Safety and Compliance

e-Cigarette and e-Liquids

October 2014

London Borough of Camden and London Trading Standards Association

Objectives and conclusions

This work drew together Trading Standards teams from across London to collaborate in gaining more understanding of e-cigarette and e-liquid products being encountered by Trading Standards teams in their boroughs. It involved assessment and analysis of disposable e-cigarettes, e-liquids and electrical safety testing of five rechargeable e-cigarettes provided by Trading Standards teams in collaborating boroughs. Its aim was to gain insight into whether these products were compliant with relevant regulations and standards and of the potential risks these products might pose to consumers.

This analysis is based on a snapshot of samples from a limited number of London Boroughs. However, the samples are considered to be representative of the type of goods teams are encountering across London and has raised some important issues that need attention including:

i) **The work implies that electrical safety may be a significant issue for rechargeable e-cigarettes and in particular there is a risk of fire caused by incorrect use of products or faulty/poorly constructed products.** This is supported by recent warnings issued by the London Fire Brigade regarding fires caused by e-cigarettes.

ii) **The majority of products that contained nicotine failed to correctly state the concentration present or carry the correct warnings.** Nicotine is acutely toxic and some refills contained sufficient to be lethal to a small child. [1] However, none of those tested fully comply with the relevant CHIPP and consumer safety regulations. This implies clear grounds for seizing products, grounds for prosecution and implies a clear danger to consumers from nicotine containing products.

iii) **Twenty of the nicotine containing e-liquid products would correctly be classified as 'toxic' and should have been supplied in containers with child-resistant closures.** It was unclear from the analytical reports whether e-liquid bottles had child resistant packaging.

iv) **The chemical analysis showed that the products tested contained a wide range of chemicals that are potentially harmful to health.** In total twenty four chemicals were identified in addition to nicotine, propylene glycol and glycerol including industrial solvents and flavouring compounds. There is evidence of at least one food flavouring compound (diacetyl) causing serious and irreversible lung damage when inhaled. The safety of the compounds detected in the samples analysed is at best unknown and several were known to be irritant and/or toxic. [1]

[1] See Annex A

Recommendations

While it is beyond the scope of this report to explore potential actions, approaches or strategies it is suggested that in addressing the issues raised by these products three things are considered:

i) **That currently e-cigarettes are not prohibited products and are unlikely to become so in the near future**. Based on current government policy and the views of organisations such as the European Union, Public Health England and Action on Smoking and Health (ASH) there is a desire to develop these products as smoking cessation aids.

This implies that working with legitimate manufacturers, importers and retailers to create a market based on compliant and safe products should be attempted. The first step in achieving this is probably achieving compliance with current labelling, packaging and electrical safety regulations.

ii) **That one of the most obvious current safety concerns is electrical safety and fire**. Currently product safety regulations do not address the issues specific to rechargeable devices employing lithium ion batteries and USB type power sources. This implies that in the longer term new regulations capable of dealing effectively with this class of products is required. In the short term there is a need to educate consumers and retailers of the dangers associated with these products.

iii) **There is an almost total lack of toxicological information available regarding the health effects when inhaled or 'vaped' of the range of chemicals used in these devices.** In this regard there are obvious parallels with the sale of 'legal highs' where chemicals of unknown toxicity and provenance are sold as recreational products. Like 'legal highs' it may be children and young adults that are the ones most at risk.

It is also likely that products will emerge where psychoactive compounds, are part of the e-liquid formulation. The most obvious being synthetic cannabis type compounds. This implies a need to explore approaches to removing products containing potentially dangerous substances from sale and a need to educate consumers and retailers.

Summary of analysis

The results of the testing and assessment of compliance of the samples with appropriate regulations and safety standards were as follows:

i) **Of the thirty three disposable sticks only three were found to be fully compliant with the appropriate labelling regulations.** While there was a broad range in the degree of compliance, with some products having relatively minor errors and other failing on all counts, the samples overall showed poor levels of compliance.

ii) **Of the thirty e-liquid refills or cartridges assessed only three were found to be fully compliant with the appropriate labelling regulations.** While there was again a broad range in the degree of non-compliance overall they showed poor levels of compliance.

iii) **Twenty of the nicotine containing e-liquid products would correctly be classified as 'toxic' and should have been supplied in containers with child-resistant closures.** It was unclear from the analytical reports whether e-liquid bottles had child resistant packaging.

iv) **Of the three e-cigarettes subjected to detailed electrical safety testing none passed.** There was a marked difference in the quality of the three devices assessed, with one being of a notably higher quality than the others. However, even for the higher quality product there were significant issues regarding its safety in its intended use.

v) **Chemical analysis of the e-liquids in refills and single use sticks showed a wide variety of chemicals present and unreliable levels of nicotine.** In total twenty four chemicals were identified in addition to the anticipated nicotine, propylene glycol and glycerol. Several of these are worthy of concern as they are known irritants or know to be toxic. However, detailed toxicology data is not available for any of these chemicals and the effects of inhalation are 'unknown'.

Overall these results imply that very few of the products tested were compliant with current regulations and that:

i) The three re-chargeable e-cigarette products tested had significant electrical safety issues implying that products are being sold which are inherently unsafe or potentially unsafe when operated without clear instructions on safe use.

e-Cigarette and Shisha 'Sticks'

Disposable 'sticks'

Thirty three disposable 'sticks' or 'pens' were assessed in terms of their packaging and chemical composition. The products described as 'shisha' were typically flavoured and did not contain nicotine and those describes as 'cigarettes' typically contained nicotine and were free of flavouring. However, this is was not true of all samples and in one case a 'shisha' product which did not declare any nicotine contained a nicotine concentration of 8mg per ml of nicotine. Furthermore, although these products tend to be marketed as either 'e-cigarettes' or 'e-shisha pens' there is no clear distinction between them in terms of construction of the device.

