A Comparison of Electronic Cigarette Emissions With Those of Human Breath, Outdoor Air, and Tobacco Smoke

John Madden
Ecigarette Reviewed
February 20th, 2014

Abstract

Background Local lawmakers across the United States have been amending their cities' smoke-free air acts to include e-cigarettes, ensuring the devices are regulated the same as tobacco cigarettes. While e-cig vapor has generally been found to be far safer than tobacco smoke with exposure to bystanders posing no apparent concern, the purpose of this paper is to compare existing data on its contaminants with those in other forms of air people may be exposed on a daily basis.

Methods Existing data on e-cigarettes was pulled from peer-reviewed studies analyzing both mainstream vapor using smoking machines and secondhand vapor generated by volunteer vapers in a cramped experimental chamber. That data was compared with particulate matter of three Los Angeles elementary schools, human breath emissions and cigarette smoke, also pulled from existing papers and studies. Threshold Limit Value (TLV) ratios were then calculated for each data point to show how each measured up to the most stringent workplace exposure standards.

Results The research used for the purpose of this paper found that electronic cigarettes contain levels of volatile organic compounds comparable to those found in human breath emissions, as many are naturally produced by the body. Most contaminants found in secondhand vapor and human breath were at levels <1% of TLV. However, isoprene was found both secondhand e-cig vapor and in human breath at levels in between 7-10% of TLV, although it wasn't detected in mainstream e-cig vapor. In n terms of trace elements (metals) found in e-cigs, levels were comparable those detected in outdoor air of a major US city. It should be noted that, outside of the reports on tobacco cigarettes used, the other three sources studied have contaminant levels well within what TLVs allow for.

Conclusions Several VOCs found in secondhand e-cig vapor are also found in human breath at similar levels. This shows that occurrence in e-cigarette vapor may be primarily a direct result of natural production by the human body. Due to variances in methods used to measure the air in each reference, comparisons can only be considered preliminary until a more uniform study is conducted. However, while passive vaping can be expected from electronic cigarette use, it may be no more injurious to human health than inhaling outdoor air or human breath emissions that occur naturally in public spaces. Further study is warranted to compare secondhand breath analysis with e-cig vapor in a crowded room using identical measurement methods. Hopefully this paper raises public awareness that e-cigarette vapor is relatively comparable to existing air in public places, especially in terms of safety.

Keywords: e-cigarettes, smoke-free air law, passive vaping, human breath, outdoor air

Background

The use of electronic cigarettes in public places has been a popular debate topic among city councils. Ordinances and amendments have passed in New York and Chicago have already voted to regulate e-cigarette usage the same way they treat tobacco smoking, meaning vaping, or use of e-cigs, is prohibited anywhere smoking isn't allowed in public places. Los Angeles city council has announced a plan to amend its own smoke-free law to include e-cigarettes, on the basis their vapor contains toxins and carcinogens. Recent studies have also found levels of lead, chromium, nickel, and nicotine in the second-hand vapor of e-cigs. Prohibiting electronic cigarette use wherever smoking is banned, Feuer contends, is necessary in order to protect bystanders from involuntary inhalation of the vapor they emit.

While recent studies on electronic cigarettes have indeed found trace elements and compounds in passive e-cig vapor, none have been detected at levels that warrant any concern to public health (Burstyn, 2014). Dr. Igor Burstyn's recent study analyzed over 9,000 observations of electronic cigarette vapor content reported in various peer reviewed and grey literature studies and concluded secondhand exposure poses no concern to bystanders. However, lawmakers seem to exclude these results from their proposals. Furthermore, they seem unaware that a high percentage of the constituents of secondhand e-cig vapor already exist in smoke-free air and can even be attributed to natural production by the human body.

The purpose of this review is to compare the results from Dr. Burstyn's analysis of e-cigarette vapor constituents with those of peer reviewed studies on other forms of air humans are exposed to on a daily basis. It is hypothesized that e-cigarette vapor, aside from its appearance, is not much more different or dangerous than the air one might already be exposed to from living in a city or eating at a crowded restaurant. If many of the same elements found in e-cigarette vapor are already present at similar levels in smoke-free air, the argument that they contaminant air in public spaces should not be used.

