5	<0.5	<0.5	<0.5
N'-Nitrosoanabasine (NAB)	<0.5	<0.5	<0.5	<0.5

3.7. Study Limitations and Strengths

The key aim of our study design was to replicate a real-life scenario with unrestricted use of a disposable "closed" system product by the vaping volunteers. In doing so, overhead sampling of the ambient air was chosen rather than personal dosimetry approaches to reduce potential confounding of vaping behaviors from intrusive sampling.

Our use of volunteers in conditions designed to replicate those in a real-world situation limited the sample duration and therefore the sensitivity of the some of the methods employed, which were not as sensitive as in some other studies which used a machine generated aerosol. Arguably, if the presence of certain chemicals can only be detected by employment of artificial or atypical conditions, it is reasonable to question the appropriateness of such data. The use of consumers within the study removed many of the issues associated with the use of smoking machine generated aerosols, for example questions around the potential retention of chemicals in the body or that of different machine protocols not replicating product consumption profiles. With regards to the method to measure glycerol in our study, sensitivity was not as low as anticipated. While there could be some scope for reducing the LODs for these and other chemicals further by increasing sampling duration, this would be difficult without introducing other potential confounding factors such as opening and closing meeting doors for refreshment breaks. By excluding opening and closing doors in this study, and by limiting the air exchange to natural room ventilations, the levels reported in our study are likely to represent an overestimate of normal conditions. The measurement of air exchange and other environmental parameter measurements in the methodology are supportive of this.

Another limitation in this study was the use of a single product; as noted above, other research groups have reported findings that were not replicated in this present study. Such studies used different products which may reflect variations in e-liquid or device quality, sufficient details of which are often not reported. Additionally, given the focus on ambient air, the primary emissions of the analyzed product were not determined in this study, which may be of interest in future work focusing on consumer rather than bystander exposures. Further air quality studies could also investigate other product types as well as different settings and volunteer groups.

The potential issue of cross contamination with cigarette smoke has been noted previously [2]. Given the sensitivity of the methods employed in this study, potential confounding from recent tobacco smoking was minimized. A strength of this study was that the rooms used here had never been smoked in nor were they used for any prior tobacco research.

4. Conclusions

The present study offers an indoor air quality assessment by an independent, UKAS accredited laboratory following use of a disposable 'closed' system e-cigarette in a real life setting. Since this was not a long-term repeated exposure study; in providing a context, findings were related to indoor air quality guidelines, where available. Our data indicate that exposure of bystanders to the chemicals in the exhaled e-cigarette aerosol, at the levels measured within our study, are below current regulatory standards that are used for workplaces or general indoor air quality. This finding supports the conclusions of other researchers that have stated there is no apparent risk to bystanders from exhaled e-cigarette aerosols [6,11,47].

There has been conflicting and at times confusing information reported regarding the potential risks of bystanders and non-e-cigarette users to exhaled e-cigarette aerosol. The regulatory outlook from a public health perspective currently remains undetermined; there is a clear need for further research in this area to support the development of appropriate product standards and other science-based regulatory measures.

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Author Contributions

All authors conceived and designed the experiment. All authors analyzed and interpreted the data. Grant O'Connell and John D. Pritchard wrote the manuscript. All authors contributed to the manuscript and approved the final version.

Conflicts of Interest

All authors are employees of Imperial Tobacco Group. The work in this manuscript was supported by Imperial Tobacco Group. Imperial Tobacco Group is the parent company of Fontem Ventures B.V., the manufacturer of the e-cigarette products used in this study.

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Evaluation of Chemical Exposures at a Vape Shop

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Contents

The employer is required to post a copy of this report for 30 days at or near the workplace(s) of affected employees. The employer must take steps to ensure that the posted report is not altered, defaced, or covered by other material.

The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from the owner of a vape shop. The employer was concerned about employees' potential exposure to vaping chemicals in the shop.

What We Did

- We evaluated the vape shop in January 2016.
- We collected air samples for flavoring chemicals (diacetyl, 2,3-pentanedione, 2,3-hexanedione, acetaldehyde, and acetoin), nicotine, formaldehyde, and propylene glycol.
- We took wipe samples for nicotine and metals on commonly touched surfaces.

We evaluated concerns about exposure to vaping-related chemicals in a vape shop. Exposure to flavoring chemicals (diacetyl, 2,3-pentanedione, acetaldehyde), formaldehyde, nicotine, and propylene glycol were all below occupational exposure limits. We found that not all employees wore chemical protective gloves when handling liquids containing nicotine. We saw chemicals being stored in a refrigerator used for food.

What We Found

- Employees vaped at work.
- Concentrations of vaping-related chemicals in our air samples were below occupational exposure limits.
- Not all employees wore chemical protective gloves when they were working with liquids that contained nicotine.
- The bottle of stock nicotine solution was stored in the same refrigerator used to store employees' food.

