

E-Liquid Quality by Design to Manufacture Safer Products

Case Study: VML's Mojito Lemonade – Liquid Ingredients



Mojito Flavor/Liquid Composition

| Flavor Composition | CAS Number | Relative Percentage in Flavoring | Is the ingredient found in emissions? |
|---------------------------------------------|------------------|----------------------------------|---------------------------------------|
| Propylene Glycol | 57-55-6 | 60-85 | No |
| Polyethylene Glycol sorbitan monooleate | 9005-65-6 | 1 | No |
| Oils, lemon, psoralen-free | 68916-89-2 | 1 | No |
| Vanillin | 121-33-5 | 1 | No |
| Benzaldehyde, 3-ethoxy-4-hydroxy | 121-32-4 | 1 | No |
| (+)- Menthol | 89-78-1 | 1 | No |
| L-Menthan-3-one | 14073-97-3 | 1 | No |
| Oil, peppermint | 8006-90-4 | 1 | No |
| Alpha Pinene | 80-56-8 | 1 | No |
| Possible propylene glycol reaction products | | 5.9 | No |
| Ethyl Citrate | 77-93-0 | 2.4 | No |
| Sabinene | 3387-41-5 | 1 | No |
| Unresolved 1,4-Cineole | 470-67-7/99-86-5 | 1 | No |
| Beta Phellandrene | 555-10-2 | 1 | No |
| 2,2,4-trimethyl-1,3-dioxolane | 1193-11-9 | 0.5 | No |
| Ethanol | 64-17-5 | 10.0-15.0 | Yes |
| Acetylaldehyde ^b | 75-07-0 | 1 | Yes/No |
| Beta Pinene | 127-91-3 | 1 | Yes |
| Gamma terpinene | 99-85-4 | 1.6 | Yes |
| Geranial | 5392-40-5 | 4.7 | Yes |
| Limonene | 138-86-6 | 10.0-15.0 | Yes |
| Myrcene | 123-35-3 | 1 | Yes/No |
| Neral | 106-26-3 | 3.5 | Yes |
| Para cymene | 99-87-6 | 0.6 | Yes |
| Terpinolene | 586-62-9 | 0.5 | Yes |

^bAcetylaldehyde is a known toxic ingredient that is banned in the UK & Germany

| Bulk Flavor Ingredients (both natural and artificial) | Percent |
|--------------------------------------------------------|---------|
| Glycerin | 74% |
| Lemonade | 10% |
| Key lime | 4% |
| Lemon Lime | 4% |
| Mint Candy | 1% |
| Sweetener - Old Formulation - Primarily Acetylaldehyde | 1% |
| Nicotine (6 mg/mL) | 6% |

Sweetener (New Formulation)

- This study demonstrates how hazardous ingredients found in E-Liquids can be removed to produce a safer product
- Following flavor and vapor analysis Mojito Lemonade was found to contain 13 potentially harmful ingredients
- It was identified that these ingredients originated from the Sweetener ingredient used in the E-Liquid formulation
- Old sweetener was replaced with new Sweetener and the harmful ingredients were removed

E-Liquid Quality by Design to Manufacture Safer Products Compared to Combustion Cigarettes – Vapor Components



Mojito Vapor Composition

| Emission Composition | CAS Number | Concentration (ug/puff) | |
|----------------------|------------|-------------------------|-----------------|
| | | Old Formulation | New Formulation |
| Nicotine | | 10 | 20 |
| Formaldehyde | 50-00-0 | 2.38 | <0.1* |
| Acetaldehyde | 75-07-0 | 16.32 | <0.1 |
| Acrolein | 107-02-8 | 5.2 | <0.1 |
| Crotonaldehyde | 123-73-9 | <0.007 | <0.1 |
| Diacetyl | 431-03-8 | <0.014 | <0.1 |
| Acetyl Prionyl | 600-14-6 | <0.18 | <0.1 |
| Ethylene Glycol | 107-21-1 | 0.7 | <0.2 |
| Di-ethylene Glycol | 112-34-5 | <0.20 | <0.2 |

