36 Winchester St Lyttelton Christchurch 8082 New Zealand Ph: +64 3 3288688 Cell: 027 488 4375 Skype: murraylaugesen laugesen@healthnz.co.nz www.healthnz.co.nz	Health NEW ZEALAND	**Health NEW ZEALAND** Research and policy advice to reduce heart disease, cancer and smoking **Dr Murray Laugesen** QSO, MBChB, FAFPHM, FRCS, Dip Obst ***Managing Director***

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EASY PUFF with cartomiser compared with other brands. Report of tests July to September 2013

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Aims To compare EasyPuff brands of electronic cigarette with other (EC) brands for a voluntary standard, on price, puffs, smokers' ratings, and nicotine and toxicant yield.

Method We selected 6 brands applying to the Health New Zealand voluntary EC standard, and 3 popular in the US and UK. Thirty smokers were randomly allocated and blinded to assess 3 ECs each. Puffs (70 mL) per cartomiser were measured by syringe and 3-way tap. Standard puffing parameters measured vapour toxicity and nicotine, comparing brands with the first EC (Ruyan 2008) and the Marlboro cigarette, all tested at Labstat International ULC according to Health Canada approved methods.

Results EC toxic aldehydes by brand were 100-500 times less than in cigarette smoke. Nicotine yield per 70 mL puff varied from 19 to 49 mcg compared to 100 -147mcg for a Marlboro cigarette. Compared with Ruyan, 2013 brands emitted 56 percent less mean toxicant, and 1.9 times more mean nicotine per puff. Diethylene and monoethylene glycol were not detected in vapour. Higher nicotine per puff was correlated with greater intention to reduce, quit or seriously stop smoking.
Cartomisers labeled as high strength, (16-18 mg/mL) contained 7.8 mg to 19 mg nicotine. Vapour volumes per cartomiser were equivalent to smoke from 14-29 cigarettes. Nicotine strength per EC puff varied from 19 micrograms (brand used in the Auckland EC trial) to 45-49 micrograms per puff. Intention to reduce, quit, or stop smoking varied from 26 percent for the zero nicotine brand, to 41 percent for a brand with cartomiser (19 mcg per puff), to 47 percent to 45 mcg per puff); 59 percent would make aim to stop smoking if the top nicotine brand (49 mcg/ puff) was available.

Conclusion
1) Providing smokers with legal purchase of nicotine ECs is a priority.
2) All brand tested were at least 100 times safer than tobacco cigarettes with respect to the aldehydes in vapour.

3) Nicotine in the vapour is inadequate in most cases to gain smokers commitment to use the brand instead of smoking.

Introduction

Electronic cigarettes (ECs) are battery-powered to vapourise nicotine in a mist of propylene glycol, creating a mist but no smoke. In New Zealand nicotine refills are illegal to sell, and brands purchased on the internet vary in quality, and battery quality is a frequent problem.

This study provides raw data to inform the creation of Health New Zealand voluntary standard for ECs to be launched on 23 October 2013 in Auckland, New Zealand. www.healthnz.co.nz/healthNZstandard_Ecigs The standard assists smokers to choose, and health professionals to recommend, EC brands with adequate puff generation, low toxicity and high nicotine efficacy. The standard does not replace future official standards or the manufacturer's warranty, nor guarantee product safety. The quality benchmarks set can be raised over time. The puffing parameters are derived from Goniewicz,[1] except that puff duration is set at 3 seconds not 1.8 seconds, to include ECs with heating coils which are slower to heat.

Method

Selection of test products. Ten brands were identified, seven submitted for testing for the Health New Zealand voluntary standard (brands A, B, C, D, E, F, J), and three selected on popularity (G) or good reviews in the UK (H, I). The brands were requested or purchased by internet from the distributor. Brands with no manufacturer or distributor known, rechargeable brands generating less than 150 puffs, and a highly advertised very expensive EC providing no future access to refills, were not included.

ECs were labeled for testing. For consumer testing the brand names were masked. All comprised battery plus cartomisers (cartridge and atomiser combined) except D and F. All ECs were labeled as high nicotine (16-18 mg) strength except for brand J (with zero nicotine). Only tobacco flavour variants were tested. For a comparator tobacco cigarette, we selected the Marlboro king size filter cigarette brand sold in the USA, tested under Health Canada Intensive mode, 55 mL per puff, one puff every 30 seconds,[2] as the closest smoking mode to that used for an electronic cigarette.