What the Employer Can Do

- Implement a policy prohibiting vaping in the shop with e-liquids that contain diacetyl and 2,3-pentanedione. These chemicals are often found in dairy flavorings, brown flavorings such as butterscotch and caramel, and some fruit flavorings.
- Do not store chemicals such as nicotine in the same area where food is stored or eaten.
- Provide disposable funnels to prevent liquid nicotine from spilling during transfer between containers.
- Inspect and maintain the shop's exhaust ventilation systems.

What Employees Can Do

- Wear nitrile gloves whenever handling liquids that contain nicotine.

- Wear nitrile gloves, a long-sleeve laboratory coat, and goggles when handling the stock nicotine solution.

Abbreviations

µg/100 cm²	Micrograms per 100 squared centimeters
µg/m³	Micrograms per cubic meter
ACGIH®	American Conference of Governmental Industrial Hygienists
cc/min	Cubic centimeters per minute
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
mL	Milliliter
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
ppb	Parts per billion
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
VOC	Volatile organic compound

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Introduction

The Health Hazard Evaluation Program received a request from the manager of a vape shop. We were asked to evaluate employees' exposures to chemicals associated with vaping in the shop. We visited the shop in January 2016. During our visit we met with employer and employee representatives and measured employees' exposures to vaping-related chemicals.

Background

Vaping is the process in which liquid is heated by an atomizer housed in an electronic nicotine delivery system or "e-cigarette." The liquid becomes an aerosol of liquid droplets in air (commonly referred to as vapor) that is inhaled by the user. The liquid (known as e-liquid or e-juice) is typically comprised of propylene glycol, vegetable glycerin, nicotine, and flavoring chemicals. Chemicals that have been associated with vaping include flavorings, nicotine, glycols, glycerin, other volatile organic compounds (VOCs), metals, and ultrafine particles composed of these chemicals, among others [AIHA 2014]. Diacetyl and its substitute, 2,3-pentanedione, are widely used flavoring chemicals. Serious respiratory disease and decreased lung function have been reported in employees exposed to diacetyl [NIOSH 2016]. Other flavoring chemicals that can be used in e-liquid such as acetaldehyde and acetoin can also have adverse respiratory health effects [NIOSH 2016]. Recently, a laboratory study has shown that diacetyl and 2,3-pentanedione are present in the heated vapor produced by e-cigarettes [Allen et al. 2016]. Other studies have directly measured exposures to vaping-related chemicals in well-characterized rooms and chambers, though they often did not sample for flavoring chemicals [Czogala et al. 2014; Maloney et al. 2016; Schober et al. 2014; Schripp et al. 2013].

The vape shop began operating at its current location in 2014. They sell e-cigarettes as well as the e-liquids that are used in the e-cigarettes. The employer estimated that the facility was approximately 1,000 square feet, with about 800 square feet devoted to retail and lounge space. The lounge area was a place for customers to congregate and vape. At the time of our visit, the company had 10 employees, including the owners who also worked in the shop. The shop was open from 11 a.m. to 8 p.m. Monday through Thursday. On Friday and Saturday, the shop was open from 11 a.m. to 9 p.m. On Sunday, the shop was open from 12 p.m. to 5 p.m. Shift lengths were variable, with employees working 3 to 10 hours, depending upon the day. Generally two employees worked in the shop at any one time.

This vape shop purchased pre-mixed e-liquids from a supplier and resold them to customers. They also hand mixed custom e-liquid blends according to the customer's taste, nicotine, propylene glycol, and vegetable glycerin preferences. Hand mixing of chemicals potentially exposes employees to concentrated levels of liquid nicotine. All employees generally performed the same tasks each day. The primary task was hand mixing of e-liquids for customers at a location referred to as the juice bar (Figure 1). Employees used syringes to transfer the flavoring chemicals into 10-milliliter (mL) and 30-mL bottles that the customers purchased. The syringes used for the flavoring chemicals, propylene glycol, and vegetable glycerin were washed each night and disposed of weekly. The syringes used for transferring nicotine were reportedly disposed of nightly.

Figure 1. Photo of juice bar mixing station.

The shop employees and manager reported that the flavoring chemicals make up approximately 20% of the e-liquid. The remaining 80% is propylene glycol, vegetable glycerin, and nicotine. The vegetable glycerin to propylene glycol ratio can be specified by the customer, and it was reported that customers typically use more vegetable glycerin than propylene glycol. The amount of nicotine added was based upon the amount a customer requested. If customers did not know how much nicotine they wanted, the employees discussed the customer's previous cigarette or cigar smoking history and made a recommendation based upon how much they typically smoked. The shop's stock nicotine solution is 100 milligrams per milliliter. The stock solution is diluted to shop-defined concentrations that correspond to smoking from one half of a pack up to 2.5 packs of tobacco cigarettes. This nicotine level can be adjusted according to customers' preferences.

