NSW Health

NSW E-Cigarette Analysis Project

Summary Report

UNIVERSITY OF WOLLONGONG AUSTRALIA

NSW GOVERNMENT

NSW Ministry of Health
1 Reserve Road
St Leonards NSW 2065
Tel. (02) 9391 9000
Fax. (02) 9391 9101
TTY. (02) 9391 9900

www.health.nsw.gov.au

This research was conducted by the Mass Spectrometry User Resource and Research Facility (MSURRF) at the University of Wollongong, and was funded and commissioned by NSW Health.

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The NSW Ministry of Health acknowledges the traditional custodians of the lands across NSW. We acknowledge that we live and work on Aboriginal lands. We pay our respects to Elders past and present and to all Aboriginal people.

For further information email MOH-Tobacco@health.nsw.gov.au

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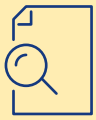
SHPN (CPH) 230758
ISBN 978-1-76023-626-7

September 2023

Key findings

750 e-cigarette devices were tested for nicotine and other banned and potentially harmful substances.

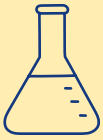


Samples were sourced from Sydney government and non-government high schools (322 products) **and from retailers** throughout NSW (428 products).

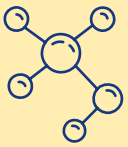
Collection and seizure of devices began in early 2022, and **all chemical analyses were carried out in the 2022/23 financial year.**

97.5% of e-cigarettes confiscated from students contained nicotine, which has the potential to lead to nicotine poisoning or dependence.

Most nicotine e-cigarettes were not labelled as containing nicotine. Products with identical packaging were found to both contain nicotine and be nicotine-free, making it impossible for users to know what they are vaping.



Testing identified many other **chemicals not listed in the ingredients and preliminary advice indicates the concentrations of flavour chemicals detected in these devices were hundreds of times higher than those reported in food and cosmetics.**[1] The safety of inhaling flavour chemicals, rather than ingesting through food, has not been established.



Substances known to harm health, and banned from legal nicotine products by the Therapeutic Goods Administration, **were detected in 30 (4%) of the samples.** These included **acetoin, benzaldehyde, cinnamaldehyde and ethylene glycol.**

Ethylene glycol, a substance used in anti-freeze and engine coolant, **was detected in potentially harmful concentrations in e-cigarettes** confiscated from schools.

Samples confiscated from schools had a significantly higher proportion of fruit flavours, indicating that fruit flavours are particularly popular among children.

23% of samples confiscated from schools had been tampered with, possibly for the purposes of replenishing or altering the contents or recharging the battery. Tampering with vapes can **increase the risk of nicotine poisoning** and the **risk of burns** as a result of devices exploding.

The e-cigarette market is constantly evolving, and this study sampled only 750 devices collected during a limited research period.

1. Dinu, V et al 2020, 'Policy, toxicology and physicochemical considerations on the inhalation of high concentrations of food flavour', *npj Science of Food*, vol. 4. DOI: https://doi.org/10.1038/s41538-020-00075-y.

Purpose

NSW Health commissioned the NSW e-cigarette analysis project in collaboration with the University of Wollongong. The project aimed to add to the evidence base and understanding of the nature of e-cigarette devices currently on the market in NSW, to better inform and target awareness campaigns and enforcement activities.

This project undertook e-cigarette liquid sample analyses by carrying out gas chromatography mass spectrometry analysis of 750 samples of e-liquids extracted from devices seized or confiscated in NSW. Before this project, the largest analysis of e-liquids in Australia was a study conducted in Western Australia and published in 2021, in which 65 samples were analysed, and only three were sourced from NSW.[2] These samples pre-date the significant shift in the nicotine vape market towards disposable devices. Of the 750 samples examined in the NSW e-cigarette analysis project, 726 were disposable devices and 24 were pods.

Background

The Mass Spectrometry User Resource and Research Facility (MSURRF) at the University of Wollongong (UoW) initiated a program in 2019 to analyse e-cigarettes for nicotine, and a range of contaminants, selected either because they are explicitly prohibited by the current Therapeutic Goods Administration *Therapeutic Goods (Standard for Nicotine Vaping Products)* (TGO 110) *Order 2021* or because they have been otherwise identified as of potential interest for further study (e.g. coolants or acetals).