Labelling and packaging – Products containing nicotine

Out of the thirty three samples analysed nicotine was detected in ten of them and of these only seven had declared its presence on the product packaging. This meant that three products had failed to declare its presence. In all of the cases where the presence of nicotine had been declared on the product packaging the detected concentrations were lower than that declared. These results are shown in Table 1 below.

Table 1: Disposable Stick Nicotine Concentrations

Lab Ref	Sample Description	Nicotine concentration stated on packaging (mg/ml)	Nicotine concentration detected
BC17993	e-cigarette nicolite	16	13
BC17995	e-cigarette neo classic	18	14
BC18604	Apollo e-cigarette - medium	0	**7**
BC18611	e-cigarette -shisha time strawberry	0	**8**
BC18614	e-cigarette -Jensen 11mg	11	6
BC18618	e-cigarette Puffin lites original	18	12
BC19275	e-cigarette -Nicolites	0	10
BC19276	e-cigarette NJOY King	45	29
BC19279	e-cigarette – Vype ecpopure disposable	45	23
BC19281	e-cigarette NJOY King	30	17

These results of the assessment of compliance with labelling and packaging regulations are shown in Table 2 below. From this it can be seen that of the ten samples that contained nicotine only one was fully compliant with the relevant regulations. Of the remainder two failed to comply on any requirement and the others failed on a one or more of the requirements. In terms of being able to contact manufacturers or importers of the products six provided a name, address and telephone number. One provided just a telephone number and three provided no information on the supplier.

Table 2: Disposable sticks, compliance with labelling requirements

Lab Ref	Nicotine concentration detected	Correct Classification	CHIP - Presence of nicotine displayed on packaging	CHIP - Name and Address of supplier	CHIP - Telephone number of supplier	CHIP- Appropriate Risk Phrases	CHIP- Appropriate Safety Phrases	Appropriate Picture Warnings Displayed	Picture Warnings are correct size/shape	Tactile Warning
BC17993	13	**Toxic**	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
BC17995	14	Toxic	Yes	No	Yes	No	No	Yes	No	No
BC18604	7	Toxic	No	No	No	No	No	No	None	No
BC18611	8	Toxic	No	No	No	No	No	No	No	No
BC18614	6	Toxic	Yes	No	No	Yes	Yes	Yes	No	No
BC18618	12	Toxic	Yes	Yes	Yes	No	No	No	No	No
BC19275	10	Harmful	No	Yes	Yes	Yes	Yes	Yes	No	Yes
BC19276	29	Toxic	Yes	Yes	Yes	No	No	No	No	No
BC19279	23	Toxic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
BC19281	17	Toxic	Yes	Yes	Yes	No	No	No	No	No

Labelling and packaging – Products not containing nicotine

Although the labelling regulations for products not containing nicotine are less stringent, there remains a requirement to provide the contact details of the supplier on the packaging and obligations in terms of traceability of products. Of the twenty three products examined seventeen had no information regarding the supplier; four had just a telephone number and two just a name and address.

Chemical Composition

The analytical method used to determine the chemicals present in the e-liquids within the disposable sticks was mass spectroscopy. This technique has the advantage of potentially being able to screen for the presence of a very large number of known compounds, provide a quantitative result for nicotine concentrations and do so for a relatively low cost. It should be noted that many more chemicals than those listed are likely to be present in the samples but will either have been below the detection threshold or not matched by the library used.

The sticks containing nicotine all showed the presence of glycerol and propylene glycol which appear to be key components of any 'vaping' liquid. One of these samples contained propylene glycol acetate a solvent and acetol a flavouring additive. [2] Overall the nicotine containing products appeared to be simpler in composition and (with the exception of the one product noted above) contained only propylene glycol, glycerol and nicotine. The sticks not containing nicotine had a much wider range of chemicals present as shown in Table 2 below, all sticks contained propylene glycol and glycerol. The chemicals most frequently present are solvents some of which are known to be used in the flavourings and scents industry. The remaining identified chemicals are known to be used flavourings or scents.

Table 2: Chemical components present

Chemical	Number of disposable sticks containing it
Diacetin*	8
Triacetin*	8
Vanillin	5
Menthol	4
Propylene glycol acetate*	4
Ethyl vanillin	3
Monoacetin	3
Acetol	2
Diethyl succinate	2
Benzaldehyde	1
Benzaldehyde propylene glycol acetal	1
Benzyl acetate	1

* Solvents

[2] For details on the chemicals detected see Annex A.

e-Liquids

In total twenty eight samples of 'e-liquids' from re-fill bottles and two samples from re-usable e-cigarette cartridges were examined. Of these products twenty five contained nicotine and five were nicotine free based on chemical analysis.

Labelling and packaging – Products containing nicotine

The analysis reports for the nicotine containing e-liquids and cartridges are provided in Table 3. From Table 3 it is apparent that of the 25 samples that contained nicotine only three fully complied with the relevant labelling requirements. Although most indicated the presence of nicotine, very few gave the required supplier contact information and few provided the appropriate risk phrases, symbols etc. on the packaging. It should also be noted that there were many samples where the detected nicotine content was significantly below the detected levels.

Twenty of the nicotine containing e-liquid products would correctly be classified as 'toxic' and should have been supplied in containers with child-resistant closures. It was unclear from the analytical reports whether e-liquid bottles had child resistant packaging. The primary protection should derive from products with warning labels being kept out of reach of children. However, child safe closures are a requirement for products that are classified as 'toxic' or 'very toxic' and are of particular importance for products like e-liquids regularly used in the home.