Methods

Our primary objective was to evaluate employees' potential exposures to chemicals associated with vaping in the shop. Our work involved (1) sampling air for specific flavoring chemicals associated with respiratory disease; (2) sampling air for nicotine, propylene glycol, formaldehyde, and other VOCs; (3) sampling work surfaces for metals and nicotine; and (4) observing work practices.

Air Sampling for Vaping-related Chemicals

We collected personal air samples for specific flavoring chemicals on three employees during their full work shift on day 1, and on four employees on day 2. We also collected full-shift personal air samples for formaldehyde on two employees on day 1 and on three employees on day 2. We selected two locations in the shop to sample general room air (referred to as "area" air samples). One set of area air samples was collected directly behind the juice bar (Figure 2). The other was taken in the front of the shop, near the lounge area (Figure 3). Area samples behind the juice bar were collected for nicotine, propylene glycol, flavoring chemicals, and formaldehyde. Lounge area samples were collected for nicotine, flavoring chemicals, and formaldehyde.

Figure 2. A National Institute for Occupational Safety and Health (NIOSH) investigator preparing to collect an air sample. An area sampling station is next to the window behind juice bar. Photo by NIOSH.

Figure 3. Area sampling basket in the front lounge area. Photo by NIOSH.

Flavoring Chemicals

We measured flavoring chemicals using two air sampling methods, evacuated canisters and silica gel tubes. Using evacuated canisters, we collected personal and area air samples for diacetyl, 2,3-pentanedione, 2,3-hexanedione, and acetaldehyde. The evacuated canister sampling setup consisted of a 450-mL evacuated canister equipped with a restricted flow controller set to collect a 9-hour air sample.

The canister air samples were analyzed using a preconcentrator/gas chromatograph/mass spectrometer system according to a published method validation study [LeBouf et al. 2012] with the following modifications: the preconcentrator was an Entech Instruments Model 7200 and four additional chemicals, acetaldehyde, diacetyl, 2,3-pentanedione, and 2,3-hexanedione, were included in the analysis. The limit of detection of the sampling and analytical method is the lowest mass that can be currently measured. The limit of quantitation is the lowest mass that can be reported with acceptable precision. The analytical limits of detection were as follows: acetaldehyde, 0.3 parts per billion (ppb); diacetyl, 0.3 ppb; 2,3-pentanedione, 0.4 ppb; 2,3-hexanedione, 0.6 ppb. The limits of quantitation were as follows: acetaldehyde, 0.89 ppb; diacetyl, 0.86 ppb; 2,3-pentanedione, 1.2 ppb; 2,3-hexanedione, 2.1 ppb. These detection and quantitation limits were multiplied by the individual sample pressure dilution factors to obtain the minimum detectable and quantifiable concentrations displayed in the results table footnotes.

We collected full-shift area air samples for acetoin, diacetyl, 2,3-pentanedione, and 2,3-hexanedione using sets of two silica gel sorbent tubes in series with pumps calibrated to a flow rate of 50 cubic centimeters per minute (cc/min), at both area sampling locations over 2 days. These samples were analyzed for flavoring chemicals in accordance with Occupational Safety and Health Administration (OSHA) Method 1013 [OSHA 2008] and OSHA Method 1016 [OSHA 2010a]; however, an alternate detector (mass spectrometer) was used to increase method sensitivity [LeBouf and Simmons 2016]. The analytical limits of detection were as follows: acetoin, 0.04 micrograms per sample (μg/sample); diacetyl, 0.03 μg/sample; 2,3-pentanedione, 0.03 μg/sample; and 2,3-hexanedione, 0.04 μg/sample. The limits of quantitation were as follows: acetoin, 0.14 μg/sample; diacetyl, 0.088 μg/sample; 2,3-pentanedione, 0.094 μg/sample; and 2,3-hexanedione, 0.13 μg/sample.

Formaldehyde in Air

We collected full-shift personal and area air samples for formaldehyde using SKC UMEx 100 passive badges. The air samples were collected and analyzed in accordance with OSHA Method 1007 [OSHA 2005].

Nicotine in Air

We collected area air samples for nicotine using XAD-4 tubes with pumps calibrated to a flow rate of 200 cc/min. The air samples were analyzed in accordance with NIOSH Method 2551 [NIOSH 2017].

Propylene Glycol in Air

Area air samples for propylene glycol were collected and analyzed in accordance with NIOSH Method 5523 [NIOSH 2017].

Volatile Organic Compounds in Air

VOCs in the air were measured by two methods. First, we collected area air samples to qualitatively screen for VOCs using thermal desorption tubes with pumps calibrated to 50 cc/min. The samples were collected for up to approximately 3 hours as VOC concentrations were assumed to be low. The air samples were analyzed according to NIOSH Method 2549 [NIOSH 2017]. We collected these samples at the area sampling location behind the juice bar.