The TGO 110 regulates the minimum safety and quality requirements for legal nicotine vaping products available for therapeutic purposes via prescription. It is assumed that samples within this study have not been accessed through the prescription pathway, however the banned substances have still been assessed as a point of comparison. The samples referred to in this report as containing chemical agents that are listed as banned substances under TGO 110 are those that contain banned substances other than nicotine.

The full list of chemicals tested for is at Figure 1.

Methods

Three sample sets and a total of 750 devices were examined:

- 428 devices were provided from NSW Health's stockpile, acquired through covert purchases and seizures, and all still sealed in their original packaging. These devices were carefully selected to provide the widest possible cross-section of the devices available on the market; with as many different brands, models and flavours selected as possible.
- 322 devices were collected from nine high schools throughout Greater Sydney; both public and private schools were included.

It is important that the analysis of devices seized by NSW Health is viewed separately to the school samples. These seized products were confiscated via compliance and enforcement efforts and on the basis that they contain nicotine and are therefore illegal in the retail setting. As such, they are artificially selected for nicotine content. While this means that the presence of nicotine in these samples is not informative, the wide selection of devices provides the best possible information on the presence of other contaminants. It is also of note that a large proportion of these devices will have been in storage for a significant period, as a small subset of the NSW Health stockpile was placed aside for sample selection from the beginning of 2022.

The devices provided by schools represent samples of the devices commonly used by young people in NSW. These results will be useful for informing the ongoing policy response to e-cigarette use among young people, and communications strategies with young people.

2. Larcombe, A et al 2022, 'Chemical analysis of fresh and aged Australian e-cigarette liquids', *Medical Journal of Australia*, vol. 216, no 1, pp. 27-32. DOI: https://doi.org/10.5694/mja2.51280.

Sample set 1: Devices seized from retailers

A total of 428 devices were selected by the University of Wollongong from the Ministry of Health stockpile of seized devices. Devices were selected for maximum variety and to minimise duplication. Efforts were made to select only one or two items of each flavour/brand/model combination, with further samples of the same combination selected if they had arrived in a different batch. This was intended to enable analysis of the manufacturing consistency. Of the 428 devices analysed, 47 different brand/model combinations across 19 brands were represented. A total of 160 unique flavour names were recorded, with fruity flavours being the most prevalent at 72%. Flavours that contained a cooling component in their flavour name ("ice", "frozen" or "cool") accounted for 44.6% of all devices. 1.4% of devices were tobacco flavoured. IGET was the most prevalent brand.

Nicotine was detected in 423 of the devices analysed (98.8%) with an average concentration of 42.5 mg/mL and concentrations ranging from 15.5 to 60 mg/mL. In 98.6% of the devices where nicotine was detected, nicotine was in the form of the nicotine benzoate salt (confirmed by presence of benzoic acid). It is reasonable to expect that a small number of non-nicotine devices may be captured amongst the majority of nicotine devices seized by NSW Health, partly due to inconsistencies in manufacturing. Of the five devices that did not contain nicotine, the IGET King and IGET XXL devices were identical to other devices that tested positive for nicotine, and the majority of samples tested (noting that they were provided in their original brand new packaging) did not have any mention of nicotine or nicotine concentration on their packaging. It was found that any ingredient list provided on the product packaging was not an accurate representation of the chemical composition.

Coolant compounds were detected in 99.3% of all seized devices. The addition of these cooling agents is likely an attempt to reduce the throat irritation experienced by the user (particularly nicotine-naïve individuals) in products with a high concentration of nicotine.[3] On average, coolants were found in approximately half the concentration of the nicotine content of all nicotine positive devices.

All samples tested contained at least one flavour or coolant molecule. The most commonly occurring flavour chemicals were cis-3-hexene-1-ol (grassy, green flavour), ethyl maltol (sweet, caramel, candy flavour) and 1,3-diacetin (fatty, buttery flavour). On average, flavour chemicals were detected in concentrations of 5mg/mL or lower. The exception was 1,3-diacetin, which was found in concentrations higher than 60 mg/mL.

