Journal of Elementology ISSN 1644-2296

Wojciechowska, M., Żeber-Dzikowska, I., Wojtowicz, B., Miracka, I. and Chmielewski, J. (2025) 'Anti-health behaviour of the youth: a case study of the use of e-cigarettes and electronic nicotine delivery systems', *Journal of Elementology*, 30(2), 329-342 available: https://doi.org/10.5601/jelem.2025.30.2.3527

RECEIVED: 9 April 2025
ACCEPTED: 1 May 2025

REVIEW PAPER

Anti-health behaviour of the youth: a case study of the use of e-cigarettes and electronic nicotine delivery systems*

Mariola Wojciechowska[1], Ilona Żeber-Dzikowska[1], Izabela Miracka[2], Bożena Wójtowicz[3], Jarosław Chmielewski[1]

[1] Faculty of Pedagogy and Psychology
The Jan Kochanowski University in Kielce, Poland
[2] Academy of Medical Sciences of Applied and Holistic Sciences in Warsaw, Poland
[3] Faculty of Humanities and Social Sciences
Academy of Applied Sciences in Konin
[4] Department of Public Health
Academy of Medical Sciences of Applied and Holistic Sciences in Warsaw, Poland

Abstract

Use of e-cigarettes is displacing the smoking of traditional cigarettes among adolescents and young adults. The dangers resulting from this habit are becoming even graver as the awareness of the growing scale of the problem is still neither widespread nor sufficient. Due to their attractive taste and smell as well as the accompanying high nicotine concentration, the above-mentioned products constitute an easy path to the development of addiction. Purpose of the study: The purpose of this publication is to present potential negative health effects associated with the use of e-cigarettes, as well as to organize and supplement existing knowledge with the latest research findings. Research methods: Epidemiological studies showing adverse health effects have been reviewed. Bibliometrics covering the years 2020-2024 has been used. The literature review has been conducted by searching PubMed, Scopus and Google Scholar databases. The criterion of selected subject classification entries has been applied to analyze bibliographic data. Results: The use of e-cigarettes has been found to have adverse effects primarily due to the highly addictive substance, nicotine. However, there are also numerous other substances present in e-cigarettes that may not be harmful at room temperature, but when heated, can form a toxic mixture. This can lead to direct damage to the respiratory system, including structures such as the bronchi and blood vessels. Additionally, the heating process also generates oxidative stress, resulting in the formation of large amounts of free radicals that can damage tissues and potentially contribute to the development of diseases, such as neoplasms and chronic obstructive pulmonary disease. Conclusions: It is concerning to note that the use of e-cigarette among young individuals is rising. Thorough research that takes into account the wide-ranging effects of e-cigarettes on the human body with a particular focus on minors is necessary.

Keywords: e-cigarettes, nicotine, health effects

Jarosław Chmielewski, Ph.D., Academy of Medical Sciences of Applied and Holistic Sciences, St. Kasprzaka 49, 01-234 Warsaw, Poland, e-mail: jaroslaw.chmielewski@amh.edu.pl

* Source of financing: The project is financed from the Research Fund of the Jan Kochanowski University in Kielce, which is intended to support the continuity and development of the university's scientific research.

INTRODUCTION

Undertaking risky behaviour is usually attributed to adolescents. The negative consequences of these behaviours take their toll on both an individual and his or her environment. Risky behaviours are of a more serious nature in adolescents and occur more quickly than in adults due to the unfinished biological, emotional, intellectual and social development. Examples of anti-health behaviours include the use of e-cigarettes (ECs) and electronic nicotine delivery systems (ENDs).

Data shows that smoking cigarettes among adolescents is a serious problem in many countries, including Poland. As adolescents grow up, there is a significant increase in the percentage of cigarette users. In all age groups, regardless of gender, the percentage of young people who have ever smoked e-cigarettes, as well as those who have smoked them in the last 30 days, is higher than the percentage of traditional cigarette users. According to representative epidemiological surveys, in 2022, 28.8% of Polish adults (27.1% of women and 30.8% of men) smoked tobacco (cigarettes) every day. Additionally, 4.8% of Polish adults (4% of women and 5.6% of men) reported using e-cigarettes every day, and 4% used electronic nicotine delivery systems daily (5.1% of women and 2.9% of men). In 2016, the prevalence of e-cigarette use among students in Poland ranged from 3.5% to 8.3%. However, in 2019-2020, 50% of high school students had tried e-cigarettes at least once, 29.5% had used them in the past 30 days, and 10.6% used them daily. Shockingly, for about 30% of adolescents in Poland, their first exposure to nicotine was through the use of e-cigarettes. The phenomenon of dual use, also known as the simultaneous use of a cigarette and an e-cigarette or tobacco warmer, has become a cause for concern in recent years among users of nicotine products (Zarobkiewicz et al. 2016, Brożek et al. 2017, Jankowski et al. 2022, Stoklosa et al. 2022, Świątkowska et al. 2024, Kaleta et al. 2024). Dynamics of sales of disposable, flavoured e-cigarettes in Poland from 2019 to 2022 is presented in Table 1 (IPAG 2024).

Tobacco smoke contains approximately 7,000 different chemicals, including nicotine. Among these chemicals, 93 have the potential to cause harm to the body through inhalation, ingestion, or absorption. These toxic sub-

Table 1

Dynamics of sales of disposable, flavoured e-cigarettes in Poland in the years 2019-2022

Number of pieces	2019	2020	2021	2022
	114 355	55 550	1 941 050	14 663 879
Pace of change r/r (%)		-51% Pandemic COVID-19	+3394%	+655%

The source: Compilation by the Institute for Economic Forecasting and Analysis based on data from the Ministry of Health (IPAG 2024)

stances can lead to life-threatening conditions that affect the cardiovascular, respiratory, and digestive systems. E-cigarettes or electronic nicotine delivery systems are battery-powered devices designed to vapourize a nicotine-containing solution (known as an e-liquid) for a relatively fast and efficient nicotine delivery system to the brain, which is more comparable to traditional cigarettes. However, e-liquids also contain propylene glycol (PG) and/or vegetable glycerin (VG), as well as potential additives, such as nicotine and flavors. These e-liquids may also contain small amounts of volatile organic compounds (VOCs), which have been linked to adverse health effects (Chmielewski 2020, Alshareef, Omaye 2021, Effah et al. 2022, Kim et al. 2022).