We collected short-term task-based samples using evacuated 1-liter canisters that were analyzed via Environmental Protection Agency (EPA) method TO-15 for VOCs [EPA 1999]. For these task-based air samples, we placed the inlet of the flow controller as close as possible to the employees (within approximately 3 feet) as they performed their work task. The flow controller was designed to fill the canister over a 15-minute period. In this method, each canister was analyzed for 65 target compounds. Additional compounds were tentatively identified using the Wiley Registry 9th edition/National Institute of Standards and Technology 2008 mass spectral library (John Wiley and Sons, Hoboken, NJ).

Surface Sampling for Elements and Nicotine

We collected wipe samples for elements (minerals and metals) from several surfaces in the vape shop that employees commonly touched during their work. These samples were collected using premoistened Palintest® Dust Wipes following NIOSH Method 9102 [NIOSH 2017]. We used a disposable template to collect each wipe sample over an area of 100 square centimeters. The wipe samples were analyzed according to NIOSH Method 7303 [NIOSH 2017].

We collected surface wipe samples for nicotine using sterile cotton swabs (ITW Texwipe Model STX705W) that were field desorbed in 1 mL of ethyl acetate. Most samples were collected using a disposable template, covering an area of 100 square centimeters. Some samples required a smaller template of 25.8 square centimeters. The wipe samples were analyzed according to NIOSH Method 2551, which was modified to incorporate the use of cotton swabs [NIOSH 2017].

Results

Workplace Observations

Employees and customers vaped inside the shop. During our site visit, we observed no haziness or lingering vapor clouds in the shop. However, employees reported that it could get "cloudy" or hazy inside the shop when many people were vaping simultaneously. On the days of our visit, we observed that most of the vaping inside the shop was from the employees vaping while working. Customers would sometimes vape while sampling flavors at the juice bar, but this practice was infrequent. When customers did sample flavors, they stood directly across from employees working at the juice bar. Customers could use the company's e-cigarette and tank along with a disposable safety tip to try different e-liquid flavors (Figure 4). The disposable safety tip was not reused between customers. The employer reported that each night employees cleaned the individual e-cigarettes with Lysol® wipes, as customers sometimes neglected to use the safety tips.

Figure 4. Assortment of e-liquid tanks and e-cigarettes customers used to sample different flavors at the juice bar. Photo by NIOSH.

Ventilation in the shop was provided by an air handling unit in the attic that delivered ducted supply air to the entire shop. Supply vents were located in the ceiling. Employees had blocked airflow from several of the vents because they felt that airflow was excessive. The shop had an exhaust vent fan in the ceiling above the juice bar. Employees turned on the exhaust fan at the beginning of the workday and turned it off at the end of the workday. The employer reported that the exhaust fan was vented into the attic.

Employees reported that they cleaned floors, counters, displays, and the juice bar each night with cleaning agents including Windex®, Simple Green®, Mop & Glo®, and bleach. The windows were cleaned weekly using Windex. The floors were swept nightly and were mopped with bleach four times per week. While we were at the shop, we observed employees cleaning the juice bar multiple times throughout the day.

On our first day at the shop, 18 customers entered the shop over the course of the day. Of these 18 customers, 12 did not vape inside the shop. On our second day of sampling, we noted nine customers entering the shop, two of whom vaped in the shop. On both days, all employees vaped throughout the day.

We observed that the stock (100 milligrams per milliliter) nicotine solution was stored in a refrigerator also used for food storage (Figure 5).

Figure 5. Stock nicotine solution stored in the bottom of a refrigerator that was also used to store food. Photo by NIOSH.

Personal Protective Equipment

Employees were provided with nitrile gloves for use when mixing e-liquids and when working with chemicals. We observed that not all employees wore gloves during these tasks. When wearing gloves, employees generally used a new pair for each bottle of e-liquid they were mixing, and did not reuse gloves between juice-making tasks. We observed only one employee transferring nicotine from the stock bottle to smaller transfer bottles. This employee wore new gloves when transferring nicotine.

Air Sampling Results

Flavoring Chemicals

Table 1 presents the results for personal air monitoring for flavoring chemicals using evacuated canisters. None of the personal air samples for the flavoring chemicals were above any 8-hour time-weighted average (TWA) occupational exposure limit (OEL). The lowest OEL for these chemicals was the NIOSH recommended exposure limit (REL) of 5 ppb for diacetyl, and 9.3 ppb for 2,3-pentanedione. Appendix A describes these and other OELs in more detail.

Table 1. Personal air sampling results for flavoring chemicals (ppb)*

Job title	Day	Sample duration (minutes)†	Acetaldehyde	Diacetyl	2,3-Pentanedione	2,3-Hexanedione
Employee 1	Day 1	514	5.9	[0.8]	[1.4]	ND
Employee 1	Day 2	180	26	ND	ND	ND
Employee 2	Day 1	345	6.7	[1.1]	ND	ND
Employee 2	Day 2	335	ND	ND	ND	ND
Employee 3	Day 1	180	9.9	ND	ND	ND
Employee 3	Day 2	165	28	ND	ND	ND
Employee 4	Day 2	337	ND	[1.7]	2.4	2.5
ACGIH TLV			25,000 (ceiling)	10	—	—
NIOSH REL			—	5.0	9.3	—
OSHA PEL			200,000	—	—	—

ACGIH TLV = American Conference of Governmental Industrial Hygienists threshold limit value

OSHA PEL = OSHA permissible exposure limit

ND = Not detected

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum detectable concentration was 1 ppb for acetaldehyde and 1 ppb for diacetyl. It ranged from 1–2 ppb for 2,3-pentanedione and from 2–4 ppb for 2,3-hexanedione. The minimum quantifiable concentration ranged from 2.8–4.7 ppb for diacetyl and from 3.7–6.6 ppb for 2,3-pentanedione.