Labelling and packaging – Products not containing nicotine

Of the five products not containing nicotine only one provided the name, address and telephone number of the supplier.

Chemical Composition

The analytical method used to determine the chemicals present in the e-liquids was mass spectroscopy and the results are shown below in Table 4. As with the liquids contained within the sticks all samples of e-liquids contained glycerol and propylene glycol which appear to be key components of any 'vaping' liquid. However, both the nicotine containing and nicotine free samples tended to contain flavourings. It should also be noted that in several cased a product that we would have expected to be flavoured e.g. 'blueberry high' or 'Jamaica mist' did not show an identified flavouring additive by mass spectroscopy. This was to be anticipated given the potentially low concentrations present and huge number of potential flavouring chemicals that could be used. The chemicals most frequently present are solvents some of which are known to be used in the flavourings and scents industry. The remaining identified chemicals are known to be used flavourings or scents.

Table 3: Nicotine containing e-liquids compliance with labelling requirements

Lab Ref	Nicotine concentration stated on packaging (mg/ml)	Nicotine concentration detected	Correct Classification	CHIP - Presence of nicotine displayed on packaging	CHIP - Name and Address of supplier	CHIP - Telephone number of supplier	CHIP- Appropriate Risk Phrases	CHIP- Appropriate Safety Phrases	Appropriate Picture Warnings Displayed	Picture Warnings are correct size/shape	Tactile Warning
BC18593	18	15	Toxic	Yes	No	No	Yes	Yes	Yes	No	Yes
BC18597	18	16	Toxic	Yes	No	No	Yes	Yes	Yes	No	Yes
BC18598	24	22	Toxic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	on bottle
BC18599	12	5	Toxic	Yes	No	No	No	No	No	No	No
BC18601	24	21	Toxic	Yes	Yes	No	No	No	No	No	On Box
BC18603	6	5	Toxic	Yes	Yes	No	Yes	Yes	Yes	No	on bottle
BC18608	16	13	Toxic	Yes	Yes	No	No	No	No	No	On Box
BC18609	24	21	Toxic	Yes	No	No	No	No	No	No	No
BC18616	4.5	4	Harmful	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BC18617	18	16	Toxic	Yes	Yes *	No	No	No	No	No	No
BC18622	24	23	Toxic	Yes	No	No	No	No	No	No	No
BC19262	18	15	Toxic	Yes	No	No	Yes	Yes	No	No	Yes
BC19263	12	10	Harmful	Yes	No	No	Yes	Yes	No	No	Yes
BC19264	24	22	Toxic	Yes	No	No	Yes	Yes	No	No	Yes
BC19268	18	15	Toxic	No	Yes	No	No	No	No	No	on bottle
BC19269	24	22	Toxic	No	Yes	No	No	No	No	No	on bottle
BC19270	11	9	Toxic	Yes	Yes	No	No	No	No	No	on bottle

* Supplier not in EEA.

Table 3: Nicotine containing e-liquids compliance with labelling requirements Continued..

Lab Ref	Nicotine concentration stated on packaging (mg/ml)	Nicotine concentration detected	Correct Classification	CHIP - Presence of nicotine displayed on packaging	CHIP - Name and Address of supplier	CHIP - Telephone number of supplier	CHIP- Appropriate Risk Phrases	CHIP- Appropriate Safety Phrases	Appropriate Picture Warnings Displayed	Picture Warnings are correct size/shape	Tactile Warning
BC19271	11	10	Toxic	Yes	No	No	No	No	No	No	On Box
BC19272	18	15	Toxic	Yes	No	No	No	Yes	No	No	On Box
BC19273	18	9	Toxic	Yes	Yes*	No	No	No	No	No	on bottle
BC19284	12	9	Harmful	Yes	No	No	No	No	Yes	Yes	Yes
BC19286	12	9	Harmful	Yes	Yes	No	No	No	No	No	No
BC18606	18	10	Toxic	Yes	No	No	No	No	No	No	Yes
BC18596	7	7	Toxic	No	No	No	No	No	No	No	No
BC18619	11	7	Harmful	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* Supplier not in EEA.

Table 4: Chemicals present in e-liquids

Chemical	Samples containing this chemical
Ethanol*	6
Diacetin*	5
Triacetin*	4
Ethyl butyrate*	3
Monoacetin*	3
Propylene glycol acetate*	3
Linalool	2
Acetol	1
Butyl acetate*	1
Cinnamaldehyde	1
Corylone	1
Dimethyl pyrazine	1
Estragole	1
Ethyl isovalerate	1
Iso-amyl acetate	1
Iso-amyl valerate	1
Limonene*	1

* Solvents

Re-Chargeable products: Electrical safety

All e-cigarette or shisha devices typically rely on a lithium battery to provide current which heats the e-liquid and 'vaporises' it. In the case of single use sticks or pens when the battery is discharged the device is disposed of and there is no provision for re-charging or re-filling it. In the case of re-usable devices the battery may be re-charged and the e-liquid reservoir re-filled. However, if an e-cigarette is charged at the wrong voltage or over-charged there is a danger that the cell will break down which may result in an intense fire and/or venting of flammable gas. In order to re-charge a lithium ion battery safely it needs to be charged at the correct voltage and charging must be discontinued once the cell has reached its fully charged state.

Currently there are no electrical safety standards specific to e-cigarette type devices whether they are disposable or re-chargeable. Trading Standards, as with many other consumer goods, can only use electrical safety and general product safety regulations when dealing with these products though these may not lead to a satisfactory [safe] outcome for consumers. Furthermore, the nature of lithium ion batteries and the use of (USB) connections create additional dangers and complications. This is because the overall safety of the device in use depends on three components; an AC/DC adapter (if employed) which provides power via a USB socket, a power cable that connects the USB socket to the e-cigarette and the e-cigarette itself which contains the battery.