Contrary to the claims of manufacturers of e-cigarettes or electronic nicotine delivery systems, vaping exposes consumers to harmful substances. While these substances may be present in smaller amounts and lower concentrations compared to traditional tobacco smoking, they can still have negative health effects in the future. These substances include tobacco-specific nitrosamines (TSNAs), metals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), carbonyl compounds and aldehydes. Even nicotine-free vapourizers contain potentially harmful substances, such as lead, nickel, propylene glycol, and vegetable glycerin, which are the main components of e-liquid. When heated, these substances can form aldehydes that have possible acute toxic effects (Lin et al. 2019, Alshareef, Omaye 2021, Vivarelli et al. 2022, Goel et al. 2024). Studies have quantified the presence of metallic contaminants in e-liquids and e-cigarette aerosols, including lead, cadmium, chromium, cobalt, arsenic, antimony, manganese, tin, nickel, zinc, copper, aluminum, iron, tungsten and barium (Kamilari et al. 2018, Olmedo et al. 2018, Gaur et al. 2019, Zhao et al. 2019). Analysis of the chemical composition of 166 e-cigarette products, including disposable products, revealed 119 flavouring chemicals. Flavouring chemicals have been detected in at least 5% of products. The most commonly detected aromatics included 1-methylnaphthalene, 2-methylnaphthalene and isoquinoline. Detected aromatic chemicals with potential inhalation toxicity were benzyl alcohol (19.9%), benzaldehyde (21.7%) and vanillin (21.7%). Several additional potentially harmful chemicals were detected. For example, acrolein is toxic to the respiratory system, toxic to the skin and an eye irritant. Other pharmacologically active chemicals detected included nicotine N-oxide, myosmine and caffeine. Tobacco-specific nitrosamines (TSNA) were detected in 70% of the tested products (Czoli et al. 2019). The presence and amounts of identified e-cigarette components are shown in Table 2, while Table 3 presents substances identified in e-cigarette liquid samples (Chmielewski 2020).

Public perception of the use of e-cigarettes and electronic nicotine delivery systems as a safe alternative or substitute for traditional cigarette smoking has led to an increase in their popularity in the recent years, in particular among never-smokers. Data on the use of e-cigarettes and electronic nicotine delivery systems by country are very limited, especially for countries outside the EU. E-cigarettes are the most widely used tobacco product as of 2014

Table 2

The presence of tobacco-specific chemical compounds in e-cigarette aerosol, μg/intake (modified)

Identified chemicals	Electronic cigarette (aerosol)
Carbon monoxide (II)	<0.1
Total carbonyl compounds	0.5-0.9
Acetaldehyde	0.32
Acrolein	0-0.15
Total phenolic compounds	0.01-0.03
Phenol	0.0017
Total volatile compounds	0.004-0.08
Metals	0.0004-0.0006
Polycyclic aromatic amines	0.00004-0.00014
Polycyclic aromatic hydrocarbons	0.0004-0.002

The source: Chmielewski 2020

Table 3

Substances identified in EC fluid samples

RT	Name of substance (systematic and commercial)	CAS
12.35	propylene glycol	57-55-6
11.35	acetic acid	64-19-7
8.11	toluene	108-88-3
26.46	4-hydroxy-3-methoxybenzaldehyde (vanillin)	121-33-5
10.58	1-hexanol	111-27-3
10.06	1-hexyl acetate	142-92-7
8.74	isoamyl acetate	123-92-2
13.59	benzyl acetate	140-11-4
10.87	3-octanol	589-98-0
14.06	heptanoic acid	111-14-8
8.26	n-Butyl acetate	123-86-4
16.64	3-phenyl-2-propenal (cinnamaldehyde)	104-55-2
22.49	ethyl citrate	077-93-0
29.23	benzyl benzoate	120-51-4
8.81	1-butanol	71-36-3
13.24	ethyl benzoate	93-89-0

The source: Chmielewski 2020, RT – retention time of a chromatographic peak, CAS – the numerical designation assigned to a chemical substance by the U.S. Chemical Abstracts Service

among youths in the US, while electronic nicotine delivery systems are particularly appealing to adolescents and young adults. According to the National Youth Tobacco Survey (NYTS) data from the 2011-2018 U.S. survey, a signi-

ficant increase in the use of electronic nicotine delivery system products among high school students was observed; their use increased from 1.5% in 2011 to 20.8% in 2018 (estimated at 3.1 million students). In contrast, current e-cigarette use among high school students increased from 0.6% in 2011 to 4.9% in 2018 (estimated at 570,000 students). Data from the 2019 NYTS show that 27.5% of high school students (estimated at 4.1 million) admit to using e-cigarettes (Cullen et al. 2019, Gentzke et al. 2019, Wang et al. 2020). As the data show, the current use of e-cigarettes among high school students in the US declined between 2022 and 2023 (from 14.1% to 10.0%), while there was no statistically significant change among high school students (from 3.3% in 2022 to 4.6% in 2023). Despite the decline in the use of e-cigarettes among high school students, nearly 40% of high school students using e-cigarettes reported frequent use and 29.9% reported daily use. Furthermore, 550,000 high school students currently use e-cigarettes, with 20.7% reporting frequent use. Among students who reported current use of e-cigarettes, disposable ones were the most common type of the device used. Disposable e-cigarettes are gaining a larger market share; they are relatively inexpensive, have a high nicotine content and are available in flavours that appeal to the youth e.g. fruit and candy (Birdsey et al. 2023).

