Study identifies two additional carcinogens not previously reported in e-cigarette vapor

July 27 2016

Berkeley Lab researchers (from left) Lara Gundel, Marion Russell, Hugo Destaillats demonstrate filling a glass syringe with vapor from an e-cigarette. Credit: Paul Mueller/Berkeley Lab

While previous studies have found that electronic cigarettes emit toxic

compounds, a new study from Lawrence Berkeley National Laboratory (Berkeley Lab) has pinpointed the source of these emissions and shown how factors such as the temperature, type, and age of the device play a role in emission levels, information that could be valuable to both manufacturers and regulators seeking to minimize the health impacts of these increasingly popular devices.

The study, which was published in *Environmental Science & Technology*, found that the thermal decomposition of propylene glycol and glycerin, two solvents found in most "e-liquids" (the substance that is vaporized by the e-cigarette), leads to emissions of toxic chemicals such as acrolein and formaldehyde.

"Advocates of e-cigarettes say emissions are much lower than from conventional cigarettes, so you're better off using e-cigarettes," said Berkeley Lab researcher and the study's corresponding author Hugo Destaillats. "I would say, that may be true for certain users—for example, long time smokers that cannot quit—but the problem is, it doesn't mean that they're healthy. Regular cigarettes are super unhealthy. E-cigarettes are just unhealthy."

In the paper, "Emissions from electronic cigarettes: Key parameters affecting the release of harmful chemicals," Destaillats and a team of researchers simulated vaping using three types of e-liquids in two different vaporizers operated at various battery power settings. The two e-cigarettes were quite different, one fairly cheap with one heating coil, the other more expensive with two heating coils in parallel. The researchers used gas and liquid chromatography to determine what was in the vapor, looking at the first puffs as well as later puffs after the device heated up and reached a "steady state."