Use of standard USB fittings also means that a user may decide to charge their e-cigarette from some device other than the charger supplied with it. Such devices may include computers, laptops, mobile phone chargers or a range of other USB enabled devices. However, even if this other device provides the correct voltage and power it is likely to lack an appropriate mechanism from preventing over charging of the battery. In some cases the protective features that prevent over charging are in the connecting lead or the supplied AC/DC adapter rather than the cigarette. This creates a complex situation where at least three separate safety assessments would be necessary:

i) Is any mains transformer/power supply unit electrically safe in its own right.

ii) Is the e-cigarette safe when used in conjunction with the transformer/power supply unit and power cable that it was supplied with.

iii) Is the e-cigarette safe when used with USB power sources and leads other than the one it was supplied with.

The safety testing carried out involved the assessment of three complete sets of charger, power cable and e-cigarette with a detailed assessment the electrical safety of the charger unit and an assessment of its use in combination with the relevant leads and e-cigarette. In addition an assessment was carried out of two e-cigarettes designed to charge from a standard USB power source rather than a dedicated AC/DC adapter.

Findings

The three full sets of AC/DC charger, power cable and e-cigarette were tested in accordance with British Standards BSEN 60950-1: 2006 + A12: 2011, BS 1363-1: 1995 +A4: 2012 and General Product Safety Regulations 2005. In summary all three products failed against the assessment criteria set as shown in Table 5 Below and explained in full in the relevant test reports. One of the recommendations made in the assessment report was that manufacturers of these devices should be asked to provide additional information on over-charge protection. In particular the reliability of any protection built into the charger or leads and the consequences of charging from a standard USB power source was identified as a common risk in this type of product.

Table 5: Electrical Safety Assessment e-cigarettes plus AC/DC adapters

	E-Health (M5628)	JOYTECH (M5686)	Unknown Brand (M5627)
Assessment Criteria	*AC/DC Adapter*		
Correct Operation	Pass	Pass	Pass
Marking/Instructions	FAIL	Pass	FAIL
Construction	FAIL	Pass	FAIL
Protection against contact with live parts	Pass	Pass	Pass
Protection against non-electrical dangers	N/A	N/A	N/A
Suitable insulation provided	FAIL	Pass	FAIL
Expected mechanical requirements met	Pass	Pass	Pass
Resistance to non-mechanical influences	N/A	N/A	N/A
Plug or plug pins	FAIL	FAIL	FAIL
	e-Cigarette		
Marking	FAIL	FAIL	FAIL
Instructions	FAIL	FAIL	FAIL

In addition two more e-cigarettes that employed leads that charge from standard USB power sources were tested by charging the cigarette over a three hour period. This did not result in any noted increase in temperature of the charger or cigarette unit. While this does not imply they are 'safe' it does imply there is no extremely obvious and immediate threat from charging the products for a short period.

Annex A: Chemicals present and their toxicity

Background

Electronic cigarettes have previously been the subject of a consultation exercise by the UK Commission on Human Medicines Working Group on Nicotine Containing Products (NCPS). [3] This work showed that e-cigarettes typically rely on propylene glycol and glycerol as 'carrier' solvents which decompose into water vapour and carbon dioxide 'vapour' when heated. If nicotine is present in the original liquid this 'vapour' then carries it into the user's lungs where it enters the blood stream.

There are a very wide range of factors that will affect the composition of the vapour produced by an e-cigarette, including the composition of the 'e-liquid', the temperature of the heating element and the rate at which air is drawn through the device. Similar factors will affect the amount of nicotine delivered to the user. Research to date has shown that e-cigarettes cannot be considered 'safe' due to the known dangers of certain chemicals present in the vapour produced by decomposing e-liquids and uncertainties regarding others. But, current consensus appears to be that they are likely to be significantly safer than conventional cigarettes as a means of delivering nicotine. [2]

However, it is increasingly common for e-cigarettes and similar devices to contain additional chemicals beyond nicotine, glycerol and propylene glycol designed to impart flavours and aromas to the vapour. Our evidence suggests that many also contain industrial solvents. Those products that contain nicotine may also contain chemicals designed to mimic the aroma and flavour of tobacco or an entirely artificial aroma and flavour. There is also a whole class of 'e-shisha' products that rely entirely on these flavours and aromas and contain no nicotine whatsoever. These products are often marketed to young people and children using bright packaging and flavours such as 'grape' or 'bubble-gum'. This implies that in assessing safety it is necessary to look beyond the core ingredients and at the multitude of additional chemicals present.

Chemicals found

Propylene glycol and glycerol were found in all samples and are assumed to be the standard 'carrier' solvent for these devices. However, in total twenty four different additional chemical compounds were identified in the samples tested in addition to nicotine, propylene glycol and glycerol. Many more chemicals will be present but would not have been detected because of the limitations of the analytical technique.

It is of potential significance that the next most common group of chemicals after propylene glycol and glycerol were monoacetin, diacetin and tracetin. These are commonly used in the fragrance industry as 'carrier' solvents for flavour and scent compounds and as humectants.[4] It is possible they have been used as part of the formulation rather than to impart any specific flavour or scent to the product. However, they will be 'vapourised' and inhaled along with all the other ingredients. The remaining nineteen compounds identified were known flavour or scent compounds many of which are commonly used in foods and beverages. These compounds are listed in the table below.

[3] UK Commission on Human Medicines Working Group on Nicotine Containing Products (NCPS). Quality Safety and Efficacy of Unlicensed NCP's 2013.

