Chemical Papers (2021) 75:6169–6180
https://doi.org/10.1007/s11696-021-01779-5

REVIEW

# Analytical methods for the identification of micro/nano metals in e-cigarette emission samples: a review

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Received: 5 February 2021 / Accepted: 4 July 2021 / Published online: 18 August 2021


## Abstract
In this review, numerous analytical methods to quantify the heavy and trace elements emitted from electronic cigarettes, cigarettes liquid and atomizer. The selection of a method was dependent upon the purpose, e.g., quantification or identification of elements only. The introductory part of this review focuses on describing the importance of setting up an electronic cigarettes- associated safety profile. The review dealt with studies that assessed elements in sizes ranging from nano to micro. The formation of different degradation chemical substances as well as impurity trends can be indicated through chemical investigation of metals in electronic cigarettes. Some studies have been covered that show the uses and benefits of. It is noticeable from all the collected sources that the minerals emitted from the smoke of e- cigs do not constitute any significant damage, as the percentage is very small, with the exception of minerals that may be emitted from the components of the device after heating it if the components of the e- cig are of poor specifications, except in the case of long-term accumulation. For this reason, an electronic cigarette can help smokers to quit smoking tobacco and replace it with electronic cigarettes smoke with distinctive flavors.

**Keywords** Electronic-cigarettes · Atomizer · Heavy metals · Analytical methods · Nanoparticles · And COVID-19

## Introduction

Electronic cigarettes (E-cig) are battery-charged device that mimics the act of smoking by generating the physical sensation, used to vaporize a liquid that may or may not contain nicotine (Susi et al. 2020). E-cigs are submitted to by different names, including “electronic cigarettes,” “e-cigarettes,” “electronic nicotine delivery systems (ENDS),” “alternative nicotine delivery systems (ANDS),” “electronic vapor products,” “e-cigars,” “e-pipes,” “e-hookahs,” “e-shishas,” “mods,” “personal vaporizers,” “vape pens,” “vapes”, “vapor pens,” “hookah pens” and “tank systems” (Pearson et al. 2018). It was invented by Chinese pharmacist Hon Lik in 2003 (Patent and Link, xxxx). E-cig consists of a heating system, and a fluid container having pump generates aerosols by heating an e-liquid solution with a metal coil (Levy et al. 2018). Atomizers are ionized the analyte by isolated it in the gas phase and evaporates the e-liquid fillers to introduce wet aerosol. An aerosol has been created from atomizer e-cigs called vapor contains of propylene glycol, vegetable glycerin (VG) and/or propylene glycol (PG) with water (Goniewicz et al. 2014) to produce aerosol, glycerine (G), nicotine (N) (in various concentrations) (0–36 mg/mL) (Glasser et al. 2017), chemical constituents for flavoring (F) agents (Dai 2017), which have a sleek design are even more attractive to adolescents (Julia et al. 2019; Goniewicz et al. 2018a; Huang et al. 2019; McKelvey et al. 2018) and other additives to users via an inhaled aerosol.

Three types of e-cigs may be classified: cig-a-like, tank and pod-based e-cigs. E-cigs were designed with components of heavy metals that have already been reported throughout the vapor of aerosol, which poses a hazard to public health of smokers due to various their toxicity (Nicholas et al. 2019). To warm the wick and evaporate the e-liquid, conductive wire filaments (Ni–Cr or other elements) are used. These resistive wires are often connected