The Brazilian Institute of Geography and Statistics reports that according to a national survey of school-age children's health involving 159,245 Brazilian students, 16.8% of individuals aged 13 to 17 have experimented with e-cigarettes at some point, and 3.6% have used them in the past 30 days. The use of any tobacco-related products, including traditional cigarettes, vapourizers, and others, has increased among adolescents from 9% in 2015 to 12% in 2019 (Scholz et al. 2024).

There has been a noticeable rise in the use of e-cigarettes among adolescents in Canada, the United Kingdom, and Eastern and Central Europe (Brozek et al. 2019, Hammond et al. 2019, Jackson et al. 2024).

Data from the European School Survey Project on Alcohol and Other Drugs (ESPAD) indicate an increase in use of e-cigarettes in the recent years. The Health Behaviour Survey of School-Age Children (HBSC) and the Global Youth Tobacco Survey (GYTS) also confim similar trends, highlighting the increasing prevalence of the use of e-cigarettes among the youth worldwide (Mokinaro et al. 2020).

The current state of knowledge does not support the notion that e-cigarettes/electronic nicotine delivery systems are completely safe for health. There has been a significant rise in their use among both adolescents and adults worldwide. However, as most of these devices contain nicotine, they may contribute to addiction and potentially lead to smoking traditional cigarettes in the future. The use of e-cigarettes/electronic nicotine delivery systems carries a risk of toxicity, making it crucial that thorough research on their health effects will be conducted, providing relevant medical information.

MATERIAL AND METHODS

We analyzed a range of scientific content taken from PubMed, the English-language online database of the National Library of Medicine, National Institutes of Health, Bethesda, MD, USA (http://www.ncbi.nlm.nih.gov/PubMed), SCOPUS, Google Scholar, covering articles in the field of medicine, including adverse health effects of the use of e-cigarettes/electronic nicotine delivery systems. We reviewed literature published in various scientific databases between 2019 and 2024, assuming this time frame for analysis in order to include the most recent reports on this topic. Advanced search options based on keywords or combinations of keywords (Step 1, Table 3) were applied in the search process for scientific articles. Reviews, conference proceedings, letters to the editor, book chapters as well as conference and training notes have not been included in the review, and they have been excluded from the analysis.

The search was limited to literature in the English language and published with a link to full free text access.

Table 3

Step one of the analysis of the literature trends on the basis of key words

Key words	e-cigarettes, electronic nicotine delivery systems, nicotine, health, health effects

RESULTS

The conducted analysis has revealed that there are 3,106 publications in the scientific database PubMed (as of 12 December 2024) related to the use of e-cigarettes/electronic nicotine delivery systems and their health effects for the period 2019-2024. Table 4 presents a quantitative list of publications related to e-cigarettes/electronic nicotine delivery systems and their health effects for the analyzed period. A total of twenty-five papers directly related to potential health effects associated with the use of e-cigarettes/electronic nicotine delivery systems have been thoroughly analyzed, as shown in Table 5.

HEALTH RISKS

The World Health Organization (WHO) has stated that the use of e-cigarettes or electronic nicotine delivery systems is detrimental to health. They have specifically highlighted the potential for these devices to cause lung injury. A common additive in electronic nicotine delivery systems that con-

Table 4

Publications on the use of e-cigarettes/electronic nicotine delivery systems and their impact on consumer health 2019-2024

Year of publication	Number of publications based on searching by key words
	e-cigarettes, electronic nicotine delivery systems, nicotine, health, health effects
2019	393
2020	591
2021	561
2022	578
2023	493
2024	490
Results in total	**3 106**

The source: the authors, on the basis of PubMed database (http://www.ncbi.nlm.nih.gov/PubMed)

tains cannabis (or THC) is thought to have played a significant role in these cases of lung injury (WHO 2024).

Cigarette smoking is associated with chronic obstructive pulmonary disease and chronic bronchitis. Acquired ion transport abnormalities, including dysfunction of the cystic fibrosis transmembrane conductance regulator (CFTR) caused by cigarette smoking, have been identified as potential mechanisms of mucous obstruction in chronic bronchitis. E-cigarettes may induce dysfunction of ion channels in airway epithelial cells. The above is due to acrolein exposure, which is related to the onset and progression of chronic bronchitis as well as severity of chronic obstructive pulmonary disease (Lin et al. 2019).

ENDS products contain chemicals, some of which have been linked to respiratory irritation or damage, such as menthol, benzyl alcohol and corylon (Czoli et al. 2019). The heating elements and tanks of ENDS devices consist of metals that can be released into e-liquid and aerosol during use, with chromium and nickel being major contributors to cancer risk (Olmedo et al. 2018, Fowles et al. 2020). E-cigarettes emit volatile carbonyls, reactive oxygen species, furans and metals (nickel, lead, chromium), many of which are toxic to the lungs (Gotts et al. 2019). The literature reveals that e-cigarettes are associated with increased risk of cardiovascular and other diseases and mortality (Skotsimara et al. 2019, Raja et al. 2021, Zhou et al. 2024). As of 2019, there is an increase in cases of severe acute lung injury associated with the use of e-cigarettes/electronic nicotine delivery systems (Skotsimara et al. 2019, Buchanan et al. 2020).

