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# Indoor air quality (IAQ) evaluation of a Novel Tobacco Vapor (NTV) product

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A R T I C L E I N F O

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A B S T R A C T

The impact of using a Novel Tobacco Vapor (NTV) product on indoor air quality (IAQ) was simulated using an environmentally-controlled chamber. Three environmental simulations were examined; two non-smoking areas (conference room and dining room) and one ventilated smoking area (smoking lounge). IAQ was evaluated by (i) measuring constituents in the mainstream NTV product emissions, (ii) and by determining classical environmental tobacco smoke (ETS) and representative air quality markers. Analysis of the mainstream emissions revealed that vapor from the NTV product is chemically simpler than cigarette smoke. ETS markers (RSP, UVPM, FPM, solanesol, nicotine, 3-ethenylpyridine), volatile organic compound (toluene), carbon monoxide, propylene glycol, glycerol, and triacetin were below the limit of detection or the limit of quantification in both the non-smoking and smoking environments after using the NTV product. The concentrations of ammonia, carbonyls (formaldehyde, acetaldehyde, and acetone), and total volatile organic compounds were the same levels found in the chamber without NTV use. There was no significant increase in the levels of formaldehyde, acetone or ammonia in exhaled breath following NTV use. In summary, under the simulations tested, the NTV product had no measurable effect on the IAQ, in either non-smoking or smoking areas.

## 1. Introduction

Environmental tobacco smoke (ETS) consists of both highly diluted and aged side-stream smoke, which is generated from the lit end of a burning cigarette, as well as mainstream smoke exhaled by the smoker (exhalation stream). ETS from the use of cigarettes can affect indoor air quality (IAQ) and has been widely investigated in various indoor areas of actual environments (Johnsson et al., 2006; Bolte et al., 2008; Vainiotalo et al., 2008; Arku et al., 2015).

Over the past decade, there has been a rise in the availability of electronic cigarettes (e-cigarettes) as new alternatives to traditional tobacco products such as cigarettes (Pepper and Brewer, 2014; Brown and Cheng, 2014). The chemical composition of the aerosol of e-cigarettes has been shown to be quantitatively different to that of conventional cigarette smoke (Margham et al., 2016) and exposure of bystanders to the chemicals in the exhaled e-cigarette aerosol have been reported to be below current regulatory standards that are used for workplaces or IAQ in general (O'Connel et al., 2015).

In parallel to the emergence of e-cigarettes, new types of tobacco products, in which tobacco is directly heated, but not combusted, during intended use, have emerged onto the market. Products in this category have been studied with respect to their mainstream emissions and toxicity (Dayan, 2016; Haziza et al., 2016a, 2016b, 2017; Kogel et al., 2016; Martin et al., 2016; Oviedo et al., 2016; Patskan and Reininghaus, 2003; Schaller et al., 2016a, 2016b; Sewer et al., 2016; Smith et al., 2016; Wong et al., 2016; Szostak et al., 2017). The effects on IAQ have also been reported, using validated analytical methods (Mottier et al., 2016), and consistently found to result in no significant increases, above background levels, for both volatile gas-vapor phase and particulate-phase ETS constituents (Tricker et al., 2009; Mitova et al., 2016).

More recently, a Novel Tobacco Vapor (NTV) product, which generates an inhalable nicotine containing aerosol, has been developed and marketed in Japan. When using this product, a nicotine-free aerosol is generated which then passes through a tobacco-containing capsule. In

*Abbreviations:* CO, carbon monoxide; $CO_2$, carbon dioxide; DNPH, 2,4-dinitrophenylhydrazine; e-cigarette, electronic cigarettes; ETS, environmental tobacco smoke; FPM, fluorescent particulate matter; GC-FID, gas chromatograph coupled with a flame ionization detector; GC-MS, gas chromatograph mass spectrometer; GC-NPD, gas chromatograph coupled with a nitrogen phosphorus detector; HEPA, high-efficiency particulate air filter; HPLC, high performance liquid chromatography; IAQ, indoor air quality; IC, ion chromatography; LED, light emitting diode; LOD, limit of detection; LOQ, limit of quantification; LWRL, lower working range limit; MMAD, mass median aerodynamic diameter; NTV, Novel Tobacco Vapor; PAH, polycyclic aromatic hydrocarbons; $PM_{2.5}$, particulate matter below the mass median aerodynamic diameter (MMAD) of 2.5 μm; $PM_{10}$, particulate matter below the mass median aerodynamic diameter (MMAD) of 10 μm; RSP, respirable suspended particles; SPM, suspended particulate matter; TVOC, total volatile organic compounds; UV, ultraviolet; UVPM, ultraviolet particulate matter; UWRL, upper working range limit; VOC, volatile organic compounds; WRL, working range limit