[4] A humectant is a substance that absorbs water and these are often used in the food industry to bulk up products and/or prevent them from drying out.

Table 1: Chemicals identified in e-cigarette samples

Chemical	Number of Samples Containing Chemical
Glycerol	All
Propylene glycol	All
Diacetin	12
Triacetin	12
Propylene glycol acetate	7
Ethanol	6
Monoacetin	6
Vanillin	5
Menthol	4
Ethyl butyrate	3
Ethyl vanillin	3
Acetol	2
Diethyl succinate	2
Benzaldehyde	1
Benzaldehyde propylene glycol acetal	1
Benzyl acetate	1
Butyl acetate	1
Cinnamaldehyde	1
Corylone	1
Dimethyl pyrazine	1
Estragole	1
Ethyl isovalerate	1
Iso-amyl acetate	1
Iso-amyl valerate	1
Limonene	1
Linalool	1

Toxicity

The toxicity of a chemical component within a mixture is based crudely on three things; its inherent toxicity or biological activity, the typical level of exposure a person experiences and the nature of the exposure e.g. oral, inhaled or skin contact. Assessing the toxicity of the chemicals present in the e-cigarette samples is complicated by three fundamental features of e-cigarettes:

i) **It is very hard to predict how much of each chemical a device will deliver to a user per 'use' or how often a user will use the device**

If the user is using the e-cigarette as an alternative to conventional cigarettes that may mean using it several times a day for significant periods and using the device for many months or even years. If it is more of a 'novelty' product with no nicotine present they may use it less often. Conversely if a person – typically a child- ingests an e-liquid cartridge the exposure may be acute and massive.

ii) **The mixture in the e-cigarette liquid will not be the same as the mixture entering the users lungs**

The heating element will break down both the carrier solvent and to a lesser extent other chemicals present in the e-liquid. While the major components are likely to be carbon dioxide and water there will be many other compounds produced and many of these, such as formaldehyde or carbon monoxide, will be toxic. While there is research that implies the breakdown products of propylene glycol and glycerol are relatively safe to inhale – or at least safer than cigarette smoke- no such evidence exists for most of the other chemicals present in the e-cigarette samples.

iii) **Inhaling chemicals as concentrated vapours into the lung is an unusual exposure mechanism and safety data for this means of delivery is often unavailable even for commonly used chemicals**

Typically the toxicity of a compound is assessed in terms of oral ingestion or exposure of the skin to the chemical as these are the normal modes of exposure in the workplace or home. It is unusual for chemical to be tested in terms of inhaling vapours or aerosols of the type produced in e-cigarettes. Otherwise benign materials such as medicinal paraffin oil or flour that are benign by ingestion or skin contact can be acutely toxic if delivered directly to the lungs.

Specific Potential Risks

In looking at the potential hazards of the chemicals identified they have been grouped together to make risk assessment simpler.

Nicotine

Nicotine is acutely toxic and an overdose can prove fatal. While there is debate regarding what the lowest recorded lethal dose is for a human, there are anecdotal reports of young children being harmed or killed by ingesting e-liquid cartridges. This risk of poisoning seems credible as e-liquid refill may contain up to 24 milligrams of nicotine per millilitre and a 'small' 5ml refill bottle would contain around twice the theoretical lethal dose of nicotine for an adult.

Propylene glycol, glycerol

These chemicals are essential to the operation of e-cigarettes and are considered essentially non-toxic when ingested and are widely used in the food and pharmaceutical industries. When heated in the e-cigarette to produce vapour evidence suggests that the chemicals produced are relatively benign and significantly less toxic than cigarettes smoke.

Monoacetin, diacetin and triacetin

These chemicals appears to widely used in the food and fragrance industry and may well be safe in that context. However, rudimentary searches imply that heating them produces irritant breakdown products. They appear to be present in a large number of the samples tested and their use in e-cigarettes may be potentially harmful.

Other flavours and scents

In the samples tested around nineteen chemicals were identified as scents or flavourings and there are a vast number of compounds approved for food use that could be used individually to flavour these products. These may be the most problematic of all the potential components of e-cigarettes. There may clearly be an incentive to create new and distinctive products using these chemicals. However, little is known of the effect these chemical have if inhaled and what evidence exists implies some may be highly toxic.

The most relevant and well evidenced example of a flavouring causing harm is the use of diacytyl. This chemical has been approved for food use and imparts a 'buttery' aroma and flavour to popcorn and confectionary. However, repeated inhalation can cause severe and irreversible lung damage. This was demonstrated in several workers exposed to the material in factory environments in the USA. While diacytyl was not detected in the samples analysed it has been identified in e–liquids being sold in the UK.

As stated above, very little is known about the effects of these chemicals when inhaled. However, there were a number of specific flavourings/scents that stood out as potential hazards:

i) **Vanillin:** Eight samples tested contained vanillin or ethyl vanillin which are known irritants or sensitizers for human skin. Directly inhaling a vapour containing such compounds would seem inadvisable.

ii) **Estragole:** One sample contained this and although it is found naturally in certain herbs it is known to cause serious toxic effects. Inhalation at high concentrations may cause Central Nervous System (CNS) depression and asphyxiation. It causes respiratory tract irritation, aspiration (inhalation) may lead to pulmonary edema, it can produce delayed pulmonary edema.

iii) **Corylone:** This is used commercially as a cockroach bait and while it has no reported toxic effects in humans, its safety by inhalation is unknown and most consumers would probably not wish to smoke cockroach bait.

Detailed Information on Chemicals Identified

Given the number of chemicals involved only a very limited research could be done into likely toxicity and the results of this are provided below.