Materials and Methods

Literature search

In addition to having open access to a provisional PDF of Dr. Burstyn's analysis of e-cig vapor on Biomed Central (2014), references for human breath emissions, outdoor air quality and secondhand smoke were searched online and through Google Scholar. Keywords searched included "human breath emissions", "human breath vocs", "formaldehyde human breath", "los angeles vocs", new york vocs" "chicago vocs" "la air quality", "los angeles air quality", "secondhand smoke emissions", "secondhand smoke particulates", "secondhand smoke vocs", "cigarette vocs", and "environmental tobacco smoke", all with and without the search term "pdf" added. Several articles were researched but few met the criteria, explained below, in relation to the purpose of this paper. To fill in a few gaps and ensure more compatible cross-references, a few other previously researched articles on electronic cigarettes were used. In order to meet criteria for the purpose of this paper, articles needed to quantify data on either VOC emissions or inorganic compounds and metals contained in the air studied. One study was purchased through ScienceDirect (Charles, Batterman & Jia, 2007) and data from two others was accessed through reports on third-party websites. For example, formaldehyde content of secondhand e-cig vapor was not reported in the Burstyn study (2014), but it was detected by Schripp, Markewitz, Uhde, & Salthammer (2013). However the Schripp et al. paper was not purchased because the data on formaldehyde levels detected in e-cig vapor was reported by Tobacco Truth (Rodu, 2013). Likewise, data for formaldehyde emissions was reported by Moser et al. (2005) and accessed through a press release (MHARR, 2008).

Regulatory and Recommended Limit Calculations

All relevant data was imported manually into a spreadsheet, with a separate tab for each group of results. The spreadsheet included seven tabs for data entry and one tab for charts. For the study on outdoor air at three LA elementary schools (Resurrection, Central LA, the average of all three was used for volatile organic compounds. Since total suspended particulate matter for trace elements was only measured at one school (Resurrection) just those results were used.

After entering in previously reported VOC and inorganic compound results, all data was converted into either PPM or mg/m^3 if it wasn't reported as such. The lowest regulatory or recommended exposure limit for each was searched on either the OSHA (accessed Jan 30, 2014) or, in the case of Isoprene, the AIHA 2011 WEELs (accesed Jan 30, 2014) website. Lowest, or most stringent, exposure limits reported for each article in either PPM or mg/m^3.

For the Burstyn (2014) study, exposure limit ratios had already been calculated but ratios for all other groups of study results, except mainstream and sidestream cigarette smoke, were calculated in the spreadsheet for the purpose of this paper.

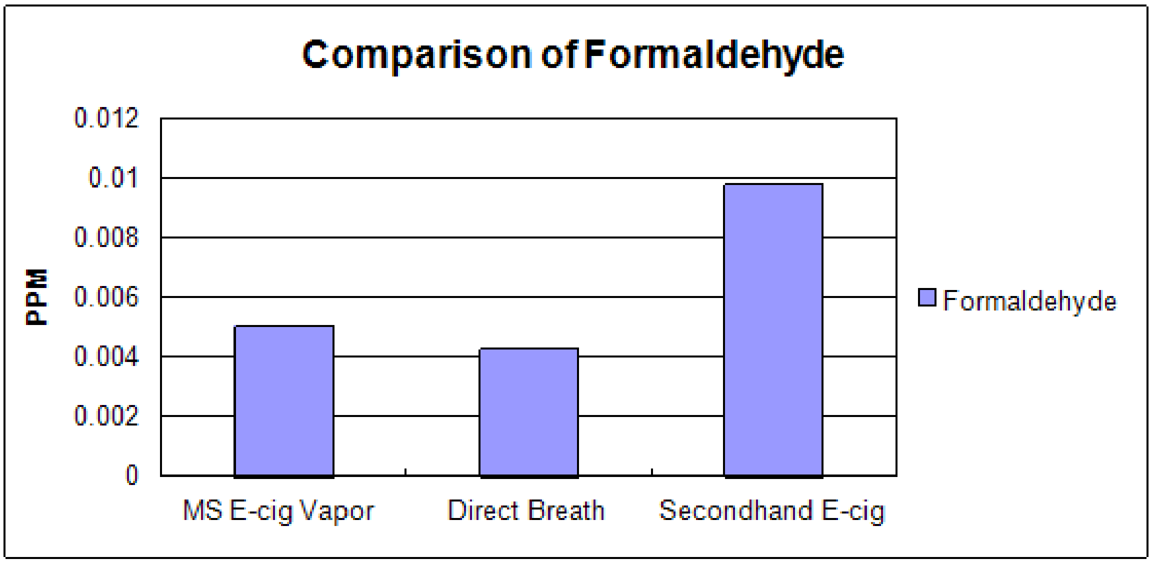
Comparison and Charts

Any relevant and comparable data was pulled into a separate tab on the spreadsheet to create charts. For elements and compounds with multiple results, the average was used for comparisons. The only problem with the comparisons was that the way human breath was measured made results directly incomparable to secondhand/passive vapor. Hence no charts were made comparing human breath solely with passive vapor. However, it could be used to show that breath combined with mainstream e-cig vapor could produce similar results to the those of passive vapor.