A growing body of preclinical evidence suggests that the use of e-cigarettes/electronic nicotine delivery systems may be a risk factor for several chronic pathologies, including cancer, e-cigarettes/electronic nicotine delivery system contain the toxic metals Cd, Ni, Pb and Cr. Exposure to these metals

Table 5

Characteristics of the studies according to the prevalence of health consequences associated with the use of e-cigarettes/ electronic nicotine delivery systems

Authors of the study	Health consequences
Lin et al. 2019	Airway surface dehydration and/or inhibition of CFTR ion transport
Chung et al. 2019	Inhalation of e-cig vapour causes airway mucociliary dysfunction in vitro and in vivo
Lee et al. 2019	Flavored e-liquids and commonly used flavoring additives have been shown to impair endothelial cell function in vitro
Gaur et al. 2019	Lung, nasal and paranasal cancer
Abafalvi et al. 2019	Dry or sore mouth, tongue or throat
Abafalvi et al. 2019	Tachycardia (increased heart rate) and palpitations
Chadi et al. 2019	Jitteriness, anxiety, irritability, headache
	Lack of concentration and sleeping difficulties
	Contact dermatitis
Vindhyal et al. 2019	E-cigarette users have an over 50% higher risk of developing MI
Md Isa et al. 2019	Prominent ocular surface dryness and poor tear film quality
Gathright et al. 2020	E-cigarettes can worsen heart failure
Layden et al. 2020	Hemoptysis (coughing blood)
	Mild, nonspecific inflammation, acute diffuse alveolar damage, foamy macrophages as well as interstitial and peribronchiolar granulomatous pneumonitis
	Nausea, vomiting, diarrhea, abdominal pain
	Acute renal insufficiency
Jabba et al. 2020	Solvent adducts of reactive flavor aldehydes are cytotoxic to pulmonary epithelial cells and inhibit their mitochondrial
Kuntic et al. 2020	Oxidative stress, inflammation, increased blood pressure
Osei et al. 2020	Risk of developing symptoms of chronic obstructive pulmonary disease (COPD)
Stokes et al. 2021	Tender inflammatory response; oxidative stress
Li et al. 2021	Progression in atherosclerosis
Kligerman et al. 2021	Diffuse alveolar damage/acute lung injury
	Acute eosinophilic-like pneumonia
	Diffuse alveolar hemorrhage
Chaffee et al. 2021	Respiratory disorders, including coughing, wheezing, breathlessness, asthma and bronchitis
Rebuli et al. 2023	Lung damage
Zhang, Wen 2023	The chemicals in ENDS increase the susceptibility to tooth decay, increase the risk of periodontal disease, peri-implant, and oral mucosal lesions. Nicotine aerosols from ENDS can be a potential risk factor for oral cancer due to the presence of carcinogenic components
Soto et al. 2023	Dyspnea, cough, pleuritic chest pain, hemoptysis, nausea, vomiting, diarrhoea, abdominal pain, constitutional symptoms included headache, malaise, weight loss, fevers, chills
Lyytinen et al. 2023	The nicotine in e-cigarettes mainly impacts arterial stiffness and endothelial dysfunction markers, such as platelet activation, thrombus formation (T-TAS) and extracellular microvesicles
Siddiqi et al. 2023	Adverse cardiovascular effects, including heart rate, blood pressure and arterial stiffness
Nguyen et al. 2023	Ocular discomfort, including pain, burning, itching, redness, dryness, glare, blurriness, strain and headaches
Shehata et al. 2023	Usage of EC/ENDS contributes to lung cancer

is associated with an increased risk of malignancies (Granata et al. 2024). More than 500 chemicals have been detected in tested vapourization cartridges, and most of them have been classified as carcinogens or probable carcinogens, including formaldehyde, acrolein, acetaldehyde, metallic nanoparticles, benzene, toluene, ethylbenzene and xylene (Muthumalage et al. 2020). The health effects of exposure to Cd, Ni, Pb and Cr have been described in the literature (Boroń et al. 2018, Chmielewski et al. 2020*a-c*, Fowles et al. 2020, Mahmoud et al. 2023).

Scientific reports indicate that exposure to e-cigarettes causes a number of stress and inflammatory reactions in the pulmonary system, including shortness of breath, coughing, wheezing, bronchial and pulmonary irritation and impaired lung function. In the oral and gastrointestinal tract, e-cigarette users reported health problems related to gingivitis, sore throat, nausea, vomiting and diarrhoea. Among e-cigarette users, reactions were reported in the cardiovascular system; increased tachycardia and blood pressure were noted. In the neurological system, headaches, irritability, anxiety, dependence and insomnia were observed. Other effects included eye irritation, contact dermatitis, acute renal failure, toxicity and potential carcinogenicity (Seiler-Ramadas et al. 2021).

Health consequences associated with the use of e-cigarettes/electronic nicotine delivery systems are shown in Table 5.

CONCLUSIONS

The rapid growth of sales of e-cigarettes/electronic nicotine delivery systems is making these products an increasingly significant public health and educational challenge. The risks involved are greater as the awareness of the growing scale of the problem is still neither widespread nor sufficient.

Based on the cited studies, contrary to advertisers' claims, it is clear that e-cigarettes/electronic nicotine delivery systems are not safe products. Available scientific evidence confirms that the use of e-cigarettes/electronic nicotine delivery systems is not without risk of harm. A dramatic increase in prevalence of e-cigarettes/electronic nicotine delivery systems worldwide among both adolescents and adults is evident. E-cigarettes/electronic nicotine delivery systems attract consumers with their modern design and wide range of flavourings and fragrances. Flavours in e-liquids as well as substances created during the use of e-cigarettes/electronic nicotine delivery systems can cause adverse health effects.

The most important aim of the education of e-cigarette/electronic nicotine delivery system users about the harms of nicotine addiction is to strengthen their motivation to stop using nicotine products. Stricter public health policies are required to reduce the exposure of adolescents and young

adults to the use of e-cigarettes/electronic nicotine delivery systems. Educational campaigns are necessary in the public space regarding the effects of nicotine addiction and the use of nicotine products, with a focus on e-cigarettes/electronic nicotine delivery systems. To build awareness of the harmfulness of the use of e-cigarettes/electronic nicotine delivery systems, schools at the primary and secondary levels should be involved. Intensifying the educational impact on young people for building pro-healthy behaviour and at the same time pro-healthy lifestyles is becoming a serious scientific challenge. Thus, there is a need to conduct an in-depth analysis of individual factors (sociodemographic, social and cultural ones) conducive to the use of e-cigarettes/electronic nicotine delivery systems, which will provide a basis for determination of the support and assistance in building health-promoting behaviour.