Compound: Acetol

"Acetol" is a trade name that has been used to represent different substances at different times including hydroxyacetone, acetylsalisylic acid, acetal, diethylaldehyde and cellulose acetate. http://www.thefreedictionary.com/acetol

Currently it is used to represent hydroxyacetone.

http://encyclopedia2.thefreedictionary.com/acetol

CAS number: 116-09-6

http://www.chemicalbook.com/ProductMSDSDetailCB0714802_EN.htm

Other names/trade names:

2-Oxopropanol

Acetone alcohol

Acetylcarbinol

Hydroxymethyl methyl ketone

hydroxypropanone

Common usage:

Used in chemical synthesis and as a food flavouring additive.

http://www.chemicalland21.com/info/Flavouring_Substances_9.htm

Toxicity:

The toxicology of hydroxyacetone has not been fully investigated.

http://chemexper.net/HY/hydroxyacetone.html

Compound: Benzaldehyde

CAS number: 100-52-7

http://www.inchem.org/documents/icsc/icsc/eics0102.htm

Other names/trade names:

Benzoic aldehyde

Benzenecarbonal

Artificial almond oil

Common usage:

Benzaldehyde is the major component of bitter almond oil – from which it may be extracted. It is used as a flavouring in the food industry as it is "generally regarded as safe" (GRAS) by the US FDA. As well as being used as a fragrance in soaps, it has uses in the cosmetic and pharmaceutical industries.

Toxicity:

Being a GRAS compound it is not considered toxic. It is absorbed through skin and lungs and is then distributed to the organs but does not accumulate in them. Repeated inhalation of volatilised benzaldehyde produced eye and nasal irritation in rabbits however, no human inhalation data was found.

http://ijt.sagepub.com/content/25/1_suppl/11.abstract

http://www.epa.gov/iris/subst/0332.htm

Compound: Benzaldehyde propylene glycol acetal

CAS number: 2568-25-4

http://www.thegoodscentscompany.com/data/rw1005031.html

Other names/trade names:

Benzaldehyde P.G.A.

Benzaldehyde PG acetal

4-Methyl-2-phenyl-1,3-dioxolane

4-Methyl-2-phenyl-meta-dioxolane

Common usage:

It is a flavour and fragrance ingredient used in the food industry.

Toxicity:

The WHO states that it has "no safety concerns" for its use as a food additive but it does have a risk statement (R37) of "irritating to the respiratory system".

http://www.inchem.org/documents/jecfa/jecmono/v48je14.htm

http://www.chemicalbook.com/ChemicalProductProperty_EN_CB1217870.htm

Compound: Benzyl acetate

CAS number: 140-11-4

http://www.lookchem.com/benzyl-acetate/

Other names/trade names:

Phenylmethyl acetate
Acetic acid, benzyl ester

Common usage:

As a solvent in the plastics industry and as a fragrance and flavouring in the food and cosmetics industries.

Toxicity:

Benzyl acetate is a known human respiratory irritant - having a risk statement (R37) of "irritating to the respiratory system".

http://chem.sis.nlm.nih.gov/chemidplus/rn/140-11-4

Compound: Butyl acetate (isomer not specified)

CAS number: 123-86-4 / 105-46-4 / 540-88-5

http://www.inchem.org/documents/icsc/icsc/eics0399.htm

Other names/trade names:

Acetic acid, butyl ester
Butyl ethanoate

Common usage:

Industrially they are used in the manufacture of lacquers, artificial leather, plastics and safety glass. They are also used as a fragrance and flavouring in the food industry.

Toxicity:

At high concentrations (200+ ppm) n-butyl acetate is known to be toxic. It has been shown to cause severe irritation of the throat in humans. All three isomers have shown respiratory irritation in humans.

http://www.inchem.org/documents/icsc/icsc/eics0399.htm

http://www.cdc.gov/niosh/idlh/123864.html

http://www.cdc.gov/niosh/idlh/540885.html

Compound: Cinnamaldehyde

CAS number: 104-55-2

http://www.chemspider.com/Chemical-Structure.553117.html

Other names/trade names:

Cinnamal

Benzylidene acetaldehyde

(2E)-3-Phenyl-2-propenal
(2E)-3-Phenylacrylaldehyde

(E)-3-Phenyl propenal

Common usage:

Cinnamaldehyde has numerous uses including as a fragrance and flavouring, as a fungcide (agricultural) and insecticide, as an antimicrobial agent, as an anticancer agent and as a corrosion inhibitor.

Toxicity:

It is considered to have “low toxicity”. Useful human inhalation information was not found.

Compound: Corylone

CAS number: 765-70-8

http://dir.perfumerflavorist.com/detail/ffmProduct.html?id=30097

Other names/trade names:

Methylcyclopentenolone

Cyclotene

Kentonarome

Maple lactone

3-Methylcyclopentane-1,2- dione

3-Methyl-2-cyclopenten-2-ol-1-one

Common usage:

Corylone is primarily used as a food flavouring.

Toxicity:

The adverse effects of human inhalation could not be found.

Compound: Diacetin (Isomer not specified)

CAS number: 25395-31-7 / 29860-16-0

http://www.lookchem.com/Diacetin/

http://www.chemspider.com/Chemical-Structure.59412.html

Other names/trade names:

Estol1582

Estol1583

Diacetylglycerol

Glyceryl diacetate

Glycerol diacetate

Glycerin diacetate

1,2,3-Propanetriol diacetate

Common usage:

Mainly used as solvent and a plasticiser.