Chemicals prohibited in the current TGO 110 were detected in 18 of the samples (4.2%). The TGO 110 regulates the contents of legal nicotine vaping products and prohibits the use of a number of chemicals that are known or suspected to be harmful when inhaled. The TGO 110 banned substances detected in these samples were:

- Acetoin
- Benzaldehyde
- Cinnamaldehyde
- Ethylene glycol

Notably, one sample contained a low concentration of ethylene glycol. This is a significant discovery, as it appears to be the first sample acquired from an Australian retailer to be found to contain ethylene glycol. Ethylene glycol is a toxic chemical used in antifreeze and engine coolant, and is linked to lung disease.

Acetals are new chemical compounds formed in the e-liquid under normal storage conditions, resulting from a chemical reaction between a flavour molecule and the carrier fluid. Acetals were detected in 58 samples (13.6%). This suggests the possibility that compounds not originally included in the e-liquids during manufacturing can develop after manufacture. In two such samples, all of one banned reactive chemical (benzaldehyde) appeared to have entirely converted to the propylene glycol (PG) acetal, benzaldehyde PG. Studies have indicated that the formation of some acetals in e-liquids can increase the toxicity of the e-liquids and are efficiently transferred to e-cigarette aerosol.[4]

3. Jenkins, C et al 2023, 'Synthetic cooling agents in Australian-marketed e-cigarette Refill liquids and disposable e-cigarettes: Trends follow the U.S. Market', *Nicotine & Tobacco Research*, vol 24. DOI: https://doi.org/10.1093/ntr/ntad120
4. Jabba, S V et al 2020, 'Chemical Adducts of Reactive Flavor Aldehydes Formed in E-Cigarette Liquids Are Cytotoxic and Inhibit Mitochondrial Function in Respiratory Epithelial Cells', *Nicotine & Tobacco Research*, vol. 22. DOI: https://doi.org/10.1093/ntr/ntaa185

Sample set 2: Greater Sydney high schools

A total of 322 devices collected from nine high schools in Greater Sydney were tested. As noted, there was no sample selection process, simply the first 322 devices made available were submitted for testing.

Of the 322 devices analysed, 22 different brand/model combinations across 15 brands were represented. A total of 97 unique flavour names were recorded, with fruity flavours being the most popular at 87.9%. Flavours that contained a cooling component in their flavour name ("ice", "frozen" or "cool") accounted for 44.7% of all devices. IGET was the most popular brand, followed by HQD and Gunnpod.

Nicotine was detected in 314 of the devices analysed (97.5%) with an average concentration of 39.67mg/mL and concentrations ranging from 21.4 to 61 mg/mL. In all the devices where nicotine was detected, it was in the form of nicotine benzoate salt. None of the devices provided had the word 'nicotine' written on them, with only seven devices showing a concentration value, all of which were "5%". These seven devices all tested positive for nicotine.

While 99.7% of devices had a cooling component in the flavour name, all devices analysed contained coolant compounds, including the five that didn't contain nicotine.

Chemicals prohibited in the TGO110 were detected in 12 of the samples (3.7%). The same substances detected in the seized samples were detected in the samples confiscated from schools (acetoin, benzaldehyde, cinnamaldehyde and ethylene glycol. Most notably, three of these samples contained ethylene glycol, in markedly higher concentrations (11mg/mL) than were observed in the seized samples.

Of some concern is the fact that 73 of the devices taken from schools appeared to have already been opened, likely by users before they were collected. It is possible that this tampering was the result of attempts to alter or refill the e-liquid in the device or charge the non-rechargeable battery.

Implications of the findings and further considerations

Given that the seized devices were artificially selected for containing nicotine (through enforcement efforts), it is of significant concern that the devices confiscated from high school students by schools were similarly likely to contain nicotine. This indicates that nicotine vaping products are readily accessible by young people. Average nicotine concentrations in devices acquired from high schools were also higher than in seized devices from retail premises. This may reflect the speed at which the nicotine vape product market is progressing, as seized devices were drawn from a stockpile that had been gathered by NSW Health over a period of a few months, and the samples confiscated from schools were collected approximately five months later.

As the seized devices sample set provides the widest selection of flavours, it is of note that samples confiscated from schools had a significantly higher proportion of fruit flavours, and that the general cooling flavours and tobacco flavour were particularly unpopular. It is clear from this comparison between school samples and seized samples that the fruit flavours are particularly popular among children.