Results and discussion

Volatile organic compounds were found in all three sources compared. The results for formaldehyde provided an interesting comparison, as levels detected in mainstream e-cig vapor nearly matched those of human breath. Even those these results were detected in different studies, when added together they are comparable with formaldehyde levels found in secondhand vapor.

Fig. 1a



Acetone, while detected at levels below exposure limits for both mainstream e-cig vapor and human breath, was significantly higher in the latter. Results for passive vaping were actually below those of human breath.

Fig. 1b

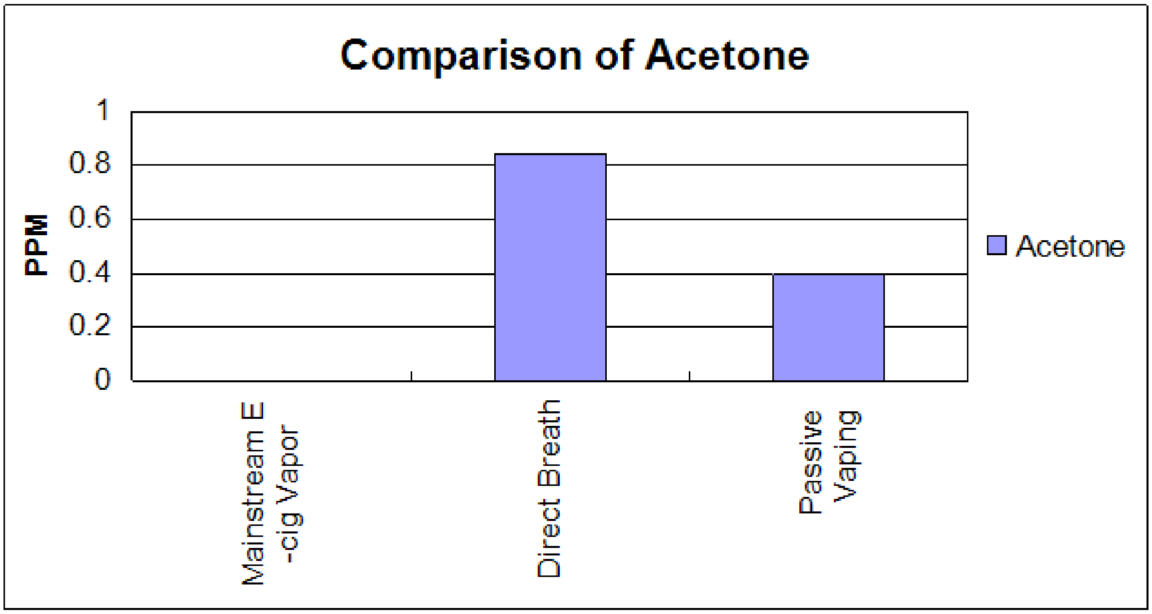
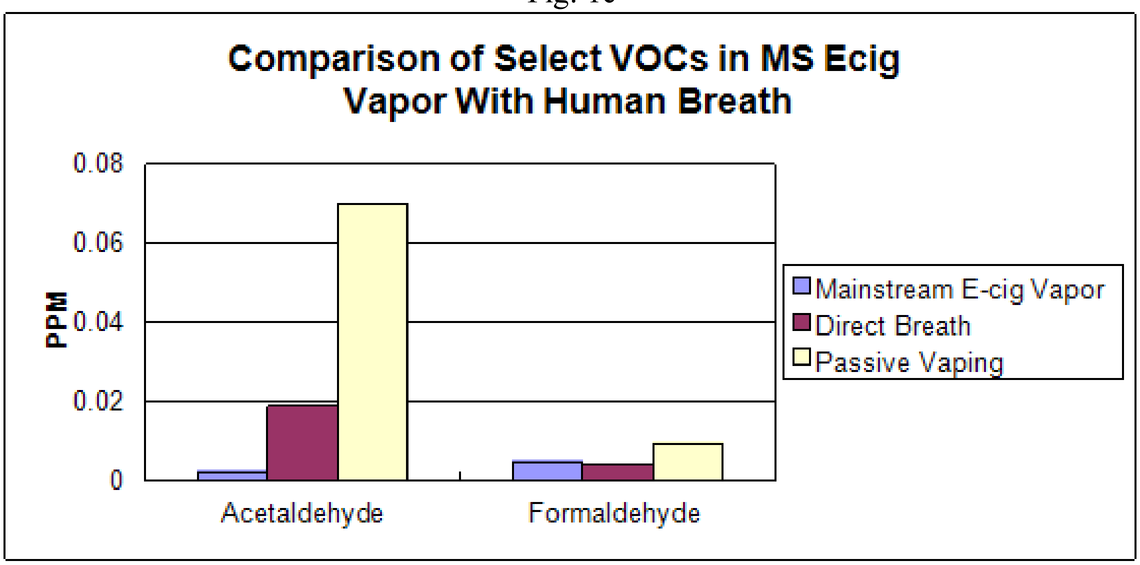