†Employee shift lengths varied. For each employee sampled, we sampled for their entire shift.

We also measured flavoring chemicals in general room air using evacuated canisters at the juice bar. These results, presented in Table 2, show very low or non-detectable concentrations.

Table 2. Area air sample concentrations (ppb) of flavoring chemicals using canister sampling*

Location	Day	Sample duration (minutes)	Acetaldehyde	Diacetyl	2,3-Pentanedione	2,3-Hexanedione
Juice bar – morning	Day 1	218	4.6	[2.3]	3.3	[3.1]
Juice bar – afternoon	Day 1	239	ND	[1.0]	ND	ND
Juice bar – morning	Day 2	223	ND	ND	ND	ND
Juice bar – afternoon	Day 2	232	17.3	ND	ND	ND

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum detectable concentration was 1 ppb for acetaldehyde, diacetyl, and 2,3-pentanedione, and ranged from 2–3 ppb for 2,3-hexanedione. The minimum quantifiable concentration ranged from 3.4–3.7 ppb for diacetyl, and from 7.9–8.6 ppb for 2,3-hexanedione.

The results for the area air samples taken over the entire work day in the juice bar and lounge areas using silica gel tubes are presented in Table 3. Diacetyl, 2,3-pentanedione, 2,3-hexanedione, and acetoin were not detected in the lounge area. For the full-shift area air samples taken behind the juice bar using silica gel tubes, we found detectable, but not quantifiable, concentrations of 2,3-pentanedione on day 1. We did not find detectable concentrations of any of the other flavoring chemicals in the other juice bar samples.

Table 3. Area air sample concentrations (ppb) of flavoring chemicals using silica gel tubes*

Location	Day	Sample duration (minutes)	Acetoin	Diacetyl	2,3-Pentanedione	2,3-Hexanedione
Juice bar	Day 1	464	ND	ND	[0.73]	ND
Juice bar	Day 2	509	ND	ND	ND	ND
Lounge area	Day 1	434	ND	ND	ND	ND
Lounge area	Day 2	498	ND	ND	ND	ND

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum detectable concentration was 1 ppb for acetoin. It ranged from 0.6–0.9 ppb for diacetyl, from 0.6–0.8 ppb for 2,3-pentanedione, and from 0.8–1 ppb for 2,3-hexanedione. The minimum quantifiable concentration ranged from 2.0–2.8 ppb for 2,3-pentanedione.

Formaldehyde in Air

Table 4 presents the personal air sampling results for formaldehyde. None of the employees we monitored had exposures to formaldehyde above OELs.

Table 4. Personal air sample results (ppb) for formaldehyde*

Job title	Day	Sample duration (minutes)†	Formaldehyde
Employee 1	Day 1	471	3.8
Employee 1	Day 2	172	[4.3]
Employee 2	Day 1	292	ND
Employee 2	Day 2	317	7.0
Employee 4	Day 2	319	7.0
NIOSH REL			16
OSHA PEL			750

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum quantifiable concentration ranged from 3–8 ppb for formaldehyde.

†Employee shift lengths varied. For each employee sampled, we sampled for their entire shift.

Table 5 presents the area air sample results for formaldehyde. Concentrations of formaldehyde in the air in the juice bar and the lounge area were very low and similar to those found in the personal air samples.

Table 5. Area air sample results for formaldehyde (ppb)

Location	Day	Sample duration (minutes)	Formaldehyde
Juice bar	Day 1	470	4.3
Juice bar	Day 2	467	6.0
Lounge area	Day 2	466	5.4

Nicotine in Air

Table 6 presents the results for the nicotine area air samples. Nicotine was not detected in the air in the lounge area. At the juice bar, airborne nicotine concentrations were detectable, but below the minimum quantifiable concentration.

Table 6. Area air sample results for nicotine (micrograms per cubic meter [μg/m³])

Location	Day	Sample duration (minutes)	Nicotine*
Juice bar	Day 1	344	[0.69]
Juice bar	Day 2	494	[0.80]
Lounge area	Day 1	435	ND
Lounge area	Day 2	478	ND

[ ] = Estimated concentration; this concentration was between the minimum detectable and minimum quantifiable concentrations.

*The minimum detectable concentration ranged from 0.3–0.4 μg/m³, while the minimum quantifiable concentration ranged from 0.97–1.4 μg/m³.