Comparators. We selected the Ruyan classic EC brand, first tested in 2008 by Health New Zealand Ltd and reported in 2013[3] to gauge the changes in ECs since that time. We selected the Marlboro king size filter cigarette brand sold in the USA, as an example of a globally known cigarette, tested under Health Canada Intensive mode, collecting one 55 mL puff every 30 seconds.[4]

Selection of toxicants in vapour. Toxicants were tested only in the vapour. The main toxicants were volatile aldehydes of which the most toxic are formaldehyde, acetaldehyde and acrolein. Diethylene glycol and monoethylene glycol were tested for in vapour. Tobacco-specific nitrosamines were not tested. Goniewicz found NNN and NNK were present in only trace quantities across 12 ECs - mean NNN (0.13 ng/L) and NNK (0.58 ng/L)[1] and not exceeding their use in nicotine gum and patches.[5]

Procedures

At Health New Zealand Ltd, Christchurch New Zealand puffs of 65 ml were extracted from each brand of EC by syringe and leak-free three-way tap until no more visible mist was obtained, despite use of a fully re-charged battery. Standard 70 mL puffs and total vapour volumes were then estimated. Nicotine delivery per cartomisers equal to nicotine per puff (Labstat), multiplied by the number of standard puffs.

Weighing of the EC or the cartomisers before and after extraction of puffs gave mass per 70 mL puff. The cost of one starter kit and one refill daily for 90 days was estimated after allowing for purchase and shipping.

At Opinions Market Research Ltd, Christchurch New Zealand, a sequential monadic design was used by Opinions Market Research NZ Ltd to test ten products on 30 smokers randomly allocated to test three of ten brands. Thirty smokers were selected, 11 were aged 18-24 years, 11 aged 25-49, and 8 aged 50 years and over; 17 were female, 13 were male; 14 smoked roll-your-own and 16 factory-made cigarettes. Smokers gave informed consent, scored their own cigarette (without smoking) then evaluated three EC brands, each participant taking at least 15 puffs per EC brand, with 10 seconds between puffs and evaluating each brand immediately afterwards before puffing the next brand. Smokers in groups of ten vaped their ECs in the same room at the same time. Each brand was tested by nine different participants. All ratings scales were from 0 to 10, a modified Juster scale.[6]

In questions 1 to 3, we asked, "On a scale of 0 to 10, compared with your own cigarette, how much is this brand likeable? or satisfying? and how does it compare for strength of the puffs on the back of the throat? In questions 4 to 6, we asked "On a scale of 0 to 10, if this EC brand was available at $3 a day, what are the chances that you would (reduce smoking, quit smoking, completely stop smoking)".

At Canterbury Health Laboratories, Christchurch, New Zealand, nicotine content of cartomisers was determined by dismantling the cartomiser, or the disposable EC itself, and then immersing the contents in ethanol. Contents were rotary mixed and ultra-sonicated to dissolve the nicotine. Dilutions were prepared and analysed in duplicate against a six point standard curve. To estimate *nicotine concentration* the cartomiser was dismantled and the liquid content squeezed out of the sorbent pad and analysed in duplicate against a six point standard curve.

At Labstat International ULC, Ontario Canada, the puffing parameters (70 mL puff volume, inter-puff interval 10 seconds, puff duration 3 seconds) were modified slightly from the Canadian Tobacco Reporting Regulations[7] and Health Canada methods used for testing cigarettes, adapting Methods T-103 (nicotine, and humectants diethylene glycol and ethylene glycol), Method T-104 (for testing carbonyls in vapour) and adapting Method T-301 for testing nicotine alkaloids in liquid rather than in whole tobacco.

Test ECs were vaped on a linear smoking machine. The vaping parameters and smoking machine specifications used were taken from cigarette testing methods[8] adapted for e-cigarettes. For mainstream nicotine and humectants, 60 puffs were collected, and for testing of carbonyls, 150 puffs per brand tested. Each electronic cigarette was smoked in

a series of 15 puffs. The first series of puffs, a priming series intended to 'condition' or 'stabilize' the electronic cigarette deliveries, were smoked on to a pad that was subsequently discarded. After 5 minutes, the second series of 15 puffs was initiated, collecting the solids on a pre-weighed and conditioned pad. The process of waiting 5 minutes and collecting 15 more puffs on the same pre-weighed and conditioned pad was repeated three to nine more times for a total of 60-150 puffs collected onto the pad, in the latter case replacing the electronic cigarette battery after the 6th series of puffs is completed.