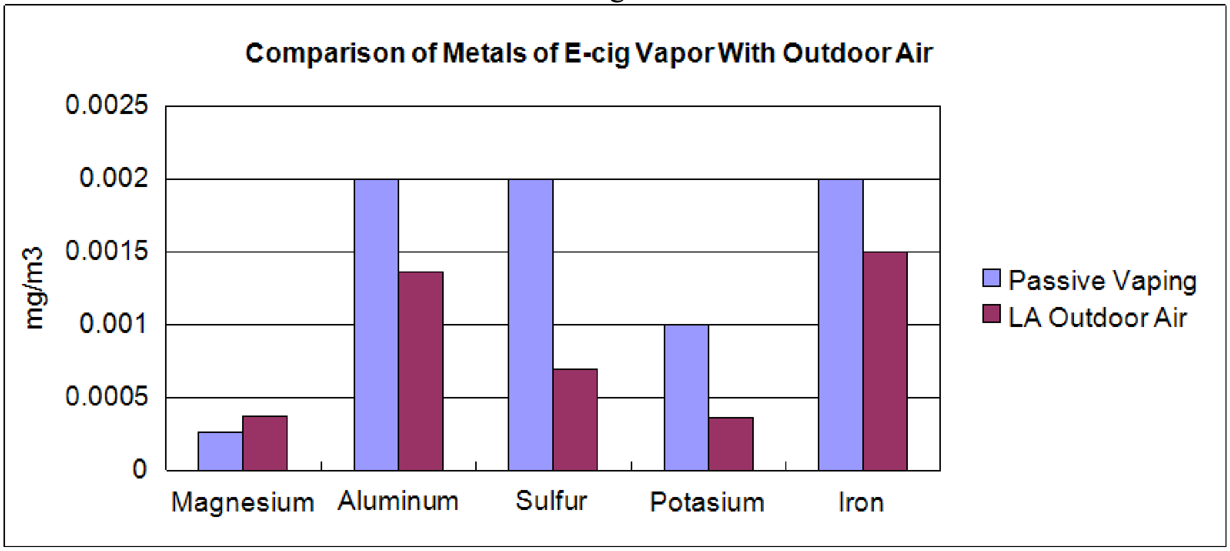
Fig. 1c



Acetaldehyde was also detected higher levels in direct human breath than in mainstream vapor. However, it was detected at significantly higher levels in passive vaping than in human breath. But in terms of exposure limits, all were well under 1%.

Figure 2 below shows comparisons of trace elements found in e-cig vapor with the same detected in Los Angeles outdoor air at Resurrection Catholic School in Boyle Heights. All trace elements found in both sources were at levels below .002mg/m^3 and well within exposure limits.

Fig 2


Comparison of Metals of E-cig Vapor With Outdoor Air
mg/m3
0.0025
0.002
0.0015
0.001
0.0005
0
Magnesium
Aluminum
Sulfur
Potasium
Iron
Passive Vaping
LA Outdoor Air

Tables

Volatile Organic Compounds

Table 1a: MS Exposure predictions based on analysis of e-cigarette aerosols generated by smoking machines

Compound	Estimated concentration in personal breathing zone		Most Stringent Limit (PPM)	Most Stringent Limit (mg/m^3)	Ratio of most stringent TLV (%)	
	PPM	mg/m^3			Calculated directly	Safety factor 10
Acetaldehyde	0.005		25		0.02	0.2
	0.003		25		0.01	0.1
	0.001		25		0.004	0.04
	0.00004		25		0.0001	0.001
	0.0002		25		0.001	0.01
	0.001		25		0.004	0.04
	0.008		25		0.03	0.3
Acetone	0.002		250		0.0003	0.003
	0.0004		250		0.0001	0.001
Acrolein	0.001		0.1		1	13
	0.002		0.1		2	20
	0.006		0.1		6	60
Butanal	0.0002		25		0.001	0.01
Crotonaldehyde		0.0004		0.86	0.01	0.1
Formaldehyde	0.002		0.3		0.6	6
	0.008		0.3		3	30
	0.006		0.3		2	20
	0.00024		0.3		<0.1	<1
	0.0003		0.3		0.1	1
	0.01		0.3		4	40
	0.009		0.3		3	30
Glyoxal		0.002		0.1	2	20
		0.006		0.1	6	60
o-Methylbenzaldehyde		0.001		0.5	0.05	0.5
p,m-Xylene		0.00003		434	0.001	0.01
Propanal	0.002		20		0.01	0.1
	0.0006		20		0.002	0.02
	0.0005		20		0.02	0.2
Toluene	0.0001		10		0.003	0.03
Valeraldehyde		0.0001		175	0.0001	0.001