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to non-resistive (sometimes Ag-coated), Cu wire extensions, and Sn the wires are attached to each other by solder joints as well as to the air tube and mouthpiece (Williams et al. 2013). In several previous studies, e-cig users have proven that it helped them reduce or even stop smoking completely and viewed as a healthier alternative to a $CC_S$ (Berg et al. 2014; Biagio et al. 2013). In recent times, it has been recorded details that e-liquids generate relatively small size (107–165 nm and 165–255 nm) (Manigrasso et al. 2015). It is essentially unsafe for finer particulate materials less than 2.5 µm in diameter (Raaschou-Nielsen et al. 2013). Small particle emissions may increase the risk of heart failure, lung cancer and asthma attacks and can interfere with lung development and function (Olmedo et al. 2018). Co-toxicity after 6 months of vaping has been identified as a cause of interstitial giant cell pneumonia (Fels Elliott et al. 2019). Owing to prolonged exposure to Co, the "cobalt lung" is known at work level to be pneumoconiosis. Zervas et al. (2014) found that many nanoparticles are formed by e-cig fluids, up to 3000 times more than found in ambient air. Laugesen (2009) discovered much smaller particles emit from e-cigs. While Ingebrethsen et al. (2012), Zhang et al. (2013), Bertholon et al. (2013), much bigger particles emit from e-cigs than in $CC_S$, and Fuoco et al. (2014) observed that e-cigs and $CC_S$ emit aerosols with similar particle sizes of fine and ultrafine vapor particles. In addition, heavy metal particles produced by e-cigs are also an important mediator of cellular oxidative stress (Chad et al. 2016). Most firms do not report e-liquid ingredients or offer documentation of protection, sound production processes and/or quality management procedures. (Brown and Cheng 2014). In addition, several tests have measured elevated levels of harmful organic and inorganic chemicals in e-cig liquid (Dunbar et al. 2018a; Kamilari et al. 2018), and aerosols (Levy et al. 2018; Mikheev et al. 2016). The presence of elements, such as As, Cr, Pb, Ni, in aerosols of e-cig is given the extreme health risks, a considerable concern, given their serious health impacts. At varying amounts, e-liquids can also contain As and other elements (Zhao et al. 2019). Zinc was significantly elevated in the e-cig users (584.5 ± 826.6 µg/g) compared with non-smokers (413.6 ± 233.7 µg/g, $p = 0.03$). Linear regression analysis showed a significant correlation between urinary zinc concentration and (8-hydroxy-2′-deoxyguanosine) 8-OHdG in the e-cig users. Pisinger et al. (2015) and Sakamaki-Ching et al. (2020) summarize the effects of the defined fluid and vapor content (glycols, nicotine, metals, dust, tobacco-specific nitrosamines). Traces of certain inorganic metals and poisonous elements such as Na, Br, Au, Sc, Fe and Co can be found in e-liquids. Long-term experiments are important to determine whether these elements are able to accumulate in the lung and cause harmful effects over exposure for a long time (Pasquale et al. 2019). In addition, heating coils are made of nichrome (a blend of Ni and Cr) and stainless steel in e-cigs. Toxic elements may be leached into vapor aerosols from heated coils (Margham et al. 2016). This is why Ni and Cr are found in e-cig aerosols, but not in e-liquids (Papaefstathiou et al. 2019; Gray et al. 2019). Although tests have shown observable element concentrations in e-liquids and aerosols, such as Al, Cr, Fe, Pb, Mn, Ni and Sn, the related vaporization hazard to health posed by these elements is not established in long-term studies (Dominic et al. 2017). The e-contribution cigs to the reflectivity of elements are not well known, particularly due to the rapidly evolving nature of devices and e-liquids (Williams et al. 2019a,b; Williams and Talbot 2019).

The objective of this review is aimed at focusing the role of various analytical techniques such as inductively coupled plasma-mass spectrometry (ICP-MS), inductively coupled plasma-optical emission spectrometry (ICP-OES), flame atomic absorption Spectroscopy (FAAS), and X-Ray Fluorescence spectroscopy (XRFS) for estimating the elements emitted from e-cigs and e-liquid, but it did not cover all available technologies that may be used in the future. As well the relationship between electronic cigarette vaping and infection with the coronavirus was also highlighted.