Nicotine and alkaloids in liquid For measurement of nicotine and its alkaloids in liquid, an entire electronic cigarette sample cartridge was transferred (or for brands D and I, 0.5g of electronic cigarette sample liquid, was weighed) into a 15mL glass culture tube. 10mL of alkaloids extraction solution was added to the tube and the tube was capped. The sample was extracted in an ultrasonic bath for 3 hours followed by 0.5 hours of shaking on a wrist action shaker. Analysis was performed for method T-301 above.

RESULTS

- *Puff volumes extracted* were as expected were lowest for the disposable cigarette.
- *Weight* per 70 mL EC puff was 1.85 mg.
- *Daily cost* was lowest for the clearomiser design. The nicotine in solution was supplied in a 10 mL bottle, expected to last 10 days.
- *Nicotine in vapour vs smoke.* The mean nicotine per puff for brands A to I can be compared to the 100 mcg calculated for mouth delivery from a national survey of tobacco cigarette brands or to the 147 mcg per puff obtained from a Marlboro cigarette under Health Canada intensive conditions. The brands with the highest nicotine per puff (45 to 49 mcg) thus delivered a third to a half of the nicotine obtained from a Marlboro cigarette.
- *Nicotine comparison 2008-2013.* Mean nicotine yield of brands in 2013 was 1.9 twice as high as in the first EC brand. (0.45 mg per litre of vapour in 2013 brands versus 0.24 mg per litre for Ruyan in 2008).

Table 1. Puff capacity, cost of daily purchase, and nicotine delivery of NECs

	Brand name	70 mL puffs extract-able	Puffs before battery needed recharge.	Vapour extracted (cartom-isers or clearo-miser)	Puff volume equivalent per cartomiser in number of factory-made cigarettes	Daily cost of starter kit and one daily refill spread over 90 days	Nicotine Delivery Per cart-omiser	Nicotine per puff
		Number	Number	Litres		NZ dollars	mg	micro-grams
B	Easy Puff	225	187	15.7	21	3.89	7.95	35
A -j	*Mean (9 brands)*	***215***	***142***	***15.0***	***20#***	***4.70***	***6.40***	***31***

* Personal charging case (PCC) is available.
# Mean value for cartridges and clearomiser and disposable.
1USD=1.22NZD, 1GBP=1.938NZD at 17 Sep 2013.

In strength of puffs EasyPuff cartomisers provided above average nicotine per puff. On nicotine per puff Easy Puff ranked 4th out of 9.

A manufactured cigarette produces approximately 15 puffs at 100 micrograms nicotine per puff or 1.5 mg nicotine.

EasyPuff cartomisers provide nicotine in their vapour equal to five manufactured (Marlboro) cigarettes, and puff equal to 14 to 21 cigarettes respectively.

Smokers' ratings of ECs

Comparisons with own cigarette Asked to rate their test EC against their own cigarette, as to how much they liked or disliked it, smokers rated ECs at 62 percent of their own brand. (4.73 vs 7.87 on the 0-10 scale); the zero NEC rated lowest. Participants rated satisfaction from EC brands 56 percent as highly as their own cigarette (4.6 vs 8.4). Mean strength of puff on the throat by brand was rated 88 percent of their own cigarette, (5.7 vs 6.7) and for brands A, D and I) strength of puffs on the throat was felt stronger than for their tobacco cigarette.

Effect on smoking intentions After each EC sampled, the smokers were asked their intentions if the EC was on sale at $3 a day. Across brands a mean 42 percent would reduce their smoking, 40 percent would seriously try to quit, and 34 percent said they would completely stop (the average percentage scores declined for the ECs tested were 42 percent, 40 percent and 34 percent, or 39 percent on average. These smokers' intentions represent willingness to switch from tobacco to e-cigarettes.