Resource: http://www.biomedcentral.com/content/pdf/1471-2458-14-18.pdf

Table 1b: Environmental Exposure predictions for volatile organic compounds based on analysis of aerosols generated by volunteer vapers

Compound	Estimated concentration in personal breathing zone (PPM)	Most Stringent Limit (PPM)	Ratio of most stringent Exposure Limit (%) Calculated directly	Ratio of most stringent Exposure Limit (%) Safety factor 10	Ref.
2-butanone (MEK)	0.04	200	0.02	0.2	[1]
	0.002	200	0.007	0.07	
2-furaldehyde	0.01	2	0.7	7	
Acetaldehyde	0.07	25	0.3	3	
Acetic acid	0.3	10	3	30	
Acetone	0.4	250	0.2	2	
Acrolein	<0.001	0.1	<0.7	<7	
Benzene	0.02	0.5	3	30	
Butyl hydroxyl toluene	0.00004	1	0.002	0.02	
Isoprene*	0.1	2	7	70	
Limonene	0.009	30	0.03	0.3	
	0.00002	30	0.000001	0.00001	
m,p-Xyelen	0.01	100	0.01	0.1	
Phenol	0.01	5	0.3	3	
Propanal	0.004	20	0.01	0.1	
Toluene	0.01	10	0.07	0.7	
Formaldehyde	0.00978	0.3	3.26	32.6	[2]
Alkaloids					
Nicotine	0.0005	0.075	0.66	6.6	[3]

1. http://www.biomedcentral.com/content/pdf/1471-2458-14-18.pdf
2. http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0668.2012.00792.x/abstract
3. http://ntr.oxfordjournals.org/content/early/2013/12/10/ntr.ntt203.short

* Limit 2 ppm per 8 hrs established by AIHA WEELs

Tables 1a and 1b show the results from Dr. Igor Burstyn's (2014) study on electronic cigarette vapor. The first table shows levels of mainstream volatile organic compounds detected by smoke machines while the second shows levels of VOCs detected in passive vapor generated by volunteer vapers. Formaldehyde wasn't reported for passive vaping by Burstyn but it had been previously measured by Schripp et al. (2012) at 12 ug/m^3, or .00978 ppm. Table 1b also shows measurement of nicotine detected in passive vapor in the Czogala et al. (2013) study.

Table 2: Concentrations of VOCs in Exhaled Human Breath

	Weighted Average		Most Stringent Limit[2]	Ratio of most stringent Limit		
Compound	ppm	mg/m3	ppm	Percentage	Safety Factor 10	Ref
Acetaldehyde	0.019	0.035	25	0.076	0.76	[1]
Acetone	0.84	2.30	250	0.336	3.36	
Butanone	0.016	0.047	200	0.008	0.08	
1-Butene	0.063	0.14	250	0.0252	0.252	
Dimethyl Sulfide	0.012	0.03	10	0.12	1.2	
Ethanol	0.77	1.40	1,000	0.077	0.77	
Ethyl Acetate	0.017	0.062	400	0.00425	0.0425	
Ethylene	0.023	0.026	200	0.0115	0.115	
Formaldehyde	0.0043	0.00528	0.3	1.43	14.33	[2]
Furan	0.014	0.039	None	n/a	n/a	[1]
Hexanal	0.011	0.045	None	n/a	n/a	
Isoprene*	0.21	0.59	2	10.5	105	
Isopropanol	0.15	0.37	200	0.075	0.75	
Methanol	0.33	0.43	200	0.165	1.65	
Methyl Ethyl Ketone	0.01	0.029	200	0.005	0.05	
Pentane	0.012	0.035	120	0.01	0.1	
1-Pentene	0.021	0.06	None	n/a	n/a	
n-Propanol	0.13	0.32	100	0.13	1.3	

1. http://www.tandfonline.com/doi/pdf/10.1080/10473289.1999.10463831
2. http://www.businesswire.com/news/home/20080404005660/en/

* Limit 2 ppm per 8 hrs established by AIHA WEELs

Table 2 shows the concentrations of volatile organic compounds detected in the Fenske & Paulson (1999) study. Formaldehyde levels were taken from a 2005 Moser et al. study and reported in a MHARR press release (2008). Isoprene levels detected from direct breath readings are actually pushing exposure safety, however when calculated for various enclosed public spaces (p. 596) they fall safely within limits.