Author contributions

M.W., J.C. – designed research, M.W., J.C., I.Ż.D., I.M., B.W. – analyzed data, and wrote the manuscript. All authors have read and approved the manuscript.

Conflicts of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The present research did not receive any specific donation from any funding agency in the public, commercial or non-profit sector. Artificial intelligence (AI) has not been used in the creation of the paper.

REFERENCES

Abafalvi, L., Pénzes, M., Urbán, R., Foley, K.L., Kaán, R., Kispélyi, B., Hermann, P. (2019) Perceived health effects of vaping among Hungarian adult e-cigarette-only and dual users: a cross-sectional internet survey, *BMC Public Health*, 13;19(1), 302, available: https://doi.org/10.1186/s12889-019-6629-0

Alshareef, H.Z., Omaye, S.T. (2021) Toxicology of Commonly Found Ingredients in E-Cigarettes: A Brief Review, *Health*, 13, 1396-1409, available: https://doi.org/10.4236/health.2021.1311100

Birdsey, J., Cornelius, M., Jamal, A., Park-Lee, E., Cooper, M.R., Wang, J., Sawdey, M.D., Cullen, K.A., Linda Neff, L. (2023) Tobacco Product Use Among U.S. Middle and High School Students – National Youth Tobacco Survey, MMWR Morb Mortal Wkly Rep, 72, 1173-1182, available: http://dx.doi.org/10.15585/mmwr.mm7244a1

Boroń, M., Dobrakowski, M., Chmielewski, J., Gworek, B., Korzonek-Szlacheta, I., Kieltucki, J., Szpringer, M., Kasperczyk, S. (2018) Health aspects of an acute exposure to lead, *Przemysł Chemiczny*, 97(4), 618-623, available: http://dx.doi.org/10.15199/62.2018.4.22

Brożek, G.M., Jankowski, M., Lawson, J.A., Shpakou, A., Poznański, M., Zielonka, T.M., Klimatckaia, L., Loginovich, Y., Rachel, M., Gereová, J., Golonko, J., Naumau, I., Kornicki, K., Pepłowska, P., Kovalevskiy, V., Raskiliene, A., Bielewicz, K., Krištúfková, Z., Mróz, R., Zejda, J.E. (2019) The Prevalence of Cigarette and E-cigarette Smoking Among Students in Central and Eastern Europe-Results of the YUPESS Study, *International Journal of Environmental Research and Public Health*, 16(13), 2297, available: https://doi.org/10.3390/ijerph16132297

Brożek, G., Jankowski, M., Zejda, J., Jarosińska, A., Idzik, A., Bańka, P. (2017) E-smoking among students of medicine – frequency, pattern and motivations, *Adv Respir Med*, 85(1), 8-14, available: http://dx.doi.org/10.5603/ARM.2017.0003

Buchanan, N.D., Grimmer, J.A., Tanwar, V.,,Schwieterman, N., Mohler, P.J., Wold, L.E. (2020) Cardiovascular Risk of Electronic Cigarettes: A Review of Preclinical and Clinical Studies, *Cardiovasc Res*, 116(1), 40-50, available: http://dx.doi.org/10.1093/cvr/cvz256

Chadi, N., Belanger, R.E. Teen vaping: There is no vapour without fire. (2019) P*aediatr Child Health*, 25(6), 337-339, available: http://dx.doi.org/10.1093/pch/pxz137

Chaffee, B.W., Barrington-Trimis, J., Liu, F., Wu, R., McConnell, R., Krishnan-Sarin, S., Leventhal, A.M., Kong, G. (2021) E-cigarette use and adverse respiratory symptoms among adolescents and Young adults in the United States, Prev Med, 153, 106766. available: http://doi.org/10.1016/j.ypmed.2021.106766

Chmielewski, J. (2020) Chemical compounds in e-cigarettes and their impact on human health, *Przemysł Chemiczny*, 99(5), 756-760, available: http://doi.org/10.15199/62.2020.5.15

Chmielewski, J., Nowak-Starz, G., Rutkowski, A., Bartyzel, M., Czarny-Działak, M., Gworek, B., Król, H., Łuszczki, J.J., Szpringer, M. (2020a) Occupational exposure to carcinogens and mutagens in the work environment, *Przemysł Chemiczny*, 99(3), 397-405, available: http://doi.org/10.15199/62.2020.3.8

Chmielewski, J., Gworek, B., Florek-Łuszczki, M., Nowak-Starz, G., Wójtowicz, B., Wójcik, T., Żeber-Dzikowska, I., Strzelecka, A., Szpringer, M. (2020b) Heavy metals in the environment and their impact on human health, *Przemysł Chemiczny*, 99(1), 50-57, available: http://doi.org/10.15199/62.2020.1.3

Chmielewski, J., Szpringer, M., Łuszczki, J.J., Czarny-Dzialak, M., Dutkiewicz, E., Zieba, E., Nowak-Starz, G. (2020c) Occupational and environmental exposure to substances and chemical mixtures that are toxic to human reproduction, *Przemysł Chemiczny*, 99(6), 865-874, available: http://doi.org/ 10.15199/62.2020.6.7

Chung, S., Baumlin, N., Dennis, J.S., Moore, R., Salathe, S.F., Whitney, P.L., Salathe, M. (2019) Electronic cigarette vapor with nicotine causes airway mucociliary dysfunction preferentially via TRPA1 receptors. *American journal of respiratory and critical care medicine*, 200(9), 1134-1145, available: https://doi.org/10.1164/rccm.201811-2087OC

Cullen, K.A., Gentzke, A.S., Sawdey, M.D., Chang, J.T., Anic, G.M., Wang, T.W., Creamer, M.R., Jamal, A., Ambrose, B.K., King, B.A. (2019) E-cigarette use among youth in the United States, *JAMA*, 322, 2095-2103, available: http://dx.doi.org/10.1001/jama.2019.18387