Table 2. Smokers' ratings of EC brands

	Brand name	Like-ability Q.1	Satis-faction Q.2	Strength of puffs Q.3	Mean of Q1, 2 and 3	Chances smoker would reduce/quit/stop smoking if this EC available at $3 a day? mean of Questions 4,5 and 6
B	Easy Puff	75	49	100	75	37
J	Zero strength	49	44	37	43	26
A-J	*Average*	***62***	***56***	***85***	***67***	***39***
	Correlation with nicotine per puff (r)	***0.49***	***0.60***	***0.63***	***0.68****	***0.74****

*p=<0.05

In the answers to mean of Q1, 2 and 3 EasyPuff was both well above average. EasyPuff rated strength of puffs as the same as their own tobacco cigarette.

Correlations

Compared with their own brand of cigarettes, perceived strength of e-puffs was correlated with EC satisfaction (r=0.82, p=<0.01). However, this correlation did not hold true for one brand; smokers rated the perceived strength of puffs of this brand as 6 percent greater than for their own brand, yet nicotine per puff was the lowest of the nine nicotine brands tested.

For questions 1 to 3 comparing EC against their own brand smokers' mean responses (but not the individual responses) was correlated with nicotine per puff of each brand (r=0.68, p=<0.05). (Figure 1, Table 1)

For questions 4 to 6 comparing smoking intentions against nicotine per puff of the brand, correlations were significant for each of these questions (r=0.70, 0.69 and 0.73 respectively, and 0.74 on average, p=<0.05).

When the zero nicotine brand was deleted, the correlations were significant for questions 4 to 6 as a group and for question 5, "would seriously try to quit".

Brand J (zero nicotine), scored lowest for likeability compared with own cigarette, but scored second to lowest on the other questions in Table 2 above.

Toxicant analysis of the vapour

Aldehydes in vapour. From Table 3 we show low aldehyde toxicants in the vapour, with four brands recording total aldehydes at < 1 microgram per litre.

Glycols in vapour Diethylene glycol (DEG) and monoethylene glycol (MEG) in vapour were below the level of detection (0.12 percent for DEG, 0.18 percent for MEG).

Table 3. Aldehyde yields from electronic cigarettes, by brand, 2013

	Laboratory: Labstat Canada	Formaldehyde, (F) Acetaldehyde (Aa) Acrolein (Acr)						
	Brand name	As micrograms per litre (mcg/L)			As percentage of Marlboro toxicants yields			
		F	Aa	Acr	F	Aa	Acr	Mean
B	Easy Puff	0.51	0.58	3.58	0.4	0.0	1.8	0.7
A-I	Average 2013	**1.07**	**0.81**	**1.06**	***0.93***	***0.04***	***0.43***	***0.48***
	Goniewicz 2013 12 Polish brands[9]	2.70	0.70	1.09	*2,3*	*0.0*	*0.5*	*0.9*
	Ruyan classic#	1.47	5.52	3.77	*1.3*	*0.2*	*1.6*	*1.05*
	Marlboro KSF*	**66**	**1293**	**131**	***100***	***100***	***100***	***100***

Ruyan 2008 tested by Labstat and reported by Lauterbach and Laugesen.[6]
* Counts 2005,[5] Health Canada intensive method, using 55 mL puffs, with no filter ventilation.

Aldehydes in all brands were 1 percent or less of that from a Marlboro full flavour cigarette.

Comparison with EC brands in Poland. The brands studied in New Zealand were lower for formaldehyde than the mean value for Polish brands.[8]

Comparison with the original EC brand. Mean EC toxicants in 2013 were 56 percent lower on average for the same aldehydes tested in Ruyan EC vapour in 2008.[6]

Comparison with a tobacco cigarette
As Table 3 shows, nine EC brands, based on the mean of three aldehydes tested, were 100 to 500 times less toxic than smoke from a Marlboro regular cigarette. A litre of Marlboro regular cigarette smoke yielded over 100 times more formaldehyde, 2800 times more acetaldehyde and over 200 times more acrolein per litre of smoke than from the mean of nine EC brands sold and tested in 2013.

Nicotine alkaloids
Nicotine alkaloids were detected and mean value for eight brands were equal to 0.49 percent of average nicotine content.