## Analytical methods for determination of trace and heavy metals in E-cig

### Inductively coupled plasma-mass spectrometry (ICP-MS)

ICP-MS is a technique for detect multi-elements with low concentrations of metals (µg/L- ng/L). In the first chemical composition test of e-cig cartridge fluids and aerosols developed in 2005 by Brown and Milton (2005), low concentrations of as much as 2–4 ng/L have been calculated for all e-liquid elements. In 2013, Goniewicz et al. (2014), 12 metals quantify analyzed such as Co, Ni, Cu, Zn, Cd, Pb, As, Cr, Se, Mn, Ba, Rb, Sr, Ag, Tl and V. Showed that Cd, Ni and Pb were present in all e-cig vapors excluding Cd not detected in the product. The concentration of Cd = 0.01–0.22 µg, Ni = 0.11–0.29 µg, and Pb = 0.03–0.57 µg per 150 puffs of e-cig. In Ruyan report (Laugesen 2008), nine metal cartridges have been tested for As, Sb, Cd, Cr, Co, Cu, Pb, Mn and Ni presence. The limited of detection (LOD) values for Cd below 0.01 µg/cartridge, As and Pb below 0.1 µg/cartridge, while Cr and Ni below 0.2 µg/cartridge. In a study by Ashraf et al., 22 cartomizers from a leading producer were analyzed (Ashraf 2011), he studied the concentration of Cd, and Pb in Saudi Arabia, and various cig brands are sold and/or made. He estimated the average levels of Cd = 1.81 µg/g, and Pb = 2.46 µg/g dry weight from smoking 20 cigs of one pack. Applied to vaping of e-cig samples. Cheng et al. (2014) have reported wide ranges in the levels of elements in 2014. Digested seven metals samples for Cr, Mn, Co, Ni, As, Cd and Pb are studied by (Steven et al. 2014), expressed as ng/regimen cigs smoked per sprint. In several e-liquid's, e-vapor samples, five metals quantifiable amounts of Al, Co, Mn, Ni and Pb were appeared by Saffari et al. (2014), in e-vapors, Be, Cu, Hg, V and Zn were not quantified in any collected solution. In certain e-vapors, up to 0.14 for Cd, 3.4 for Cr, and 0.47 for Sb pg/mL of puff. In the Kentucky 3R4F standard reference cigarettes, four metals quantified from 1.02 pg/mL puff for Tl to 44.98 pg/mL puff for Cd. Schober et al. (2014) analyzed the smoke of e-cig and 11 trace elements quantifiable amounts Al, Cd, Cr, Cu, Fe, Mn, Mg, Ni, Ti, V and Zn, to be between 0.3 and 667 ng $m^{-3}$. In 2015, Fernández et al. (María et al. 2015), a new approach for determining trace quantities of $Pb^{2+}$ based on rhodamine B dye fluorescent signal enhancement in e-cigs refill alternatives. Showed high sensitivity, sufficient selectivity and good foreign ion tolerance, validated with satisfactory performance. He found the LOL $= 7.4 \times 10^{-4}$–3.4 mg $L^{-1}$, LOD $= 2.2 \times 10^{-4}$ µg $L^{-1}$, LOQ $= 7.4 \times 10^{-4}$ mg $L^{-1}$. In 2016 Garat et al. (Beauval et al. 2016), he analyzed 48 trace elements e-liquids from French NHOSS® brand. Five metals were determined such as Cd, Cr, Pb, Mn and Ni were detected in all liquids analyzed by (Hess et al. 2017). He analyzed 10 cartomizer liquid, five metals were found in the e-liquids analyzed. They observed considerable variations in the concentration of Ni and Cr inside and between brands, which could come from heating elements. While Sandeep et al. (Vinit et al. 2017), referred to the previous researchers (Zhang et al. 2013; Bertholon et al. 2013; Chad et al. 2016; Bansal and Kim 2016). Garat et al. (Nicolas et al. 2017) studied and quantified 15 trace metals in a propylene glycol and glycerol blend in 2017 and subjected them to strong matrix effects in e-liquids. He found the LOD for Al = 4, As = 1, Be = 0.1, Cd = 0.4, Cr = 3.7, Co = 0.1, Cu = 20, Pb = 1, Mn = 1.6, Hg = 4, Ni = 16, Sb = 0.1, Ti = 0.1, V = 0.4 ng/L, except for Zn = 200 ng/L related to the studies submitted by Saffari et al. (2014), Ohashi et al. (Shintaro 2018) developed and validated methods for the simultaneous determination 13 components Al, As, Ag, Be, Cd, Cr, Co, Cu, Fe, Ni, Se, Sn and Pb in 2018. In addition, glycerol or 1,2-propylene glycol solutions have been used to study the matrix effects of large aerosol constituents. In Malaysia 2019, Chuo et al. (2019) analyzed heavy elements of interest HMOI in vapor. Used two types of aerosols emitted from e-cigs and 50 various brands of e-liquids. He used Cd, Ni, Pb and Cr metals. The results showed Cr was the highest median levels, current 6.86 ng/$m^3$, followed by Ni = 0.30 ng/$m^3$, Pb = 0.19 ng/$m^3$ and Cd = 0.01 ng/$m^3$. In the same year, Olmedo et al. (2018) studied the conversion of metals for Al = 16.3 and 31.2 versus 10.9; for Cr = 8.38 and 55.4 versus 0.5; for Ni = 68.4 and 233 versus 2.03; for Pb = 14.8 and 40.2 versus 0.476; and for Zn = 515 and 426 vs. 13.1. In most samples, Mn, Fe, Cu, Sb and Sn were detectable. In 0.0 percent of dispenser, 30.4 percent of aerosol, and 55.1 percent of tank samples, Cd was found in 10.7 percent of dispenser samples, arsenic was found median 26.7 µg/kg, and these concentrations were identical in aerosol and tank samples. In 2019, Pappas et al. (Naudia et al. 2019), a method for quantification of seven toxic metals like: Cr, Ni, Cu, Zn, Cd, Sn and Pb in e-cig liquids using triple quadrupole ICP-MS was developed. The LODs for Cr = 0.031, Ni = 0.032, Cu = 3.15, Zn = 1.27, Cd = 0.108, Sn = 0.099 and Pb = 0.066 µg/g. (Mark et al. 2019), determination 39 elements such as Ag, Al, As, B, Ba, Be, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hg, Ho, La, Lu, Mn, Nd, Ni, Pb, Pr, Rb, Se, Sm, Sr, Th, Ti, Tl, Tm, U, V, Yb and Zn. In kinetic energy discrimination (KED) mode, all samples were performed, using helium of elevated purity 99.999 percent as the gas collision. (Mary et al. 2019) established a clear, high metal purity, fluoropolymer trap. In conjunction with a fluoropolymer condensation trap, aerosol was produced and collected from select ENDS devices for Cr, Ni, Cu, Zn, Cd, Sn and triple quadrupole ICP-MS analysis using a typical machine regimen for puffing. Showed that the concentrations of metals varied from below the LOD to 614 ng Cu and 339 ng Zn per 10 puffs for aerosols produced under a set puffing regimen 50 puffs/collection. For all instruments tested, Cd concentrations were below LOD. System-specific Sn and Pb aerosol levels varied from below LOD to medium levels of ng. Using a typical smoking regimen, Cr and Ni were carried in aerosols at amounts equal to or significantly higher than CCs. Compared to smoke of mainstream cigs, the usually lower amounts of particular elements, Cd and Pb, carried in ENDS aerosols represent potential reductions in risk to smokers that replace the use of ENDS as cessation devices instead of CCs. Finally, a new systematic review was published in 2020 by Di Zhao et al. (Di et al. 2020) referred to the previous researchers (Goniewicz et al. 2014; Ingebrethsen et al. 2012; Dominic et al. 2017; Schober et al. 2014; Tayyarah and Long 2014; Flora et al. 2016; Beauval et al. 2017; Palazzolo et al. 2017; Song et al. 2018; Zhao et al. 2018).