Czoli, C.D., Goniewicz, M.L., Palumbo, M., Leigh, N., White, C.M., Hammond, D. (2019) Identification of flavouring chemicals and potential toxicants in e-cigarette products in Ontario, Canada, *Can J Public Health*, 110(5), 542-550, available: http://dx.doi.org/10.17269/s41997-019-00208-1

Effah, F., Taiwo, B., Baines, D., Bailey, A., Marczylo, T. (2022) Pulmonary effects of e-liquid flavors: a systematic review, *Journal of Toxicology and Environmental Health, Part B,* 25(7), 343-371, available: https://doi.org/10.1080/10937404.2022.2124563

Fowles, J., Barreau, T., Wu, N. (2020) Cancer and Non-Cancer Risk Concerns from Metals in Electronic Cigarette Liquids and Aerosols, *International Journal of Environmental Research and Public Health*, 17(6), 2146, https://doi.org/10.3390/ijerph17062146

Gathright, E.C., Wu, W.C., Scott-Sheldon, L.A.J. (2020) Electronic cigarette use among heart failure patients: findings from the population assessment of tobacco and health study (Wave 1: 2013-2014). *Heart Lung*, 49(3), 229-232, available: https://doi.org/10.1016/j.hrtlng.2019.11.006

Gaur, S., Agnihotri, R. (2029) Health Effects of Trace Metals in Electronic Cigarette Aerosols-a Systematic Review, *Biol Trace Elem Res*, 188(2), 295-315, available: https://doi.org/10.1007/s12011-018-1423-x

Gentzke, A.S., Creamer, M., Cullen, K.A., Ambrose, B.K., Willis, G., Jamal, A., King, B.A. (2019) Vital signs: tobacco product use among middle and high school students – United States, 2011-2018, *MMWR Morb Mortal Wkly Rep*, 68, 157-164. available: https://doi.org/10.15585/mmwr.mm6806e1

Goel, S., Shabil, M., Kaur, J., Chauhan,A., Rinkoo, A.V. (2024) Safety, efficacy and health impact of electronic nicotine delivery systems (ENDS): an umbrella review protocol, *BMJ*. 14, e080274, available: https://doi.org/10.1136/bmjopen-2023-080274

Gotts, J.E., Jordt, S.E., McConnell, R., Tarran, R. (2019) What are the respiratory effects of e-cigarettes? *BMJ*, 366,l5275, available: https://doi.org/10.1136/bmj.l5275

Granata, S., Vivarelli, F., Morosini, C., Canistro, D., Paolini, M., Fairclough, L.C. (2024) Toxicological Aspects Associated with Consumption from Electronic Nicotine Delivery System (ENDS): Focus on Heavy Metals Exposure and Cancer Risk, *International Journal of Molecular Sciences*, 25(5), 2737, available: https://doi.org/10.3390/ijms25052737

Hammond, D., Reid, J.L., Rynard, V.L., Fong, G.T., Cummings, K.M., McNeill, A., Hitchman, S., Thrasher, J.F., Goniewicz, M.L., Bansal-Travers, M., O'Connor, R., Levy, D., Borland, R., White, C.M. (2019) Prevalence of vaping and smoking among adolescents in Canada, England, and the United States: repeat national cross sectional surveys, *BMJ*. 365, l2219, available: https://doi.org/10.1136/bmj.l2219

IPAG. Rynek jednorazowych e-papierosów w Polsce 2024. https://www.ipag.org.pl/Content/Uploaded/files/2024_02_01_Raport_IPAG_e-papierosy.pdf

Jabba, S.V., Diaz, A,N., Erythropel, H.C,, Zimmerman, J.B., Jordt, S.E. (2020) Chemical Adducts of Reactive Flavor Aldehydes Formed in E-Cigarette Liquids Are Cytotoxic and Inhibit Mitochondrial Function in Respiratory Epithelial Cells, *Nicotine Tob Res*, 22(Suppl 1), S25-S34, available: https://doi.org/10.1093/ntr/ntaa185

Jackson, S.E., Tattan-Birch, H., Shahab, L., Brown, J. (2024) Trends in long term vaping among adults in England, 2013-23: population based study, *BMJ*, 386, available: https://doi.org/10.1136/bmj-2023-079016

Jankowski, M., Ostrowska, A., Sierpiński, R., Skowron, A., Sytnik-Czetwertyński, J., Giermaziak, W., Gujski, M., Wierzba, W., Pinkas, J. (2022) The Prevalence of Tobacco, Heated Tobacco, and E-Cigarette Use in Poland: A 2022 Web-Based Cross-Sectional Survey, *Int J Environ Res Public Health*, 19(8), 4904, available: https://doi.org/10.3390/ijerph19084904

Kaleta, D., Świątkowska, B., Szulc, M., Wojtysiak, P., Jankowski, M.(2024) Anti-smoking intervention, e-cigarettes, and heated tobacco products – what to remember? Recommendations for doctors who have direct contact with nicotine-addicted patients regarding anti-smoking intervention, *Med Og Nauk Zdr*, 30(2), 81-86. available: https://doi.org/10.26444/monz/189601

Kamilari, E., Farsalinos, K., Poulas, K., Kontoyannis, C.G., Orkoula, M.G. (2018) Detection and quantitative determination of heavy metals in electronic cigarette refill liquids using Total Reflection X-ray Fluorescence Spectrometry, *Food and chemical toxicology*, 116, 233-237, available: https://doi.org/10.1016/j.fct.2018.04.035

Kim, Y.Y., Kim, M.K., Shin, H.S. (2022) Determination of volatile organic compounds(VOCs) levels from various smoking cessation aids by using gas chromatography-mass spectrometry methodology, *J. Toxicol. Environ. Health Part A*. 85(3), 110-120, available: https://doi.org/10.1080/15287394.2021.1979436