The high proportion of devices confiscated from schools that appeared to have been previously opened warrants further investigation. It is possible that students are tampering with the contents of disposable e-cigarettes, re-filling them or trying to recharge the batteries, all of which could present significant health risks. Disposable e-cigarettes contain a coil and usually a polyester sponge, both of which degrade during use, as a result of being repeatedly heated to high temperatures. If devices are being refilled, there is likely to be further degradation of the coil and sponge, which may have impacts on the chemical composition of the e-liquid.

Coolants were detected in almost all devices analysed, and it is theorised that this is to enable a higher concentration of nicotine than the user may otherwise comfortably consume, as the coolant dulls the pain in the throat. Of the 750 devices tested, 744 contained the coolant WS-23, and 142 also contained WS-3.

The discovery of ethylene glycol (both in retail and school samples) is of significant concern. There were moderately high concentrations detected in the samples confiscated from schools. Also of concern is the detection of a total of 30 devices (4% of all samples) containing chemicals that are known to harm health and are prohibited under TGO110 from legal nicotine vaping products.

Figure 1: list of chemicals tested for by MSURRF

- Vanillin (0.6 - 30 mg/ml);
- Ethyl vanillin (0.4 - 20 mg/ml);
- γ-Decalactone (0.2 - 10 mg/ml);
- γ-Nonalactone (0.2 - 10 mg/ml);
- p-Anisyl alcohol (0.8 - 40 mg/ml);
- p-Anisaldehyde (0.4 - 20 mg/ml);
- Benzyl alcohol (0.6 - 30 mg/ml);
- Piperonal (0.5 - 25 mg/ml);
- 1,2-Diacetin (0.4 - 20 mg/ml);
- 1,3-Diacetin (0.4 - 20 mg/ml);
- Sulfurol (0.4 - 20 mg/ml);
- 1-Methylnaphthalene (0.4 - 20 mg/ml);
- Ethyl butanoate (1 - 50 mg/ml);
- Furfural (0.4 - 20 mg/ml);
- Cis-3-hexen-1-ol (0.6 - 30 mg/ml);
- Ethyl hexanoate (0.4 - 20 mg/ml);
- 2-Acetylpyridine (0.4 - 20 mg/ml);
- p-Dimethoxybenzene (0.4 - 20 mg/ml);
- Menthol (0.8 - 40 mg/ml);
- 4-Acetylanisole (0.4 - 20 mg/ml);
- Methyl cinnamate (0.4 - 20 mg/ml);
- Benzyl benzoate (0.2 - 10 mg/ml);
- Maltol (0.8 - 40 mg/ml);
- Ethyl Maltol (0.8 - 40 mg/ml);
- 2,3-Pentanedione* (1 - 50 mg/ml);
- Butanoic acid (1 - 50 mg/ml);
- Benzaldehyde* (0.4 - 20 mg/ml);
- 3-Methyl-1,2-cyclopentanedione (1 - 50 mg/ml);
- Guaiacol (0.6 - 30 mg/ml);
- Iso-amyl isovalerate (0.4 - 20 mg/ml);
- Diethyl succinate (0.6 - 30 mg/ml);
- d-Decalactone (0.4 - 20 mg/ml);
- g-Undecalactone (0.2 - 10 mg/ml);
- Valeraldehyde (0.8 - 40 mg/ml);
- WS23 (Coolant) (1 - 50 mg/ml);
- Ethylene glycol* (1 - 50 mg/ml);
- Diethylene glycol* (0.6 - 30 mg/ml);
- Acetoin* (0.4 - 20 mg/ml);
- Diacetyl* (1 - 50 mg/ml);
- Cinnamaldehyde* (1 - 50 mg/ml);
- Vitamin E Acetate* (1 - 50 mg/ml); and
- Veratraldehyde (1 - 50 mg/ml).
- PG and VG acetals of:
  - Vanillin;
  - Ethyl vanillin;
  - Piperonal;
  - p-Anisaldehyde;
  - Benzaldehyde;
  - Furfural;
  - Valeraldehyde;
  - Veratraldehyde;
  - 2-3-Pentanedione; and
- PG and/or VG acetals of:
  - 3-Methylcyclo-pentane-1,2-dione;
  - 4-Acetylanisole;
  - δ-Decalactone;
  - Benzyl alcohol;
  - p-Anisyl alcohol; and
  - Butanoic acid.

NB: values in brackets include the concentration range tested for in samples, with limit of detection value for all flavours around half the concentration of the low end concentration.

* denotes compounds that are prohibited under TGO110

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