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doing so, some tobacco constituents, such as nicotine and flavors, pass into the aerosol, which is then inhaled. The tobacco is not directly heated during use, instead is indirectly warmed up to around 30 °C by the aerosol passing through it.

The objective of this study was to evaluate (1) NTV product emissions (i.e., mainstream and sidestream) and (2) the effect of particulate and gas-vapor phase constituents on IAQ by testing ETS parameters whilst using the NTV product in an environmentally-controlled chamber simulating "a dining room (i.e., restaurant)", "a conference room", and "a smoking lounge" representing public areas.

## 2. Materials and methods

### 2.1. Standards and regulations for air quality

#### 2.1.1. Ventilation and cigarette consumption rates

Indoor air quality is a function of many parameters, such as outdoor air quality, the design of the enclosed space, the ventilation system installed, and the presence and strength of sources of contaminants. In the USA, ANSI/ASHRAE® standard 62–2001 (2001) specifies minimum ventilation rates for acceptable indoor air quality to human occupants and is intended to minimize the potential for adverse health effects. This standard applies to all indoor or enclosed spaces including non-smoking and smoking areas.

ANSI/ASHRAE® standard 62.1–2007 (2007) includes requirements for buildings containing ETS and ETS-free areas but does not describe how to achieve an acceptable IAQ through ventilation in smoking areas.[1]

British standard BS EN 15251:2007 (2007) specifies the indoor environmental parameters which have an impact on the energy performance of buildings. The standard is applicable mainly to non-industrial buildings where the criteria for indoor environment are set by human occupancy. The standard defines ventilation rates for smoking areas assuming 20% of the occupants smoking 1.2 cigarettes per hour.

International Organization for Standardization standard ISO 16814 (2008), is intended to specify methods to express the quality of indoor air suitable for human occupancy. The document does not prescribe a specific method but refers to existing methods in the US and Europe.

Finally, the World Health Organization (WHO) provides specific values for individual chemicals in their air quality guidelines for Europe (WHO Regional Publications, European Series, No.91, 2000).

In this study, three scenarios were chosen to simulate indoor air quality in two non-smoking and one ventilated smoking areas by using an environmentally-controlled chamber. The selected parameters and parameter settings were based on ANSI/ASHRAE® standard 62–2001 (2001) and British standard (BS EN 15251:2007, 2007) and are summarized in Table 1. The air requirements for the different enclosed spaces included two types of ventilation: (i) "A base ventilation rate for an ETS-free area (i.e., a non-smoking room)" and (ii) "extra ventilation added to the base ventilation rate for an ETS-area".

ANSI/ASHRAE® standard 62–2001 (2001) was considered more applicable to public place simulations than the British standard when considering the proportion of smokers and cigarette consumption rate. For the ETS-area, the differences between "Dining room 1" and "Dining room 2" were in the number of smoking occupants (0.5 for dining room 2, 0.2 for Dining room 1). The proportion of smokers relates to total cigarette consumption rate, so that the two proportions correspond with total cigarette consumption rates of "Dining room 2" of 21 cigarettes/h and 8.4 for "Dining room 1", respectively (see Table 1). For the three different applications, the ventilation rate requirements to let in outdoor air were 64.8, 57.6, and 118.8 $m^3$/h person for the "Dining room 2", "Conference room", and "Smoking lounge", respectively.