Table 3: Concentrations of VOCs in Outdoor Air at Three LA Measuring Sites

Compound	Average found in air of 3 LA measuring sites (PPM)	Most Stringent Limit[1] (PPM)	Ratio of Most Stringent Limit	
			Percent	Safety Factor 10
Toluene	0.00124	10	0.0124	0.124
m+p-xylenes	0.00064	100	0.00064	0.0064
Benzene	0.00042	0.5	0.084	0.84
Methylene Chloride	0.00056	25	0.00224	0.0224
2-butanone	0.00065	200	0.000325	0.00325
o-xylene	0.00022	100	0.00022	0.0022
Ethylbenzene	0.00018	20	0.0009	0.009
1,3-butadiene	0.00008	1	0.008	0.08
Acetone	0.00684	250	0.002736	0.02736
Formaldehyde	0.0032	0.3	1.067	10.667
Acetaldehyde	0.0014	25	0.0056	0.056

Reference: http://www.aqmd.gov/tao/AQ-Reports/Resurrection_Catholic_School_Study.pdf

Table 3 reflects averages of volatile organic compounds captured using a gas chromatograph-mass spectrometer at three Los Angeles testing sites (Resurrection, Rubidoux and Central LA). All are well within recommended and regulatory limits.

Table 6 below contains the levels (in micrograms per cubic meter) of VOCs found in environmental tobacco smoke (ETS) from an IARC Monographs study (2004) and Schripp (2013). These make up just a small fraction of the contaminants found in secondhand cigarette smoke. Nicotine, an alkaloid, is shown at the bottom of the table.

Table 6: VOC Levels of ETS

					Ratio of Most Stringent Limit	
VOC	Cigarette Emissions (µg/m3)	PPM	PPB	Most Stringent Limit (PPM)	Percentage	Safety Factor 10
Formaldehyde	143	0.117	117	0.3		
Benzene	30	0.00939	9.39	0.5	1.878	18.78
Toluene	54.5	0.01446	14.46	10	0.14	1.45
1,3-Butadiene	40	0.01808	18.08	1	1.81	18.08
Acetaldehyde	268	0.149	149	25	0.60	5.96
Isoprene	657	0.236	236	2		
Styrene	10	0.00235	2.35	20	0.01	0.12
Catechol	1.24	0.00028	0.28	5	0.01	0.06
3-Ethenyl pyridine	37.1	0.00863	8.63	Not listed	n/a	n/a
Ethylbenzene	8.5	0.00196	1.96	20	0.01	0.10
Pyridine	23.8	0.00736	7.36	1	0.74	7.36
Limonene	29.1	0.00522	5.22	30	0.02	0.17
Phenol	16.7	0.00434	4.34	5	0.09	0.87
m, p-xylene	28	0.00415	4.15	100	0.004	0.04
Acetone	64	0.02694	26.9	250	0.01	0.11
2-Butanone	19	0.00644	6.44	200	0.003	0.03
2-Furaldehyde	21	0.00534	5.34	2	0.27	2.67
Propanal	12	0.00488	4.88	20	0.02	0.24
Acetic Acid	68	0.02769	27.69	10	0.28	2.77
Alkalines						
Nicotine	90.8	0.01368	13.68	0.075	18.24	182.40

Inorganic Compounds

Table 4: Exposure predictions based on analysis of aerosols generated by smoking machines: Inorganic Compounds

Element quantified	Assumed compound containing the element for comparison with TLV	Estimated concentration in personal breathing zone (mg/m3)	Most Stringent Limit (mg/m^3)	Ratio of most stringent TLV (%)	
				Calculated directly	Safety factor 10
Aluminum	Respirable Al metal & insoluble compounds	0.002	10	0.2	2
Barium	Ba & insoluble compounds	0.00005	0.5	0.01	0.1
Boron	Boron oxide	0.02	10	0.1	1
Cadmium	Respirable Cd & compounds	0.00002	0.002	1	10
Chromium	Insoluble Cr (IV) compounds	3.00E-05	0.0002	0.3	3
Copper	Cu fume	0.0008	0.1	0.4	4
Iron	Soluble iron salts, as Fe	0.002	1	0.02	0.2
Lead	Inorganic compounds as Pb	7.00E-05	0.00015	0.1	1
		0.000025	0.00015	0.05	0.5
Magnesium	Inhalable magnesium oxide	0.00026	10	0.003	0.03
Manganese	Inorganic compounds, as Mn	8.00E-06	0.02	0.04	0.4
Nickel	Inhalable soluble inorganic compounds, as Ni	2.00E-05	0.015	0.02	0.2
		0.00005	0.015	0.05	0.5
Potassium	KOH	0.001	2	0.1	1
Tin	Organic compounds, as Sn	0.0001	0.1	0.1	1
Zinc	Zinc chloride fume	0.0004	1	0.04	0.4
Zirconium	Zr and compounds	3.00E-05	5	0.001	0.01
Sulfur	SO_2	0.002	0.25	0.3	3

Reference: http://www.biomedcentral.com/content/pdf/1471-2458-14-18.pdf

Table 4a shows the levels of inorganic compounds and metals from mainstream e-cig vapor detected in Burstyn's (2014) study. Again, all are well within exposure limits.