Kuntic, M., Oelze, M., Steven, S., Kröller-Schön, S., Stamm, P., Kalinovic, S., Frenis, K., Vujacic-Mirski, K., Bayo Jimenez, M.T., Kvandova, M., Filippou, K., Al Zuabi, A., Brückl, V., Hahad, O., Daub, S., Varveri, F., Gori, T., Huesmann, R., Hoffmann, T., Schmidt, F.P., Keaney, J.F., Daiber, A., Münzel, T. (2020) Short-term e-cigarette vapour exposure causes vascular oxidative stress and dysfunction: evidence for a close connection to brain damage and a key role of the phagocytic NADPH oxidase (NOX-2), *Eur Heart J,* 41(26), 2472-2483, available: https://doi.org/10.1093/eurheartj/ehz772

Layden, J.E., Ghinai, I., Pray, I., Kimball, A., Layer, M., Tenforde, M.W., Navon, L., Hoots, B., Salvatore, P.P,, Elderbrook, M., Haupt, T., Kanne. J., Patel, M.T., Saathoff-Huber, L., King, B.A., Schier, J.G/, Mikosz, C.A., Meiman, J. (2020) Pulmonary Illness Related to E-Cigarette Use in Illinois and Wisconsin - Final Report, *N Engl J Med*, 382(10), 903-916, available: https://doi.org/10.1056/NEJMoa1911614

Lee, W.H., Ong, S.G., Zhou, Y., Tian, L., Bae, H.R., Baker, N., Whitlatch, A., Mohammadi, L.,

Guo, H., Nadeau, K.C., Springer, M.L., Schick, S.F., Bhatnagar, A., Wu, J.C. (2019) Modeling cardiovascular risks of e-cigarettes with human-induced pluripotent stem cell-derived endothelial cells, *J Am Coll Cardiol*, 73, 2722-2737, available: https://doi.org/10.1016/j.jacc.2019.03.476

Li, J., Huynh. L., Cornwell, W.D., Tang, M.S., Simborio, H., Huang, J., Kosmider, B., Rogers, T.J., Zhao, H., Steinberg, M.B., Le, L.T.T., Pham, K., Liu, C., Wang, H. (2021) Electronic cigarettes induce mitochondrial DNA damage and trigger TLR9 (Toll-like receptor 9)-mediated atherosclerosis, *Arterioscler Thromb Vasc Biol*, 41(2), 839-853, available: https://doi.org/10.1161/ATVBAHA.120.315556

Lin, V.Y., Fain, M.D., Jackson, P.L., Berryhill, T.F., Wilson, L.S., Mazur, M., Barnes, S.J., Blalock, J.E., Raju, S.V., Rowe, S.M. (2019) Vaporized E-Cigarette Liquids Induce Ion Transport Dysfunction in Airway Epithelia, *Am J Respir Cell Mol Biol*, 61(2), 162-173, available: https://doi.org/10.1165/rcmb.2017-0432OC

Lyytinen, G., Brynedal, A., Anesäter, E., Antoniewicz, L., Blomberg, A., Wallén, H., Bosson, J.A., Hedman, L., Mobarrez, F., Tehrani, S., Lundbäck, M. (2023) Electronic Cigarette Vaping with Nicotine Causes Increased Thrombogenicity and Impaired Microvascular Function in Healthy Volunteers: A Randomised Clinical Trial, *Cardiovasc Toxicol*, 23(7-8), 255-264, available: https://doi.org/10.1007/s12012-023-09802-9

Mahmoud, N., Al-Shahwani, D., Al-Thani, H., Isaifan, R.J. (2023) Risk Assessment of the Impact of Heavy Metals in Urban Traffic Dust on Human Health, *Atmosphere*, 14(6), 1049, available: https://doi.org/10.3390/atmos14061049

Md Isa, N.A,, Koh, P.Y., Doraj P. (2019) The tear function in electronic cigarette smokers, *Optom Vis Sci*, 96(9), 678-685, available: https://doi.org/10.1097/OPX.0000000000001422

Mokinaro, S., Vincente, J., Benedetti, E., Cerrai, S., Colasante, E., Arpa, S., Skarupova, K. (2020) ESPAD Report 2019 Results from the European School Survey Project on Alcohol and Other Drugs. Luxembourg: Publications Office of the European Union, available: https://doi.org/10.2810/877033

Olmedo, P., Goessler, W., Tanda, S., Grau-Perez, M., Jarmul, S., Aherrera, A., Chen, R., Hilpert, M., Cohen, J.E., Navas-Acien, A., Rule, A.M. (2018) Metal Concentrations in e-Cigarette Liquid and Aerosol Samples: The Contribution of Metallic Coils, *Environ Health Perspect*, 126(2), 027010, available: https://doi.org/10.1289/EHP2175

Osei, A.D, Mirbolouk, M., Orimoloye, O.A., Dzaye, O., Uddin S.M.I., Benjamin, E.J., Hall, M.E., DeFilippis, A.P., Bhatnagar, A., Biswal, S.S., Blaha, M.J. (2020) Association between E-cigarette use and chronic obstructive pulmonary disease by smoking status: behavioral risk factor surveillance system 2016 and 2017, *Am J Prev Med*, 58(3), 336-342, available: https://doi.org/10.1016/j.amepre.2019.10.014

Raja, J., Khouzam, A., Khouzam. N., Khouzam, R.N. (2021) Smoke and Heart Should Stay Apart: A Look at E Cigarettes and Other Alternatives to Conventional Cigarettes, and Their Impact on Cardiovascular Health, *Curr Probl Cardiol*, 46(3), 100640, available: https://doi.org/10.1016/j.cpcardiol.2020.100640

Rebuli, M.E., Rose, J.J., Noël, A., Croft, D.P., Benowitz, N.L., Cohen, A.H., Goniewicz, M.L., Larsen, B.T., Leigh, N., McGraw, M.D., Melzer, A.C., Penn, A.L., Rahman, I., Upson, D., Crotty, A.L.E., Ewart, G., Jaspers, I., Jordt, S.E., Kligerman, S., Loughlin. C.E., McConnell, R., Neptune, E.R., Nguyen, T.B., Pinkerton, K.E., Witek, T.J.Jr. (2023) The E-cigarette or Vaping Product Use-Associated Lung Injury Epidemic: Pathogenesis, Management, and Future Directions: An Official American Thoracic Society Workshop Report, Ann Am Thorac Soc, 20(1), 1-17, available: https://doi.org/10.1513/AnnalsATS.202209-796ST