## Inductively coupled plasma-optical emission spectrometry (ICP-OES)

ICP-OES is a technique for detect multi-elements in a variety of different sample matrices by with usage of plasma and a vacuum-condition spectrometer (Charles and Kenneth 2004). In 2015 by Williams et al. (Monique et al. 2015) determined the initial composition of the concentrations of Sn, Cu, Zn, Ag, Ni and Cr metals in aerosols of four various brands of e-cig and atomizer. Kim et al. (2018) (Jeffrey et al. 2017) analyzed and quantify the amounts of eight aerosol elements produced from the e-liquid reference material (RM). Eight element amounts were observed to be smaller than LOD 1 ppb when a new e-cig was used, while Pb = 0.097 ± 0.003 mg/L and Mn = 0.001 ± 0.000 mg/L were observed in aerosol after 4 months of study 20-h of cumulative use, suggesting that the metals came from e-cig and not from e-liquid. Thirty-six inorganic chemical elements and their concentrations in e-cig/e-hookah aerosols were detected and determined by Williams et al. (2017), it appears that the elements originated from filament Ni, Cr, thick-wire Ag-coated Cu, brass clamp Cu, Zn, solder joints Sn, Pb, and wick and sheath Si, $O_2$, Ca, Mg, Al. In two brands of solder and aerosol are available in the e-hs, Pb was detected up to 0.165 µg/10 puffs. In 2018, France Langevin et al. (Bertrand and Maud 2018) determined five metal concentrations such as As, Cd, Hg, Pb and Sb in two e-liquid products at the concentration levels specified in The French National Organization for Standardization (AFNOR). The LOQ in an e-liquid for As = 0.069, Cd = 0.001, Hg = 0.051, Pb = 0.032 and Sb = 0.058 ppm. The concentrations in e-cig solutions of six heavy metals (Zn, Pb, Ni, Fe, Cd and Cr) were calculated by Chae-Jin Na et al. (2019) to examine their relationship with e-cig consumption trends. Finally, a new systematic review was published in 2020 by Di Zhao et al. (2020) referred to the previous researchers (Monique et al. 2015; Williams et al. 2017).

## Flame atomic absorption spectroscopy (FAAS)

FAAS is method of analysis of the concentration of over 62 different metals in a solution, and a sensitive in the ppm range. Schober et al. (2014) studied many trace elements such as Al, Cd, Cr, Cu, Fe, Mn, Mg, Ni, Ti, V and Zn. The dry weight analyzed varied from 1.33–3.61 mg $g^{-1}$ on average, with 2.46 mg $g^{-1}$ in different brands of e-cig. In 2016, Mc Adam et al. (Flora et al. 2016), he studied 150 investigated measurements in e-cig aerosol. Hg, Cd, Pb, Se, Co, Be and Sn were not found in blank samples of either e-cig spray or air system, although Ky3R4F MSS analysis revealed that Cd, Be, Sn and emissions were undetectable. In e-cig blank samples and air/process, Cr, Ni and Sn not quantifiable emissions, but were quantifiable in Ky3R4F MSSS. E-cig emissions and vacuum air/method emissions are calculated to be 78 percent lower than these from Ky3R4F. Ni e-cig and Ky3R4F emissions were observed but not quantified, while Ni was not known from the air sample/method blank in one puff mass and was the other is not quantifiable. Prokopowicz et al. (2019) were determination blood Cd and Pb concentrations in trapped samples and e-liquids were performed by the electro-thermal atomic absorption spectrometry method. The research offers analytical evidence focused not only on the analysis of the aerosol produced, suggesting e-cig as a possible harm reduction device, in particular with respect to Cd exposure. Finally, a new systematic review was conducted by Di Zhao et al. in 2020 (2020) referred to the previous researchers (Margham et al. 2016; Lerner et al. 2015; Dunbar et al. 2018b).