Propylene Glycol in Air

Table 7 presents the results for the propylene glycol area air samples. Concentrations of propylene glycol in the air at the juice bar were low.

Table 7. Area air sample results for propylene glycol (μg/m³)

Location	Day	Sample duration (minutes)	Propylene glycol
Juice bar	Day 1	445	426
Juice bar	Day 2	488	389

Volatile Organic Compounds in Air

Laboratory analysis of the samples we collected inside the vape shop using thermal desorption tubes indicated the presence of 102 chemicals. Many of the chemicals could be from sources other than vaping such as cleaning products or personal care products. The primary chemicals identified included isopropanol, limonene, and decamethylcyclcopentasiloxane. Other chemicals detected at lower relative concentrations included acetone, ethanol, propylene glycol, toluene, and glycerin. Trace amounts of a variety of flavoring chemicals, including diacetyl, were identified.

Table 8 presents the results for the 15-minute, task-based evacuated canister sampling and lists the compounds that were quantified using EPA Method TO-15. Although these were area samples, we positioned the sample media as close as possible to the employees (within approximately 3 feet), and we consider these results to be representative of employees' potential exposures. Employees' exposures to all of the compounds quantified were well below OELs. In addition to the VOCs quantified in the table, 30 other chemicals were tentatively identified in the canister air samples.

Table 8. Task-based (15 min) area air sample concentrations (ppb) for VOCs using evacuated canisters

Task	Acetone	Benzene*	Ethyl acetate	Ethyl benzene*	Isopropyl alcohol	m & p xylene	o-xylene*	Toluene
Employee making e-juice and vaping	16	ND	3.4	ND	970	2.7	ND	5.4
Employee making e-juice and vaping	19	1.2	3.1	ND	1,400	3.3	1	6.6
Employees cleaning at end of day	17	1	32	0.96	1,400	4.1	1.3	7.4
ACGIH TLV-STEL	NA	2,500	NA	NA	400,000	150,000	150,000	NA
NIOSH REL-STEL	NA	1,000	NA	125,000	500,000	150,000	150,000	150,000
OSHA PEL-STEL	NA	5,000	NA	NA	NA	100,000	100,000	NA

STEL = Short-term exposure limit

*The minimum detectable concentration for benzene, ethylbenzene, and o-xylene was 1 ppb.

Elements on Surfaces

Surface wipe samples for elements (minerals and metals) were taken throughout the vape shop. This included surfaces that employees or customers touched and included both sides of the juice bar counter, display cases, and areas near the cash register. Quantifiable concentrations of calcium (15–94 micrograms per 100 squared centimeters [$\mu g/100\ cm^2$]), copper (ND–0.49 $\mu g/100\ cm^2$), iron (ND–1.8 $\mu g/100\ cm^2$), and potassium (ND–17 $\mu g/100\ cm^2$) were identified in the wipe samples. Detectable, but not quantifiable, concentrations of chromium, lead, magnesium, nickel, phosphorus, strontium, and tellurium were also identified in some samples.

Nicotine on Surfaces

Surface wipe samples for nicotine were taken throughout the vape shop in locations similar to where the metal wipes were taken. We also wiped the bottle containing the stock nicotine solution, as well as a transfer bottle that is kept at the juice bar. None of the surfaces sampled had detectable concentrations, with the exception of the nicotine transfer bottle. There are no OELs for dermal exposure to nicotine.

Discussion

None of the airborne concentrations of the specific flavoring chemicals we measured were above applicable OELs although we detected low levels of two flavoring chemicals, diacetyl and 2,3-pentanedione, in the personal and area air samples. NIOSH has an action level for diacetyl of 2.6 ppb [NIOSH 2016] but our sampling method (evacuated canisters) does not measure exposures at this level. Therefore, some of the personal air sampling results for diacetyl could have been above the NIOSH action level. When diacetyl exposures are above the action level, NIOSH recommends that employers develop a medical surveillance program and implement engineering and work practice controls to keep exposures below the REL [NIOSH 2016].

Formaldehyde is a breakdown product of propylene glycol, which is present in the e-liquids used in e-cigarettes. Personal air sampling results for formaldehyde were well below the OSHA PEL and OSHA action level. They were also below the NIOSH REL, which is much lower than the OSHA PEL. Area sampling results showed that background formaldehyde concentrations were similar to the personal sampling results. Low concentrations of formaldehyde exist in many indoor environments because of off gassing from furnishings, clothing, and other materials.

In addition to the specific flavoring chemicals we looked for in the air samples (diacetyl, 2,3-pentanedione, 2,3-hexanedione, acetoin, and acetaldehyde), we also identified other flavoring chemicals and VOCs in the air of the vape shop. Results from the area air samples we collected using thermal desorption tubes showed very low concentrations of 102 chemicals. These included chemicals found in cleaning products used in the shop (limonene, isopropanol), chemicals that are common ingredients in personal care products (decamethylcyclopentasiloxane), and other chemicals that could be classified as flavoring chemicals. Background concentrations of airborne nicotine, propylene glycol, and VOCs in the air of the shop were also very low.