Scholz, J.R., Malta, D.C., Fagundes Júnior, A.A.D.P., Pavanello, R., Bredt Júnior, G.L., Rocha, M.D.S. (2024) Brazilian Society of Cardiology Position Statement on the Use of Electronic Nicotine Delivery Systems-2024, *Arquivos Brasileiros de Cardiologia*, 121, e20240063, available: https://doi.org/10.36660/abc.20240063

Seiler-Ramadas, R., Sandner, I., Haider, S., Grabovac, I., Dorner, T.E. (2021) Health effects of electronic cigarette (e-cigarette) use on organ systems and its implications for public health, *Wien Klin Wochenschr*, 133(19-20), 1020-1027, https://doi.org/10.1007/s00508-020-01711-z

Shehata, S.A., Toraih, E.A., Ismail, E.A., Hagras, A.M., Elmorsy, E., Fawzy, M.S. (2023) Vaping, Environmental Toxicants Exposure, and Lung Cancer Risk, *Cancers*, 15(18), 4525, available: https://doi.org/10.3390/cancers15184525

Siddiqi, T.J., Rashid, A.M., Siddiqi, A.K., Anwer, A., Usman, MS, Sakhi, H., Hall, M.E. (2023) Association of Electronic Cigarette Exposure on cardiovascular health: a systematic review and meta-analysis, *Curr Probl Cardiol*, 48(9), 101748, available: https://doi.org/10.1016/j.cpcardiol.2023.101748

Skotsimara, G., Antonopoulos, A.S., Oikonomou, E., Siasos, G., Ioakeimidis, N., Tsalamandris, S., Charalambous, G., Galiatsatos, N., Vlachopoulos, C., Tousoulis, D. (2019) Cardiovascular effects of electronic cigarettes: A systematic review and meta-analysis, *Eur J Prev Cardiol*, 26(11), 1219-1228, available: https://doi.org/10.1177/2047487319832975

Stokes, A.C., Xie, W., Wilson, A.E., Yang, H., Orimoloye, O.A., Harlow, A.F., Fetterman, J.L., Blaha, M.J., DeFilippis, A.P., Emelia J. Benjamin, E.J., Robertson, R.M., Bhatnagar, A., Hamburg, N.M. (2021) Association of cigarette and electronic cigarette use patterns with levels of inflammatory and oxidative stress biomarkers among US adults: Population Assessment of Tobacco and Health Study, *Circulation*, 143(8), 869-871, available: https://doi.org/10.1161/CIRCULATIONAHA.120.051551

Stoklosa, M., Pogorzelczyk, K., Balwicki, Ł. (2022) Cigarette price increases, advertising ban, and pictorial warnings as determinants of youth smoking initiation in Poland, *Nicotine and Tobacco Research*, 24(6), 820-825, available: https://doi.org/10.1093/ntr/ntab262

Soto, B., Costanzo, L., Puskoor, A., Akkari, N., Geraghty, P. (2023) The implications of Vitamin E acetate in E-cigarette, or vaping, product use-associated lung injury, *Ann Thorac Med*, 18(1), 1-9, available: https://doi.org/10.4103/atm.atm_144_22

Świątkowska, B., Zajdel, R., Balwicki, Ł., Kaleta, D. (2023) Is e-cigarette advertising associated with e-cigarette use among young people? New survey evidence from Poland. *Frontiers in Public Healt,* 12, 1448011, available: https://doi.org/10.3389/fpubh.2024.1448011

Vindhyal, M.R., Ndunda, P., Munguti, C., Vindhyal, S., Okut, H. (2019) Impact on cardiovascular outcomes among e-cigarette users: a review from National Health Interview Surveys, J Am Coll Cardiol, 73, 11, available: https://doi.org/10.1016/S0735-1097(19)33773-8

Vivarelli, F., Granata, S., Rullo, L., Mussoni, M., Candeletti, S., Romualdi, P., Canistro, D. (2022) On the toxicity of e-cigarettes consumption: Focus on pathological cellular mechanisms, *Pharmacological Research*, 182, 106315. available: https://doi.org/10.1016/j.phrs.2022.106315

Wang, T.W., Neff, L.J., Park-Lee, E., Ren, C., Cullen, K.A., King, B.A. (2020) E-cigarette Use Among Middle and High School Students - United States, 2020. *MMWR Morb Mortal Wkly Rep*, 69, 1310-1312, available: http://doi.org/10.15585/mmwr.mm6937e1

World Health Organization. Tobacco: E-cigarettes. 2024. https://www.who.int/news-room/questions-and-answers/item/tobacco-e-cigarettes (access: 2024.12.11)

Zhao, D., Navas-Acien, A., Ilievski, V., Slavkovich, V., Olmedo, P., Adria-Mora, B., Hilpert, M. (2019) Metal concentrations in electronic cigarette aerosol: Effect of open-system and closed-system devices and power settings. Environmental research. 2019; 174, 125-134. available: https://doi.org/10.1016/j.envres.2019.04.003

Zhang, Q., Wen, C. (2023) The risk profile of electronic nicotine delivery systems, compared to traditional cigarettes, on oral disease: a review, *Front Public Health*, 11, 1146949, available: https://doi.org/10.3389/fpubh.2023.1146949

Zhou, S.Y., Du, J.M., Li, W.J., Liu, Q.Y., Zhang, Q.Y., Su, G.H., Li, Y. (2024) The roles and regulatory mechanisms of cigarette smoke constituents in vascular remodeling. *International Immunopharmacology*, 140, 112784, available: https://doi.org/10.1016/j.intimp.2024.112784