## X-ray fluorescence spectroscopy (XRFS)

One of the most effective methods for detecting and quantifying heavy and trace elements is XRF analysis (Erick et al. 2013). Goniewicz et al. (2014) analyzed 12 elements, detected only Cd, Ni, Pb, and found in all vapors generated from 12 e-cigs brands. The results showed that Cd = 0.01–0.22 mg, Ni = 0.11–0.29 mg and Pb = 0.03–0.57 mg/150 puffs in the one e-cig. In 2017, Christiani et al. (Mi-Sun et al. 2017) determined the concentrations of 48 trace elements in the 11 Na to 82 Pb range of atomic numbers, Ag, Al, As, Au, Ba, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Eu, Fa, Ga, Ge, Hg, K, La, In, Mg, Mo, Na, Nb, Ni, P, Pb, Pd, Rb, S, Sb, Sc, Se, Si, Sm, Sn, Sr, Tb, Ti, V, W, Y, Zn, and Zr. Si, Cl, Ba and In were detected depending on the flavor and puffing time, while other metals were below the method's LOD. In 2018, Orkoula et al. (Eleni et al. 2018), the concentration of six heavy metals such as As, Cd, Cr, Cu, Ni and Pb was identified and determined in two sample series: A. e-liquids and B. constituents of e-liquids. The LOD was measured at 0.001 µg/g for Ni and Cu, at 0.002 µg/g for Cr, at less than 0.001 µg/g for Pb and As, and at 0.025 µg/g/g for Cd. In order to quantify the concentrations of 48 trace elements including Ag, Al, As, Au, Ba, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Eu, Fa, Ga, Ge, K, Pa, In, Mn, Mo, Na, Ni, P, Pb, Pd, Rb, S, Sb, Sc, Se, Si, Sn, Sr, Tb, Ti, Tl, V, W, Y, Zn and Zr. Christiani et al. (2017) (Mi-Sun et al. 2017), an energy-dispersive X-ray fluorescence (EDXRF) spectrometer was used. The results showed that trace elements such as Ba, Cl, In and Si depending on the flavor and buffing period, they have been found, while there were others below LOD. Trace amounts of harmful elements such as Cd, Ni and Pb have been found in e-cig emissions in previous research, but the same metals have been detected in blank samples as well (Goniewicz et al. 2014; Margham et al. 2016).

## Molecular fluorescence spectroscopy (MFS)

MF is measured by exciting the sample at the absorption wavelength, and measuring the emission at a longer wavelength. (Joseph 2010). In previous Argentinian research, Fernández group has developed alternative analytical methods to estimate traces of elements Pb, Cd and Ni in e-cig refillable solutions. In 2015, Fernández et al. (María et al. 2015) suggested a new approach for evaluating traces of $Pb^{2+}$ depending on the raise of the fluorescent signal of rhodamine-B (RhB) dye as a fluorophore reagent in coacervate phase formation using cationic surfactant acetyl trimethyl ammonium bromide (CTAB) and potassium iodine as an agent for increasing ionic strength. The process demonstrated high sensitivity, sufficient selectivity and good resistance to foreign ions. The calibration graph using zero-order regression was linear from $7.4 \times 10^{-4}$ to 3.4 µg/L, LOD = $2.2 \times 10^{-4}$ µg/L and LOQ = $7.4 \times 10^{-4}$ µg/L. A new technique for the isolation and pre-concentration of $Ni^{2+}$ and $Cd^{2+}$ in many and varied nicotine, molasses and refilling options for samples of e-cig was developed in 2017 by Fernández et al. (Talio et al. 2017), solid surface fluorescence (SSF) was calculated at $\lambda_{em} = 545$ nm ($\lambda_{ex} = 515$ nm) for the $Ni^{2+}$-$E_o$ complex, and the $Cd^{2+}$-$E_o$ fluorescence was quantified using $\lambda_{em} = 565$ nm ($\lambda_{ex} = 540$ nm) in an aqueous solution. This technique demonstrated strong sensitivity, sufficient selectivity and was successfully applied with acceptable results to the determination of trace quantities of Ni and Cd present in tobacco samples e-cig refill solutions, snuff used in narguille molasses and conventional tobacco. The calibration graphs for $Ni^{2+}$ resulted in a linear range of 0.058–29.35 µg/L and 0.124–56.20 µg/L for $Cd^{+2}$, LOD = 0.019 and 0.041 µg/L (S/N = 3). In 2019, Fernández et al. (María Carolina et al. 2019) established a new technique for evaluating Pb traces based on the quenching effect of the metal with 8-hydroxyquinoline and o-phenanthroline at $\lambda_{em} = 365$ nm ($\lambda_{exc} = 250$ nm) on fluorescent emission of the complex. This technique demonstrated good sensitivity, sufficient selectivity and strong foreign ion resistance and was extended to the assessment of trace quantities of Pb in tobacco leachate and e-cig fill solutions with appropriate outcomes. The calibration graph using zero-order regression was linear from 1.21 to 518 µg $L^{-1}$, with the correlation coefficient better than 0.999. LOD = 0.42µg $L^{-1}$, LOQ = 1.21 µg $L^{-1}$.