Ventilation rates calculated in accordance with British standard EN 15251:2007 (2007) were as follows. The ventilation rate for the conference room, as an ETS-free area, ranged from 15.8 to 39.6 $m^3$/(h person) in a very low-polluted building, from 17.3 to 43.2 $m^3$/(h person) in a low-polluted building, and from 20.2 to 50.4 $m^3$/(h person) in a polluted building. The ventilation rates for the restaurant (corresponding to "Dining room 2"), as ETS-free area, ranged from 16.2 to 40.5 $m^3$/(h person) in a very low-polluted building, from 17.3 to 43.2 $m^3$/(h person) in a low-polluted building, and from 19.4 to 48.6 $m^3$/(h person) in a polluted building.

The base ventilation rate for "Dining room 2" corresponded to category I and II for a very low-polluted building or for a low-polluted building and category II for neither very low- nor low-polluted building. The base ventilation rate for the "Conference room" corresponded to category II for a very low-polluted building or low-polluted building, and between category II and III for neither very low- nor low-polluted building.

The total cigarette consumption rate of 21 (cigarettes/h) shown in "Dining room 2" of ANSI/ASHRAE® standard 62–2001 (2001) was 1.3 times larger than that of British standard (16 cigarettes/h; EN 15251:2007, 2007). The total cigarette consumption rate of 11 cigarettes/h shown in the "conference room" of the ANSI/ASHRAE® standard 62–2001 (2001) was almost the same as that of British standard (12 cigarettes/h; EN 15251:2007, 2007). Considering the disparities mentioned, harmonized standards and/or guidelines for IAQ may be needed for a consistent evaluation when assessing e-cigarettes and/or other alternative tobacco products.

#### 2.1.2. Selected contaminants for buildings

ANSI/ASHRAE® standards 62–2001 (2001), 62.1–2007 (2007) and 62.1–2016 (2016) also summarize indoor environmental factors, such as carbon monoxide (CO), carbon dioxide ($CO_2$), formaldehyde, particulate matter $PM_{2.5}$, $PM_{10}$, and total particulate matter.[2]

The concentrations of indoor air constituents, set or proposed by national or international organizations, can be summarized as follows: CO concentrations from 9 ppm to 50 ppm (not to be exceeded more than once per year, or per 8 h) as enforceable and/or regulatory levels, and 10 ppm–35 ppm as guide lines and reference levels; $CO_2$ concentrations of 5000 ppm as enforceable and/or regulatory levels, and from 3500 ppm to 5000 ppm as guidelines and reference levels; formaldehyde concentrations from 0.3 ppm to 0.75 ppm as enforceable and/or regulatory levels and from 0.016 ppm (0.020 mg/$m^3$) to 0.081 ppm (0.1 mg/$m^3$) for 30 min exposure (based on irritation of sensitive people) or up to 0.3 ppm (0.37 mg/$m^3$ as ceiling) as guide lines and reference levels.

The Ministry of Health, Labor and Welfare MHLW in Japan (Act on Maintenance of Sanitation in Buildings Act No. 20 of 1970, Act No. 69 of 2014 as the revision of Act No. 20) defined CO at 10 ppm, $CO_2$ at 1000 ppm, suspended particulate matter (SPM: equal to or below 10 mm in diameter) at 0.15 mg/$m^3$, and formaldehyde at 0.08 ppm (0.1 mg/$m^3$) as maximum indoor air concentrations, the environmental temperature from 17 °C to 28 °C, and relative humidity from 40% to 70%, for the maintenance of sanitation in buildings in Japan. The concentration values of CO and $CO_2$ defined by the Act on Maintenance of Sanitation in Buildings in Japan were similar to those defined by ANSI/ASHRAE® standard 62–2001 (2001).

### 2.2. Novel tobacco vapor (NTV) product

Details of the Novel Tobacco Vapor (NTV) product are shown in

[1] It should be noted that the smoking applications has been removed from ANSI/ASHRAE® standard 62.1–2007 (2007) and the later version. In ANSI/ASHRAE® standard 62.1–2007 (2007) and ANSI/ASHRAE® standard 62.1–2016 (2016), the minimum ventilation rates in the breathing zone for ETS-free areas are shown instead of overall required ventilation rates.

[2] $PM_{2.5}$, less than 3.0 μm is considered respirable; $PM_{10}$, less than 10 μm is considered inhalable.