Over the 2 days of our evaluation, we observed that very few customers vaped inside the shop. In contrast, we found that employees vaped throughout the day. Therefore, most of an employee's exposure to vaping-related chemicals inside this vape shop was due to direct inhalation of vaping-related chemicals from their personal e-cigarette, as well as secondhand emissions from coworkers' e-cigarettes. Our air sampling only measured vaping chemicals present in the air from the emissions of e-cigarettes and exhaled breath. We did not measure chemical concentrations directly inhaled from an employee's own e-cigarette. However, the concentrations of vaping chemicals directly inhaled during vaping would likely be higher than the concentrations from second-hand emissions. Although our air sampling results showed very low exposures to vaping chemicals, exposure would have been even lower if employees had not been vaping in the shop.

We detected the presence of metals, such as chromium, lead, copper, and nickel on surfaces in the shop. This finding was not surprising given that these metals have also been measured by other researchers in e-liquids (chromium, lead, and nickel) and in vapor from e-cigarettes (chromium, nickel, and copper) [Hess et al. 2017; Williams et al. 2013]. Some of the other elements that we detected on surfaces are found in human sweat (calcium, potassium, magnesium, and phosphorous). It is unknown if their presence on surfaces was from e-cigarettes, people touching surfaces, or both.

We found detectable levels of nicotine on the outside surface of a nicotine transfer bottle. This may have occurred because employees did not use a funnel when transferring liquid nicotine. We did not find nicotine on other surfaces that we sampled. It is important to use good chemical handling procedures whenever working with the stock nicotine solution. Exposure to nicotine can occur by inhalation, skin absorption, and ingestion. Nicotine is a potent and potentially lethal toxin that is quickly absorbed from all routes of entry, including the skin or eyes [Brandon et al. 2015]. If nicotine gets on the skin, employees should immediately wash the affected area with soap and water. Research has shown that it only takes 3 to 5 minutes for nicotine to be absorbed through the skin [Zorin et al. 1999]; after that length of time, nicotine cannot be washed off and remains in the skin where it continues to be absorbed into the body.

Few standards define "acceptable" levels of workplace surface contamination. Wipe samples, however, can provide information regarding the effectiveness of housekeeping practices, the potential for exposure to contaminants by skin absorption or ingestion (e.g., surface contamination on the juice bar counter that is also used for food consumption), the potential for contamination of employee clothing and subsequent transport of the contaminant outside the workplace, and the potential for other activities (e.g., sweeping) to generate airborne contaminants. Overall, we found very low levels of some surface contaminants during our evaluation. We attribute these low levels to the effectiveness of the cleaning practices we observed, with employees wiping down commonly touched surfaces multiple times throughout the day.

The health effects associated with vaping are not well understood. According to the U.S. Surgeon General's report on e-cigarette use among youth and young adults, e-cigarette aerosol is not harmless as it contains nicotine, flavorings, other additives, and ultrafine particles [DHHS 2016]. The United States Food and Drug Administration has warned consumers about potential health risks associated with e-cigarettes and has finalized a rule extending their regulatory authority to cover electronic cigarettes [FDA 2013, 2016]. Flavoring chemicals such as diacetyl and 2,3-pentanedione have been associated with serious respiratory disease [NIOSH 2016]. One way to reduce exposure to these chemicals is to not use products containing them. Studies have shown that even flavors that are reported as being free of diacetyl may still contain it [Allen et al. 2016; Rutledge 2015]. The health risks of flavoring chemicals that may be used as substitutes for diacetyl and 2,3-pentanedione may not be known, and precautionary measures such as engineering controls are recommended to protect employees exposed to these substitutes [NIOSH 2016; OSHA 2010b].

This evaluation had limitations that could influence the generalizability of our findings. First, sampling occurred over 2 days in the winter of 2016, and our measurement results may not be representative of all other times or seasons. Over these 2 days, we did not observe a large number of customers vaping. The lounge area was not used during this time, and very few customers were present at the shop on the second day of sampling. If more customers were present and vaping inside of the shop, concentrations of vaping-related chemicals in the air may have been greater. Moreover, we do not know the chemical composition of the e-liquids employees and customers vaped over the course of our evaluation. The low air concentrations of flavoring chemicals that we measured may be due to the fact that the e-liquids used during our evaluation happened to contain very little of the specific flavoring compounds we measured.