## Scanning electron microscopy (SEM) and electron dispersion spectroscopy (EDS)

SEM–EDS is a type of electron microscope that creates sample images by scanning the surface with a directed electron beam. (Monique et al. 2015) studied Sn, Cr, Cu, Ni, Ag and Zn quantities in the aerosol of three cartomizers from each of the sample labels used in the analysis. In general, except for Sn, concentrations were below 0.20 µg/10 puffs, and elements were not detectable in some cases. It detected only Cu and Sn. There were minimal or undetectable amounts of Ag. Zn values ranged from below the quantification mark to 0.127 µg/10 puffs. Cr and Ni were either not detected or were detected at relatively low levels. Sn was the most variable element getting comparatively low tin concentrations, range = 0 to 0.036 µg/10puffs, on average, one brand had between 100 and 1000 times as much Sn as the other three labels. Tin concentrations ranged with a high concentration of 11.3 µg/10puffs for certain cartomizers and a low concentration of 0.398 µg/10 puffs for the others. Williams et al. (2017) identified 36 inorganic chemical elements and quantities thereof in aerosols of e-cig/e-h. Filament; Ni, Cr, thick wire; Ag-coated Cu, brass clamp; Cu, Zn, solder joints; Sn, Pb, and so wick and sheath were the elements that tended to come from Al, Ca, Mg, $O_2$, and Si. In the solder and aerosol of two brands of e-hs, lead was detected, up to 0.165 µg/10 puffs. The relative abundances of elements with concentrations above 0.002 µg/10 puffs in e-cig aerosols using five brands of disposable e-cigs. The relative amounts of nine trace metals: Al, As, Cd, Cu, Fe, Mn, Ni, Pb, Zn, and for each MCE membrane. The percentages and the total numbers of carbon atoms, oxygen and nitrogen, control: $n = 9$, which are taken by Dominic et al. (2017), the volume of e-cig-generated trace metals was smaller than in the typical mainstream smoke with µg contents, and just Ni was higher in e-cig-generated aerosol than in control aerosol. Naudia et al. (2019), a validated method for quantitative analysis of toxic metals in ENDS liquids is also described. Until touching a device, refilling liquids for all metals are well below the owest reportable level (LRL). Cu and Zn were raised from devices containing brass in liquids. In all liquids, Cd was minimized LRL and has not been observed in device components. Ranged from low LRL to Cr = 0.396, Cu = 903, Ni = 4.04, Pb = 13.5, Sn = 0.898 and Zn = 454 µg/g. Williams et al. (2019a) identified eight metals periods inside various brands. Al, Cr, Co, Ni, Si, Ag, Sn, and Zn. In cartomizer and tank models, the metals used in different parts were often identical. The filaments were typically Cr and Ni nichrome, but the filament often included Fe, Cu and Mn in some newer products. The thick wire in older products was typically Ag-coated Cu, whereas the thick wire was mostly nickel in some newer products. The wick was silica in all products, and the sheaths, as available, were fiberglass Si, $O_2$, Ca, Al, Mg. Wire-to-wire joints have either been brazed or brass-clamped Cu and Zn. Particle sizes have been determined by (Steven et al. 2020), for Cr, Cu, Fe, Pb, Ni, Sn and Zn oxides. Found that the pods of both manufacturers had 80—85% Ni, and 15–20% Au, as elements of the electrical connector surface alloys. Particle sizes have been determined by Pappas et al. (2020) for Cr, Cu, Fe, Pb, Ni, Sn and Zn oxides (Steven et al. 2020). Found that the pods of both manufacturers had 80—85% Ni, and 15–20% Au, as elements of the electrical connector surface alloys.

## Mass spectrometry (MS)

The detector of MS is capable of achieving greater sensitivity and precision, allowing the qualitative and quantitative detection of detectable amounts of targeted material, but at higher costs and technological skills (Stone et al. 2008). In order to test and compare indoor emission levels of chemical species during e-cig vaping and normal cigarette smoking, Saffari et al. (2014) used a single-compartment mass balance model. Cd- and Pb-based indoor pollution concentrations during normal cigarette smoking were as elevated as 1012 ng/h for Pb and 657 ng/h for Cd, although these rates are lower by 2–3 magnitude orders for e-cig vaping. Similarly, for ordinary cigs, sulfur had an indoor pollution average of around 34 mg $h^{-1}$. For normal cigarette smoking, the indoor emission rate of all components was greater compared to e-cig vaping, with the exception of Ni, Ti, Cr and Ag. This finding indicates that while the aerosols of e-cigs contain many metals like Ag, Cr and Ni that are released from e-cig at higher concentrations. In addition, e-cig emissions of Pb were significantly reduced relative to regular cigs.