| Emission Composition | CAS Number | Concentration (ng/puff) | |
|-----------------------|------------|-------------------------|-----------------|
| | | Old Formulation | New Formulation |
| Acetone | 67-64-1 | 560 | Nd ^a |
| Benzene | 71-43-2 | 26 | <10* |
| 1,3-Butadiene | 71-43-2 | 6477 | <10 |
| Isoprene | 106-99-0 | 92 | <10 |
| Toluene | 78-79-5 | 22 | <10 |
| Propanal | 108-88-3 | 557 | nd |
| Methyl glyoxal | 78-98-8 | 420 | nd |
| 1-Hydroxy-2-propanone | 116-09-6 | 344 | nd |
| 2-Propen-1-ol | 107-18-6 | 708 | nd |
| Acetic acid | 64-19-7 | 122 | nd |
| Ethanol | 64-17-5 | 959 | 1946 |
| Beta Pinene | 127-91-3 | 275 | 154 |
| Gamma terpinene | 99-85-4 | 162 | 129 |
| Geranial | 5392-40-5 | nd | 140 |
| Limonene | 138-86-3 | 2512 | 1967 |
| Myrcene | 123-35-3 | 167 | nd |
| Neral | 106-26-3 | nd | 135 |
| Para cymene | 99-87-6 | 165 | 120 |
| Terpinolene & octanal | 586-62-9 | nd | 134 |

*Below LOQ

5V, 9.3W

4.2V, 9.2W

^a Not Detected

| Cigarette Smoke Composition ^c |
|------------------------------------------|
| 1,3-Butadiene |
| Acetaldehyde |
| Acetone |
| Acrolein |
| Benzene |
| Crotonaldehyde |
| Formaldehyde |
| Isoprene |
| Nicotine |
| Toluene |
| 1-aminonaphthalene |
| 2-aminonaphthalene |
| Acrylonitrile |
| Ammonia |
| Benzo[a]pyrene |
| Butyraldehyde |
| Cadmium |
| Carbon Monoxide |
| Catechol |
| Chromium |
| Cresol |
| Hydrogen Cyanide |
| Hydroquinone |
| Lead |
| Methyl Ethyl Ketone (MEK) |
| Nickel |
| Nitric Oxide |
| NNN, NNK, and NAT |
| Phenol |
| Propionaldehyde |
| Pyridine |
| Quinoline |
| Resorcinol |
| Styrene |
| Tar |

- Composition of E-Liquids can be modified to ensure safer components whereas combustion cigarettes cannot
- Nicotine levels can be controlled in E-Cigarettes whereas combustion cigarettes cannot

E-Liquid Quality by Design to Manufacture Safer Products Compared to Combustion Cigarettes

Heavy Metal Content



Old Mojito Formulation

| Analyte | Concentration (µg/puff) |
|-----------|-------------------------|
| Aluminium | <0.0018 |
| Arsenic | <0.0004 |
| Cadmium | <0.0001 |
| Chromium | 0.0152 |
| Copper | 0.0089 |
| Iron | 0.0570 |
| Lead | <0.0054 |
| Mercury | <0.0004 |
| Nickel | 0.0077 |
| Tin | <0.0015 |

New Mojito Formulation

| Analyte | Concentration (µg/puff) |
|-----------|-------------------------|
| Aluminium | <0.0018 |
| Arsenic | <0.0004 |
| Cadmium | <0.0001 |
| Chromium | <0.0024 |
| Copper | <0.0015 |
| Iron | <0.0023 |
| Lead | <0.0054 |
| Mercury | <0.0004 |
| Nickel | <0.0018 |
| Tin | <0.0015 |

Cigarette Smoke Composition

| |
|----------|
| Chromium |
| Lead |
| Nickel |

Heavy metals in Mojito Lemonade was removed in the new formulation making a safer product

Overall Conclusion:

- 1) Mojito Lemonade was successfully reformulated to remove all hazardous ingredients found in the original formulation
- 2) The only common ingredient of the new formulation with combustion cigarettes is Nicotine and Nicotine levels in Mojito Lemonade can be adjusted down to ZERO