Toxicity:

No human inhalation data found. It a dangerous substance according to GHS. This substance is not classified as dangerous according to Directive 67/548/EEC.

http://www.guidechem.com/msds/25395-31-7.html

Compound: Diethyl succinate

CAS number: 123-25-1

http://www.thegoodscentscompany.com/data/rw1018871.html

Other names/trade names:
Succinic acid diethyl ester

Diethyl butanedioate

Diethyl butane-1,4-dioate

Butanoic acid diethyl ester

Butanedioic acid diethyl ester

Common usage:

Mainly used as food and flavour ingredient and as a plasticiser.

Toxicity:

Diethyl succinate is stated as being a human respiratory irritant - having a risk statement (R37) of "irritating to the respiratory system".

http://www.chemicalbook.com/CASEN_123-25-1.htm

Compound: Dimethylpyrazine (Isomer not stated)

All three isomers are known to be used as food flavourings:

2,3-Dimethylpyrazine; CAS 5910-89-4

2,5-Dimethylpyrazine; CAS 123-32-0

2,6-Dimethylpyrazine; CAS 108-50-9

Other names/trade names:

Common usage:

Primarily used a food flavourings.

Toxicity:

As food flavourings, there are currently no safety concerns. No inhalation toxicology could be found.

http://www.inchem.org/documents/jecfa/jecmono/v48je12.htm

Compound: Estragole

CAS number: 140-67-0

http://www.takasago.com/cgi-bin/detail.cgi?key=C114118

Other names/trade names:

1-Allyl-4-methoxybenzene

1-methoxy-4-(2-propenyl)-benzene

Estragol

Estragen

4-Allylanisole

p-Allylanisole

Chavicol methylether

Isoanethole

Common usage:

Estragole naturally occurs in basil, tarragon and fennel. It is used as a food flavouring.

Toxicity:

"Estragole has been demonstrated to be genotoxic and carcinogenic. Therefore the existence of a threshold cannot be assumed and the Committee could not establish a safe exposure limit. Consequently, reductions in exposure and restrictions in use levels are indicated."

http://ec.europa.eu/food/fs/sc/scf/out104_en.pdf

According to Material Safety Data Sheet, "Causes respiratory tract irritation. Aspiration may lead to pulmonary edema. Can produce delayed pulmonary edema. Inhalation at high concentrations may cause CNS depression and asphyxiation".

http://msds.orica.com/pdf/shess-en-cds-010-000000030374.pdf

Compound: Ethanol

CAS number: 64-17-5

http://www.commonchemistry.org/ChemicalDetail.aspx?ref=64-17-5

Other names/trade names:

Numerous – see link above.

Common usage:

Wide range of uses from industrial solvent to alternative fuel for cars.

Toxicity:

The effects of vapour inhalation are thoroughly detailed in the link below.

http://www.herc.org/msds/chemicals/ethanol.htm

Compound: Ethyl butyrate

CAS number: 105-54-4

http://www.thegoodscentscompany.com/data/rw1004792.html

Other names/trade names:

Butanoic acid, ethyl ester

Butyric acid, ethyl ester

Butyric ester

Butyric ether

Ethyl butyrate

Ethyl butanoate

Ethyl n-butyrate

Common usage:

Primarily used as a food flavouring.

Toxicity:

Ethyl butyrate is known to be a skin and eye irritant and has been given the risk statement (R37) of "irritating to the respiratory system". It is also stated as being a human mucous membrane irritant.

http://chem.sis.nlm.nih.gov/chemidplus/rn/105-54-4

http://ntp.niehs.nih.gov/testing/status/chemid/hsdb-105-54-4.html

Compound: Ethyl isovalerate

CAS number: 108-64-5

http://chem.sis.nlm.nih.gov/chemidplus/rn/108-64-5

Other names/trade names:

Ethyl 3-methylbutanoate

Isovaleric acid, ethyl ester

Ethyl 3-methylbutyrate

Ethyl beta-methylbutyrate

Common usage:

Primarily used as a food flavouring.

Toxicity:

Health hazard statement given as "Inhalation or contact with material may irritate or burn skin and eyes".

http://cameochemicals.noaa.gov/chemical/21901

Compound: Ethyl vanillin

CAS number: 121-32-4

http://www.thegoodscentscompany.com/data/rw1002652.html

Other names/trade names:

Bourbonal

Ethavan

Ethovan

3-Ethoxy-4-hydroxybenzaldehyde

2-Ethoxy-4-formylphenol

Ethyl protal

Vanirom

Common usage:

Primarily used as a food flavouring.

Toxicity:

Although ethyl vanillin was stated as being a mild irritant and mildly toxic, no human inhalation data could be found.

http://ntp.niehs.nih.gov/testing/status/chemid/hsdb-121-32-4.html

Compound: Glycerol

CAS number: 56-81-5

http://www.sigmaaldrich.com/catalog/product/sial/g9012?lang=en&region=GB

Other names/trade names:

Propane-1,2,3-triol

Glycerin

Glycerine

Propanetriol

1,2,3-Trihydroxypropane

Common usage:

Glycerol has numerous uses in many industries including the food and pharmaceutical industries.

Toxicity:

No information could be found regarding the adverse effects of human inhalation.

Compound: Iso-amyl acetate

CAS number: 123-92-2

http://www.cameochemicals.noaa.gov/chemical/8743

Other names/trade names:

3-Methylbut-1-yl ethanoate

Isopentyl acetate

Isopentyl ethanoate

3-Methylbutyl acetate

3-Methylbutyl ethanoate

Banana oil

Pear essence

Common usage:

Mainly used as food additive but also used as a solvent.