## Composition analysis, TEM images and EDX maps

By (Mark et al. 2019) characterizing both size and quantity of generated nanoparticles and their chemical compositions. The particle's TEM picture is paired with the EDX map. The maps correspond to Al, Cr, Fe, O, Mn and Si. Under each operating environment, the number of produced particles decreased dramatically within the first 15-min of each test run. Steven et al. (2020) performed a modified TEM image visual analysis, mostly displaying agglomerated individual particles rather than discrete particle images. However, for individual nanopowders, SP-ICP-MS provided the most normal size or mean size results with the use of acceptable sonic times of up to 30 min, which were very similar to the product's specified particle sizes with a few exceptions. The most common sizes (size distribution peaks) for $Cr_2O_3$ 60 nm and $Fe_2O_3$ 23 nm. After 10 min of sonication, the apparent size of the $Ni_2O_3$ particle leveled out. The most common 33 nm CuO particle size calculated by SP-ICP-MS was within the manufacturer's 25–55 nm size range. The mean particle concentrations for ZnO were low in comparison with other metal oxides, but increased by up to 10 min of sonification before decreasing. The most popular $Pb_2O_3$ particle size was 28 nm at 1 min sonic time, within the range shown by the manufacturer. For all sonic intervals above 1 min, the particle number of $Pb_2O_3$ decreased, as the limits of particle detection expanded because of dissolved background. As was the case with ZnO, until decreasing to 30 min, the most frequent and mean particle sizes increased between 1 and 15 min sonic intervals. At 10 min of sonication time, the mean very frequent particle size of $SnO_2$ was 35 nm, within the size range indicated by the maker. In 10 min, the average particle size reached a limit of 52 nm, even beyond the maker's prescribed size range. In 2016, Lerner et al. (Chad et al. 2016), using semi-quantitative methods to detect oxidant reactivity or nanoparticles, have recently been reported as components of aerosols emitted from different e-cig types and found that metal nanoparticles $TiO_2$, CuO, $Cu_{40}$, $C_{60}$ were generated at 1uM for 15 min in accordance with the manufacturing instructions (Life Technologies). In disposable ENDS/e-cig parts, batteries and cartomizers, using a fluorescein detector. The cascade particle impacter permitted the sieving of a variety of particle size distributions between 0.450 and 2.02 µm in e-cig aerosols. Cu = 120 ng, being among these particles, is 6.1 times higher per puff than previously recorded for CCs. Cu or Ti is found in e-cig aerosols. In order to decide whether these elements alone could affect mitochondrial ROS (mROS) levels, human lung fibroblasts (HFL-1) cells in culture were treated with $TiO_2$, CuO 30 nm or metallic Cu 40 and 60 nm. Shen Hu et al. (2016) also showed in 2016 that the concentration of the PNC particle number of e-cig aerosols was observed to correspond favorably with the puff duration in gas phase, whereas the PNC and size distribution will vary with various nicotine flavors and intensity. In the liquid phase, water or cell culture media, the size of e-cig nanoparticles seemed to be considerably larger than these in the gas phase, which could be due to the concentration of nanoparticles in the liquid phase. Condensation particle counter, CPC 3785, TSI Inc., Shoreview, MN, and scanning mobility particle sizer, SMPS 3080, TSI Inc., Shoreview, MN, have been tested for the accumulation of particle numbers and the scale distribution of e-cig aerosols. The SMPS sampling rate was 0.6 L $min^{-1}$, and the measuring spectrum was 7–289 nm, 100 s higher scan, 20 s lower scan. Right after each puff, the SMPS begins running. The particle measurements for each length of puff were repeated 5 times. The chamber was flushed with clean air for each measurement until the average concentration of the particles in the chamber was less than 1000 $cm^{-3}$. Silicon, iron and sodium have been contained in particles of e-cig. Also, copper was detected, though not from nanoparticles, but by the grid of TEM. TEM was used for morphology monitoring and primary size assessment of e-cig aerosol nanoparticles. EDX determined the basic structure of the e-cig aerosols. The inductively coupled plasma-optical emission spectrometry ICP-OESES is measured for the quantitative elementary analysis of e-cig aerosols.

For bio-samples, in 2020, Di et al. (2020) published a recent systematic review referred to the previous researchers, such as three studies identified metal/metalloid levels in urine in micrograms per liter (Aherrera et al. 2017; Jain 2018), in micrograms per gram of creatinine(Jain 2018; Goniewicz et al. 2018b), and among the metal/metalloid-level studies reported (Goniewicz et al. 2018b; Badea et al. 2018).

The range of aspiratory infection brought about by e-cig use (Layden et al. 2019). Examination of the gadget's e-fluid uncovered critical degrees of Co, supporting a conclusion of monster cell interstitial pneumonia related with breathed in Co from normal e-cig use. Coronavirus is causing well-being effects and disturbances internationally by Eric et al.