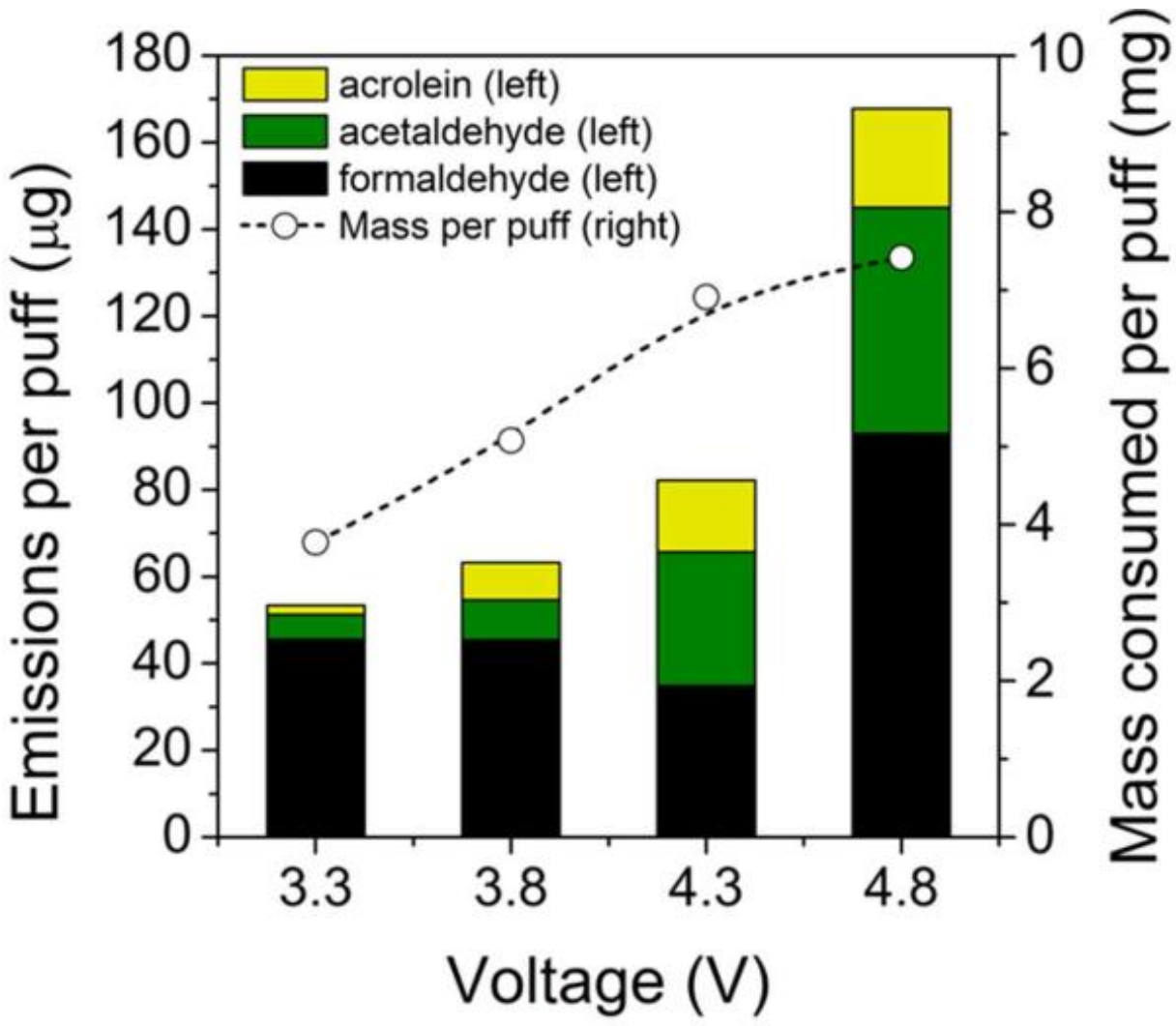
Not all puffs are equal

One finding was that the first and last puffs produce widely varying emissions. Using a custom-built vaping apparatus emulating realistic vaping habits, researchers drew on the e-cigarette by taking puffs lasting 5 seconds every 30 seconds. They found that vapor temperature rose quickly in the first 5 to 10 minutes until reaching a steady state temperature at around the twentieth puff.

Correspondingly, emissions levels between the first few puffs and the steady state increased by a factor of 10 or more in some cases, depending on the device, the battery voltage, and the emitted compound. For example, for acrolein, a severe eye and respiratory irritant, a single-coil e-cigarette operated at 3.8 volts emitted 0.46 micrograms per puff in the first five puffs, but at the steady state it emitted 8.7 micrograms per puff. "When you apply the same voltage to the double-coil e-cigarette you see a lot less emissions," said co-author and Berkeley Lab researcher Lara Gundel. "We think it has to do with lower temperatures at each of the coil surfaces."

For comparison, conventional cigarettes emit 400 to 650 micrograms of acrolein per cigarette, accounting for both mainstream and sidestream emissions. Assuming 20 puffs on an e-cigarette is equivalent to smoking a conventional cigarette, Gundel said, then total emissions of acrolein for an e-cigarette are about 90 to 100 micrograms.

Separately, to test effects due to device aging, researchers used a single device over nine consecutive 50-puff cycles without cleaning. Again, emissions of formaldehyde, acetaldehyde, and acrolein—all either carcinogens or respiratory irritants—increased with usage. "In some cases we saw aldehyde levels increase 60 percent between cycles 1 and 9," said co-author and Berkeley Lab researcher Mohamad Sleiman.



Emissions of potentially harmful compounds in e-cig vapor increase with device voltage. Credit: American Chemical Society

The researchers note in their paper: "This effect is consistent with the buildup of polymerization byproducts on or near the coil leading to accumulation of the sort of residues that are often referred to in the blogosphere as 'coil gunk' or 'caramelization.' Heating these residues would provide a secondary source of volatile aldehydes."

Lastly, because many e-cigarettes allow users to control the voltage, the researchers systematically investigated the effect of voltage on emissions. They found that as the voltage increased, both the amount of e-liquid consumed per puff and the vapor temperature were higher. In the case of acrolein and formaldehyde, the amount formed at the highest voltage of 4.8V was an order of magnitude higher than the amount at the lowest voltage of 3.3V.

Destaillats takes pains to note that the results do not mean that e-cigarettes are safe to use at lower temperatures. "We found there are emissions of toxic chemicals at any temperature at which you use the device," he said. "And the higher the temperature, the more emissions."

Two new carcinogens detected

Because there is an immense variety of e-cigarettes as well as e-liquids, the Berkeley Lab researchers decided to focus on an element that is common to all of them: the solvent in the e-liquid. Almost all e-liquids use a combination of propylene glycol and glycerin in varying proportions as a solvent.

"Both are used for making artificial smoke on stage," Destaillats said. "The ratio between the two determines things like the volume of vapor cloud that you produce. They are considered safe for food."

However, there have been few if any studies on the safety of heating and inhaling propylene glycol and glycerin. "People are not drinking the liquids—they're vaping them," said Sleiman. "So what counts is the vapor."

The researchers vaporized liquids consisting solely of the solvents to verify that they were the source of the emissions. In all, the researchers detected significant levels of 31 harmful chemical compounds, including

two that had never been previously found in e-cigarette vapor—propylene oxide and glycidol, both of which are probable carcinogens.

"Understanding how these compounds are formed is very important," Destaillats said. "One reason is for regulatory purposes, and the second is, if you want to manufacture a less harmful e-cigarette, you have to understand what the main sources of these carcinogens are."

More information: "Emissions from electronic cigarettes: Key parameters affecting the release of harmful chemicals" pubs.acs.org/doi/abs/10.1021/acs.est.6b01741

Provided by Lawrence Berkeley National Laboratory