Conclusions

Employees were exposed to detectable levels of diacetyl and 2,3-pentanedione in the air while working in the vape shop. Although the measured concentrations were below all applicable OELs, to better protect the health of employees we recommend that the employer implement a policy prohibiting vaping in the work place with e-liquids that contain diacetyl and 2,3-pentanedione. The concentration of other vaping-related chemicals that we measured were also below their relevant OELs. Employees should be trained on proper chemical handling procedures and the need for consistent use of chemical protective nitrile gloves when handling liquids containing nicotine.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the vape shop to use an employee-employer health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the vape shop.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix A). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Implement a policy prohibiting vaping in the shop with e-liquids that contain diacetyl and 2,3-pentanedione.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Do not store nicotine in the same refrigerator where food is stored, as this could lead to accidental ingestion of the nicotine solution or contamination of food with nicotine. Purchase a separate refrigerator to store nicotine. Clearly label the separate refrigerators with labels such as "Food use only" or "Nicotine storage only."
2. Use a disposable funnel to help prevent nicotine from spilling during the pouring of the stock nicotine solution into the transfer bottles.

3. Transfer nicotine from the stock solution to the transfer bottles in an area away from customers. Do this task in an area where a spill could be easily contained and cleaned up, and that has adequate ventilation.

4. Vent exhaust from the exhaust fan above the juice bar directly outdoors. Regularly inspect and maintain the exhaust fan above the juice bar and the air handling unit in the attic to ensure that they are working properly.

Administrative Controls

The term administrative controls refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Instruct employees who get nicotine on their skin to wash the affected area immediately with soap and water. Nicotine is absorbed through the skin in only 3 to 5 minutes; after that the nicotine cannot be washed off.

2. Ensure that employees understand the potential hazards in the vaping industry (such as flavorings, nicotine, and formaldehyde) and how to protect themselves. OSHA's hazard communication standard [29 CFR 1910.1200] requires that employees are informed and trained of potential work hazards and associated safe practices, procedures, and protective measures.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Train employees and require them to wear chemical protective gloves made out of nitrile whenever working with nicotine. Because nicotine can break through the glove material in as little as 6 to 9 minutes, develop and enforce a policy against employees reusing gloves and requiring a clean pair of gloves each time employees start a new task involving nicotine.

2. Provide long-sleeved lab coats and goggles and instruct employees on their use to prevent contact with the eyes, skin, or clothing when handling the stock nicotine solution, such as when transferring from the stock solution container to another container.

Appendix A: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States is the ACGIH TLVs. The TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2017].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German

Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

Hierarchy of Controls

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Diacetyl and 2,3-pentanedione

Diacetyl (2,3-butanedione) and 2,3-pentanedione, a diacetyl substitute, are VOCs with an intense buttery flavor. Exposure to diacetyl is associated with an increased risk for severe lung disease and lung function decline [NIOSH 2016]. Irreversible lung disease, such as obliterative bronchiolitis, has been reported in employees in industries with diacetyl exposures [Kreiss 2007; van Rooy et al. 2007]. Severe airway damage and disease has also been observed in laboratory animals after exposure to diacetyl or 2,3-pentanedione [Hubbs et al. 2008; Morgan et al. 2012]. Because of the potential health effects associated with diacetyl and 2,3-pentanedione exposure, NIOSH has a REL and 15-minute STEL for both of these flavoring chemicals. The NIOSH REL is 5 ppb for diacetyl with a STEL of 25 ppb. NIOSH also has an action level of 2.6 ppb for diacetyl. The REL for 2,3-pentanedione is 9.3 ppb, and the STEL is 31 ppb [NIOSH 2016]. The higher REL and STEL for 2,3-pentanedione does not imply that 2,3-pentanedione is of lower toxicity than diacetyl. Rather, the REL and STEL for 2,3-pentanedione are based upon the lowest level at which the substance reliably can be detected using the existing validated analytical method [NIOSH 2016].

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CON FIELD AIRPORT

mesa·az

Master Tenant Lease

West World War II Hangar

[F]ALCON FIELD AIRPORT

- Constructed in 1941 by U.S. government
- Used for training of British Royal Air Force & U.S. Army Air Corps pilots during World War II
- Deeded to City of Mesa after the war

CON FIELD AIRPORT

- Leased by several parties since World War II
- Primary use – aircraft storage
- Listed on National Register of Historic Places (along with East World War II Hangar)

CON FIELD AIRPORT

mesa·az

- Leased to Falcon Warbirds, LLC in 2014
- Store vintage warbird aircraft
- Educate community about Falcon Field's history during World War II
- Lease expires December 31, 2019


Terry Shelton/Shuto Images

LCON FIELD AIRPORT

mesa·az

- City wishes to continue to acknowledge & educate community about Falcon Field's role during World War II
- Set apart and designate one City asset to specifically fulfill this purpose


Aircraft

LCON FIELD AIRPORT

mesa·az

- Published Notice of Intent to Lease (A.R.S. 28-8425)
- Solicited proposals for non-profit organizations who can help achieve this goal

LCON FIELD AIRPORT

- Proposals received from Falcon Warbirds & Wings of Flight Foundation
  - Vintage warbird aircraft
  - Airport tours
  - Airport events (Annual Open House)
  - City-sponsored events (fly-overs)
- Both non-profit groups will be sharing the 20,000 sf hangar and 6,644 sf office/maintenance work area

LCON FIELD AIRPORT