(2020), e-cig use may put clients at risk due to increased exposure to people with COVID-19, which may be increased by exposure to toxic substances in e-cig aerosols such as increased exposure, financial burdens, stress and health risks. The relationship among vaping and COVID-19 has created a lot of interest (Berlin et al. 2020; Batlle et al. 2020; Guo et al. 2020), on which the potential role of nicotine in treating this epidemic is discussed, which was applied to the consistent results that prove the opposite for each of Russo et al. (2020), Leung et al. (2020a) and Brake et al. (2020a), the subsequent commentary by Leung et al. (2020b), Wrapp et al. (2020), Liu et al. (2020), Gilpin et al. (2019), Miyashita et al. (2018), Atto et al. (2019), Sohal et al. (2019) and Mc Alinden et al. (2019); on a fundamental level, the theory is that the SARS-CoV-2 infection is a nicotinic specialist which rivals nicotine for the receptor, the authors conclude that nicotine is a danger factor for coronavirus. The World Health Organization had issued warning dated May 4, 2020, regarding tobacco use during this pandemic (World Health Organization 2020). Unquestionably, the dangers of critical pneumonic injury with vaping are currently very much depicted in the writing (Werner et al. 2020), and the different ways that vaping can cause cell harm and hinder the lung's reaction to contamination are unmistakably portrayed by the creators. The hypothetical chance that vaping could take action lung for SARS-CoV-2 contamination is as yet speculative, offered that to date none of the epidemiological examinations have provided details regarding vaping predominance among their coronavirus patients.

Jasmine et al. (2020) concluded that COVID-19 ARDS has more terrible results when contrasted with ARDS because of different causes, there is ongoing exploration for treatment of COVID-19-related ARDS. Vaping increases pneumococcal adherence through an expansion in platelet-initiating factor receptor articulation, at last delivering the individuals who vape with an expanded danger of pneumonia (Miyashita et al. 2018; Atto et al. 2019). Coronavirus and movement of serious pneumonia might be bound to happen in smokers, especially in those that have smoking-related comorbidities (Liu et al. 2020). It raises the worry that all electronic nicotine delivery frameworks may put clients at more serious danger of capitulating to COVID-19 (Kielan et al. 2020). Darmawan et al. (2020) examine three adolescents who presented at hospitals with respiratory distress during COVID-19. In addition to demonstrating the common clinical symptoms of these two diseases, the authors urge clinicians to advise away from e-cig use and other vaping items—as the most ideal way to prevent lung injury. This study provides an important update that young adults who smoke e-cigs may be at double the risk of developing lung infections—from COVID-19 and new items. Kale et al. (2020) wrote in their study that a big part of current vapers changed their vaping utilization since COVID-19. Although there are very few studies on vaping and the risk of COVID-19 disease, two studies reported that analyzing COVID-19 was more likely to occur among people who smoke e-cigs, confirming that they are at risk of contracting COVID-19 (Li et al. 2020; Gaiha et al. 2020).

In a new study by Farsalinos et al. (2021) (Konstantinos et al. 2021), on the prevalence of smoking with regular cigs and e-cigs among people with COVID-19 in China, this study does not consider nicotine to be a risk factor for infection with COVID-19. Rather, it considers that nicotine may have beneficial effects for eliminating COVID-19 (Li et al. 2020). There is proof that vaping impacts lung work, along these lines expanding the danger of COVID-19 contamination. Vaping items often contain nicotine and produce airborne rather than smoke (Pushalkar et al. 2020; Gotts et al. 2019), the use of vaping elements has been linked to lung damage (Brake et al. 2020b; Javelle 2020). In addition to nicotine, particulates and flavorings in e-cigs/vape sprays can likewise impair lung function (National Academies of Sciences 2018). Three review articles detailed vaping conduct that might be related to COVID-19 transmission, irrelevant to inhalation (Agency and for Health Protection and Promotion (Public Health Ontario) 2020a; Majmundar et al. 2020; Kampf et al. 2020). Vaping involves constant hand-to-mouth contact which may increase your chances of contracting COVID-19 (Agency and for Health Protection and Promotion (Public Health Ontario) 2020a; Majmundar et al. 2020). Recent information from exploratory scans tracks that the virus remains stable for a few hours to days on surfaces, making it possible to visualize transmission of infection via the surfaces of vaping devices (Agency and for Health Protection and Promotion (Public Health Ontario) 2020b). There is introductory evidence about the expected role of smoking as well as vaping on the infection and severity of COVID-19. And included investigations that showed that people who vape or smoke may be more likely to contract COVID-19 or need mechanical ventilation compared to non-smokers (Kaur et al. 2020; Munzel et al. 2020; Archie and Cucullo 2020). There is a need to establish the effect of vaping on the lungs and whether this effect increases a person's susceptibility to COVID-19 infection and the severity of COVID-19 disease (Li et al. 2020; Lancet 2020; Galo et al. 2020). No wonder there are no studies showing a dangerous effect of heavy elements in e-cigarettes on people with COVID-19. Given that e-cigs appear to be less dangerous to the vaping user. It can be used to help quit smoking.

## Conclusions

All sources indicate that an electronic cigarette is a source of toxicity for heavy metals and trace emissions from e-liquid, files or aerosols. They have no appreciable effect except as a cumulative effect over time. Because the minerals emitted from e-cigs are in very small (nanometer) concentrations and can be released in microscopic concentrations in rare cases. A variety of sophisticated techniques have been used to estimate these elements and there are still many techniques that can be used to estimate these elements. As for the studies that included the relationship between COVID-19 and vaping, they did not address the effect of heavy metals from e-cigs on infection with the coronavirus, which may be addressed in the future.

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