Table 5: Average Levels of Trace Elements in TSP at Resurrection Catholic School

Compound	Average found in TSP of Ressurection school (mg/m3)	Most Stringent Limit (mg/m3)	Ratio of Most Stringent Limit	
			Percent	Safety Factor 10
Magnesium	0.00037	10	0.0037	0.037
Aluminum	0.00136	10	0.0136	0.136
Silicon	0.00184	5	0.0368	0.368
Sulfur	0.00069	0.25	0.276	2.76
Potasium	0.00036	2	0.018	0.18
Calcium	0.00102	2	0.051	0.51
Iron	0.0015	1	0.15	1.5
Hexavalent Chromium	0.00000011	0.0002	0.055	0.55

Table 5 shows levels of trace elements detected in air at Resurrection Catholic School in the Boyle Heights area of Los Angeles. Five of these elements were comparable to levels of inorganic compounds detected in mainstream e-cig vapor. Levels of trace elements were not reported for human breath.

Fig 3

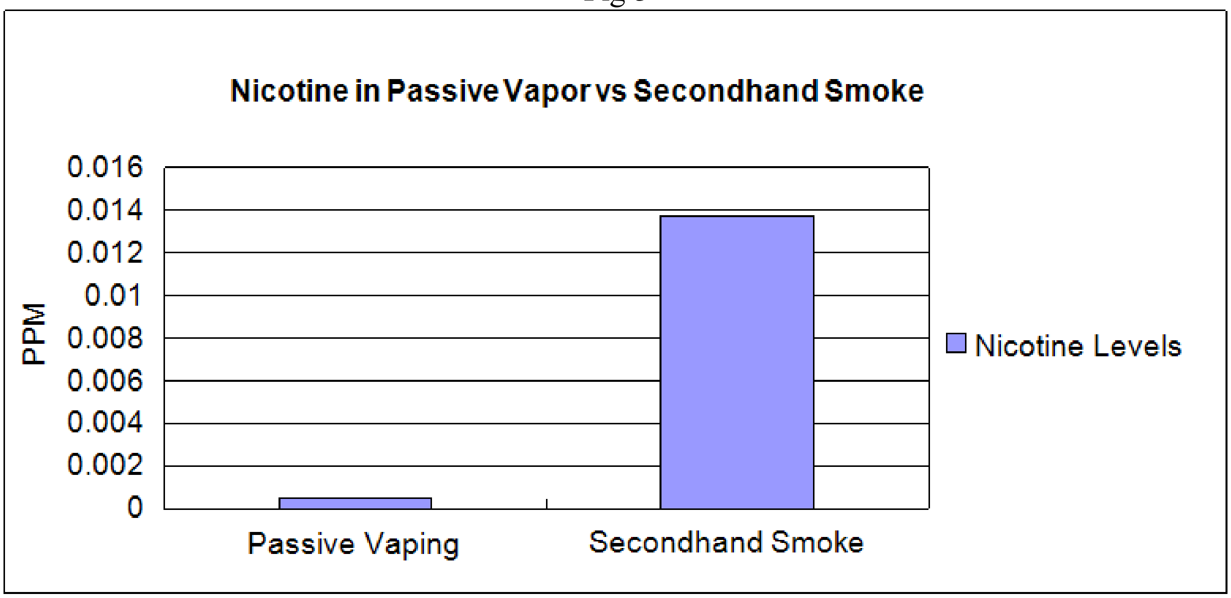


Figure 3 compares the levels of nicotine contained in passive vapor with those of secondhand smoke. Nicotine levels in ETS are ten times are 20 times more than they are in secondhand vapor. Further research is needed to assess nicotine levels of passive vaping from e-liquids with variety of nicotine strengths and from using different types of devices. However, the nicotine detected in secondhand vapor for the purpose of this study is significantly less than that of environmental tobacco smoke.

Conclusion

Prior to conducting research, it was hypothesized that volatile organic compounds of city outdoor air would be comparable to those of e-cigarette vapor, due to automobile, factory and other emission waste. However, results showed that it was the levels of metals detected in outdoor air that were actually more comparable to those of e-cig vapor. VOCs were still detected in the air of three measuring stations in Los Angeles, just not at significant levels in relation to this study.