Table 4. Nicotine and nicotine alkaloids in EC liquid, by brand

High strength nicotine liquid, tobacco flavour		**Nicotine, Nornicotibne, Anabasine, Myosmine, Anatabine, per cartomiser, or per g of liquid, and alkaloids as % of nicotine**					
	Brand name	Nic mg	Nor mcg	Anab mcg	Myo mcg	Anat mcg	% of nicotine
B	Easy Puff	14.9	23	32	22	80	1.05
	Average	**14.3**	**15**	**15**	**15**	**25**	***0.49***

Brand F, a disposable, proved impregnable to liquid extraction in the laboratory.

The fraction of other nicotine alkaloids in the vapour was 1 percent or less of the nicotine across all brands. The alkaloid levels were indirectly a guide to the purity of the nicotine used, which is judged satisfactory.

Overall rankings

EasyPuff provided more puff equal to 21 cigarettes, and was the lowest priced of the cartomisers brands we studied at under $4 a day over 90 days.

Table 5. Summary of brand comparisons, and overall rankings

		Cartomiser generates vapour equaling this many cigarettes	Would reduce quit or stop smoking if sold	Nicotine per puff Mcg /70mL puff	Mean aldehydes mcg/L of vapour	Cost per day first 90 days NZ dollars	Sum of rankings	Rank Overall
	Table reference	*1*	*2*	*1*	*3*	*1*		
B	Easy Puff	21	37	35	0.7	3.89	26	5
A-I	Average 2013	**20**	**40**	**31**	***0.98***	***5.83***	***24.6***	

Positive attributes in the first three columns attracted high rankings for high values, while in the next two columns negative attributes such as toxicity and cost attracted low rankings for high values. The rankings in each category were then summed.
Table 5 summarises a range of positive and negative brand attributes.
We have not assessed packaging, or given credit for personal charger cases. We have not assessed the risk of battery failure, though battery longevity is Table 1 is some guide. No credit is given for prompt delivery, or attractive flavours – all brands were tobacco flavoured.

DISCUSSION

The ECs studied were on average 200 (range 98-300) times less toxic than a tobacco cigarette with respect to the aldehydes - acetaldehyde, acrolein, and formaldehyde. These, the most toxic and carcinogenic volatiles in EC vapour, were found at mean concentrations 99.5 percent less than in the smoke from the Marlboro cigarette brand.

Firstly, brands on sale average one microgram per toxicant per litre of vapour, and most emit less than this for any toxicant.

Secondly, nicotine varies greatly by brand and the (Elusion) brand chosen for the University of Auckland ASCEND trial of ECs for smoking cessation was the lowest in nicotine. Yet it proved equivalent to a nicotine patch in inducing successful quitting.

Thirdly, the low nicotine yields in EC vapour compared with tobacco smoke suggests that smokers switching from tobacco to ECs may attenuate/lessen their addiction.

Fourthly smokers in 2013 can choose nicotine-adequate low toxicant electronic cigarette brands which costs much less than tobacco.

These 2013 brands are higher in mean nicotine and lower in mean toxicants yields compared with the first EC we tested in 2008. No brands leaked.

Smokers' future intentions, especially about willingness to seriously quit or completely stop smoking (and therefore rely in future on the EC for all nicotine) were strongly correlated with the EC's nicotine per puff. Smokers tend to rely on the throat hit as an instant guide to nicotine strength and satisfaction, but this was not significantly correlated with nicotine per standard puff.

The non-nicotine alkaloids made up 0.49 percent of the nicotine content of the liquid in the refills or the bottles used to fill them. This is comparable to the 0.54 percent of the nicotine for these same four alkaloids reported in an analysis of 20 brands by Etter et al in 2013.[10] He found that other impurities accounted for a further 0.7 percent of the nicotine (cis-N-oxide, trans-N-oxide, cotinine, and beta-nicotyrine.) We did not test for other impurities, but Etter's data show strong correlation between total nicotine-related substances detected and the total of the four alkaloids we tested. ($r=0.70$, $p<0.001$). This suggests that although brands in this study were not tested for these other nicotine-related impurities, high levels were unlikely.

Carcinogenicity Table 3 shows that formaldehyde concentrations for most brands were under 1 microgram per litre. Mild sensory irritation in humans occurs at $\geq$ 1 ppm and respiratory tract cancer risks are considered to be negligibly low at this level of continuous exposure.[11] In addition, e-cigarettes at 200 puffs per day account for only 3 percent of the daily inhaled air.

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