Toxicity:

Has been stated as “VAPOR: Irritating to eyes, nose and throat. If inhaled, will cause nausea, headache or dizziness”.

http://www.cameochemicals.noaa.gov/chemical/8743

Additionally, Isoamyl acetate is considered more irritating than butyl acetate. Exposure to 1,000 ppm for 30 minutes resulted in irritation, dyspnea, fatigue, and increased pulse. It is considered dangerous to life after 5 hours of exposure to 10,000 ppm.

http://www.cdc.gov/niosh/idlh/123922.html

Compound: Iso-amyl valerate

CAS number: 2050-09-1

http://www.chemspider.com/Chemical-Structure.67464.html

Other names/trade names:

Iso-pentyl valerate

Valeric acid, 3-Methylbutyl ester

3-Methylbutyl valerate

3-Methylbutyl pentanoate

Common usage:

Primarily used in the fragrances and flavourings industry.

Toxicity:

No human inhalation data could be found.

Compound: Limonene

CAS number: 138-86-3

http://www.chemicalbook.com/CASEN_138-86-3.htm

Other names/trade names:

4-Isopropenyl-1-methylcyclohexene

p-Menth-1,8-diene

Racemic: DL-limonene

Dipentene

Common usage:

Multiple uses including cosmetics industry and food manufacturing also used as an organic solvent in industrial de-greasing work.

Toxicity:

Commonly used in cosmetics and food but known to be a skin irritant and sensitiser as well as a respiratory irritant. Its oxidation products are known to be skin sensitisers. No information found on toxicity by inhalation in humans.

Compound: Linalool

CAS number: 78-70-6

http://www.chemspider.com/Chemical-Structure.13849981.html

Other names/trade names:

3,7-Dimethylocta-1,6-dien-3-ol

(±)-Linalool

Allo-Ocimenol

Common usage:

Primarily used in the fragrance industry.

Toxicity:

No human inhalation data could be found.

Compound: Menthol

CAS number: 89-78-1

http://www.commonchemistry.org/ChemicalDetail.aspx?ref=89-78-1

Other names/trade names:

(1*R*,2*S*,5*R*)-2-Isopropyl-5-methylcyclohexanol
3-p-Menthanol

Hexahydrothymol

Menthomenthol

Peppermint camphor

Common usage:

Primarily used in the fragrance industry.

Toxicity:

No information could be found regarding the adverse effects of human inhalation.

Compound: Monoacetin

CAS number: 26446-35-5

http://ntp.niehs.nih.gov/testing/status/chemid/chemical-26446-35-5.html

Other names/trade names:

Glycerol acetate

Glycerol monoacetate

1,2,3-Propanetriol monoacetate

Glyceryl acetate

Glycerine monoacetate

Eastman 9-45

Common usage:

It is used as a solvent and in the leather tanning industry.

Toxicity:

No information could be found regarding the adverse effects of human inhalation.

Compound: Propylene glycol

CAS number: 57-55-6

http://www.commonchemistry.org/ChemicalDetail.aspx?ref=57-55-6

Other names/trade names:

α-Propylene glycol

1,2-Propanediol

1,2-Dihydroxypropane

Methyl ethyl glycol (MEG)

Methylethylene glycol

Common usage:

In the food industry, it is used as a thickening agent, carrier solvent, emulsifier and humectant (E1520). Industrially it is used to make polyester resins and as a de-icer / anti-freeze. Additionally, it has numerous pharmaceutical applications including use in asthma inhalers.

Toxicity:

Propylene glycol exhibits low toxicity so that it is a "generally recognized as safe" (GRAS) additive for foods and medications. Propylene glycol rarely causes toxic effects, and then only under very unusual circumstances. Depression of the central nervous system is seen in acute poisoning.

http://www.atsdr.cdc.gov/csem/csem.asp?csem=12&po=14

Compound: Propylene glycol acetate

Thought to refer to propylene glycol mono-methy ether acetate. This is an industrial solvent its supplier indicate that to the best of their knowledge its toxicological properties have not been thoroughly investigated.

Compound: Triacetin

CAS number: 102-76-1

http://www.fishersci.in/msds/Triacetin.pdf

Other names/trade names:

Glycerol triacetate

1,2,3-Triacetoxypropane

Common usage:

Triacetin has uses as a food additive (E-1518) acting as a humectant; it is listed as a cigarette additive and has been used as a fuel additive in both petrol and diesel.

Toxicity:

It is described as "not a hazardous substance" according to Regulation (EC) No. 1272/2008 and "not classified as dangerous" according to Directive 67/548/EEC.

http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=GB&language=en&productNumber=W200700&brand=ALDRICH&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Faldrich%2Fw200700%3Flang%3DenAcute inhalation toxicity in humans was "considered to be very low". http://www.inchem.org/documents/sids/sids/102761.pdf

Compound: Vanillin

CAS number: 121-33-5

http://avogadro.chem.iastate.edu/MSDS/vanillin.htm

Other names / trade names:

Vanilla

Vanillaldehyde

4-Hydroxy-m-anisaldehyde

4-Hydroxy-3-methoxy-benzaldehyde

Lioxin

Methyl-protocatechualdehyde

p-Vanill

Common usage:

Vanillin and its derivatives are widely used in the food industry as flavourings and in the fragrance industry in perfumes.

Toxicity:

Vanillin has been classified as a skin irritant as well as a serious eye irritant. It has been linked to skin sensitization in humans and ingestion has provoked intolerance reactions. No information was found on toxicity by inhalation in humans.

http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=GB&language=en&productNumber=V2375&brand=SIGMA&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Fsigma%2Fv2375%3Flang%3Den

http://ntp.niehs.nih.gov/testing/status/chemid/hsdb-121-33-5.html

Additional information:

Vanillin is pharmacologically active, causing depressed blood pressure, increased respiratory rate and death due to cardiovascular collapse.[Patty, F. (ed.). Industrial Hygiene and Toxicology: Volume II: Toxicology. 2nd ed. New York: Interscience Publishers, 1963., p. 1696]