On the contrary, VOCs detected on human breath were not only comparable to those of e-cigarette vapor, they provide a primary source for many of the chemicals found in the latter. In both indoor and outdoor public spaces, electronic cigarettes will not be the only source of air contamination. The human body emits many of the same volatile organic compounds, while outdoor air can contain many of the same trace elements found in e-cigarette vapor.

In terms of nicotine, secondhand smoke contains significantly more nicotine than passive vapor. In fact, while passive vapor has levels of nicotine well within both required and recommended exposure limits, those of ETS exceed these limits when calculating for a safety factor of 10. So while passive vapor has considerable differences with ETS, or secondhand smoke, it shares many similarities with air contaminants from sources that already exist in public places. It would be wise to consider this when drafting ordinances that single out e-cigarettes on the basis that they contain "harmful chemicals".

Acknowledgments

The author would like to thank Dr. Igor Burstyn and Dr. Konstantinos Farsalinos for assisting with questions during the research process, as well as those scientists who conducted the studies referenced in this paper. John Madden, a researcher for E-Cigarette Reviewed, was the sole contributor to this report. Any expressed opinions are those of the author.

Link to summary of this paper:

http://ecigarettereviewed.com/contaminants-in-e-cig-vapor-found-in-human-breath-and-outdoor-air

References

Burstyn, I. (2014). Peering through the mist: systematic review of what the chemistry of contaminants in electronic cigarettes tells us about health risks. *BMC Public Health*, 14 (1), pp. 12-19. doi:doi:10.1186/1471-2458-14-18 [Accessed: 22 Jan 2014].

Charles, S. M., Batterman, S. & Jia, C. (2007). Composition and emissions of vocs in main-and side-stream smoke of research cigarettes. *Atmospheric Environment*, 41 (26), pp. 5372-5383. doi:doi:10.1016/j.atmosenv.2007.02.020

Czogala, J., Goniewicz, M. L., Fidelus, B., Zielinska-Danch, W., Travers, M. J. & Sobczak, A. (2013). Secondhand exposure to vapors from electronic cigarettes. *Nicotine |& Tobacco Research* doi:10.1093/ntr/ntt203

Fenske, J. D. & Paulson, S. E. (1999). Human breath emissions of vocs. *Journal Of The Air |& Waste Management Association*, 49 (5), pp. 594--598. doi:10.1080/10473289.1999.10463831.

Feuer, M. (2014). *Council file: 13-1204-s1*. [online] Retrieved from: http://clkrep.lacity.org/onlinedocs/2013/13-1204-S1_RPT_ATTY_01-08-2014.pdf

Manufactured Housing Association for Regulatory Reform (MHARR). (2008) Formaldehyde -- facts versus rhetoric [Press Release]. Retrieved from http://www.businesswire.com/news/home/20080404005660/en/Formaldehyde----Facts-Rhetoric#.UwZG4_l dX5d

Moser, B., F. Bodrogi, G. Eibl, M. Lechner, J. Rieder, and P. Lirk. "Mass Spectrometric Profile of Exhaled Breath--field Study by PTR-MS." *Respir Physiol Neurobiol*. PubMed15, 15 Feb. 2005.

Osha.gov. (2014). *Osha annotated pels*. [online] Retrieved from: https://www.osha.gov/dsg/annotated-pels/ [Accessed: 30 Jan 2014].

Others (2004). Tobacco smoke and involuntary smoking. *IARC Monographs On The Evaluation Of Carcinogenic Risks To Humans/World Health Organization, International Agency For Research On Cancer*, 83 p. 1194.

Polidori, A. & Fine, P. M. (2012). Ambient measurements of air toxic pollutants at resurrection catholic school in boyle heights. *South Coast AQMD*, Retrieved from: http://www.aqmd.gov/tao/AQ-Reports/Resurrection_Catholic_School_Study.pdf.

Rodu, B. (2013,December 26, 2013). Do e-cigarettes cause passive vaping?. *Tobacco Truth*, [web log] Retrieved from: http://rodutobaccotruth.blogspot.com/2013/12/do-e-cigarettes-cause-passive-vaping.htm

Schripp, T., Markewitz, D., Uhde, E. & Salthammer, T. (2013). Does e-cigarette consumption cause passive vaping?. *Indoor Air*, 23 (1), pp. 25--31. doi:10.1111/j.1600-0668.2012.00792.x

"WEEL® values." *WEELs®*. American Industrial Hygiene Association, 2011. [Accessed: 30 Jan. 2014].