

**BIAŁOGŁOWSKI, Konrad, GIŻEWSKA, Kamila, BOCHYŃSKI, Karol, DACKA, Michał, DĄBROWSKA, Paulina, ŻUBER, Michał, MOLENDĄ, Katarzyna, BORODZIUK, Barbara, BORODZIUK, Filip and CIUBA, Katarzyna. Electronic cigarettes - harmful substances contained in e-cigarette liquids and smoke. Quality in Sport. 2024;16:52716. eISSN 2450-3118.**

<https://dx.doi.org/10.12775/QS.2024.16.52716>

<https://apcz.umk.pl/QS/article/view/52716>

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.

Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).

Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.

Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

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The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 17.06.2024. Revised: 10.07.2024. Accepted: 10.07.2024. Published: 13.07.2024.

## **Electronic cigarettes - harmful substances contained in e-cigarette liquids and smoke**

### **1. Konrad Białogłowski**

University Clinical Hospital No. 1 in Lublin

ul. Stanisława Staszica 16, 20-081 Lublin, Poland

konrad.bialogłowski@gmail.com

<https://orcid.org/0009-0001-1705-254X>

### **2. Kamila Giżewska**

1 Military Clinical Hospital in Lublin

al. Raławickie 23, 20-049 Lublin, Poland

gizewska.kamila@gmail.com

<https://orcid.org/0000-0003-1682-180X>

### **3. Karol Bochyński**

4th Clinical University Hospital in Lublin

ul. Kazimierza Jaczewskiego 8, 20-954 Lublin, Poland

karolbochynski@gmail.com

<https://orcid.org/0009-0003-8309-2800>

4. Michał Dacka  
1 Military Clinical Hospital in Lublin  
al. Raławickie 23, 20-049 Lublin, Poland  
michal.dackaa@gmail.com  
<https://orcid.org/0009-0005-8783-6517>
  
5. Paulina Dąbrowska  
Province Specialist Hospital named after Stefan Cardinal Wyszyński in Lublin  
Kraśnicka 100, 20-718 Lublin, Poland  
paulina.dabrowska98@gmail.com  
<https://orcid.org/0009-0004-6439-3357>
  
6. Michał Żuber  
4th Clinical University Hospital in Lublin  
ul. Kazimierza Jaczewskiego 8, 20-954 Lublin, Poland  
michal.zuber10@gmail.com  
<https://orcid.org/0009-0000-2538-8556>
  
7. Katarzyna Molenda  
1 Military Clinical Hospital in Lublin  
al. Raławickie 23, 20-049 Lublin, Poland  
zielinskakasia98@gmail.com  
<https://orcid.org/0009-0005-1928-4220>
  
8. Barbara Borodziuk  
1 Military Clinical Hospital in Lublin  
al. Raławickie 23, 20-049 Lublin, Poland  
basia.borodziuk@gmail.com  
<https://orcid.org/0009-0009-2716-6653>
  
9. Filip Borodziuk  
1 Military Clinical Hospital in Lublin

al. Raławickie 23, 20-049 Lublin, Poland  
filipb899@gmail.com  
<https://orcid.org/0009-0000-0394-1816>

10. Katarzyna Ciuba

Province Specialist Hospital named after Stefan Cardinal Wyszyński in Lublin  
al. Kraśnicka 100, 20-718 Lublin, Poland  
katarzyna.ciuba@onet.eu  
<https://orcid.org/0009-0007-8347-3282>

## **Abstract**

Electronic cigarettes and electronic cigarette liquids are increasingly popular in society, especially among young people. However, despite the widespread belief that they are a safe alternative to traditional cigarettes, many scientific studies confirm that electronic cigarettes can be equally, if not more, harmful to health.

There are many chemicals in electronic cigarette liquids, such as nicotine, propylene glycol, glycerol, flavors and fragrances. Some of these substances are toxic and can cause a number of negative health effects, such as irritation of the respiratory tract, the onset of lung disease, neurological disorders and increased risk of cardiovascular disease.

In addition, electronic cigarettes can be harmful to the environment due to the emission of toxic substances into the air and improper disposal of used batteries.

Therefore, an informed approach to the use of electronic cigarettes and an understanding of the potential health risks associated with them is necessary. Further scientific research and education of the public about the harms of electronic cigarettes are key to preventing the negative consequences associated with their use.

## **1. What are electronic cigarettes?**

An electronic cigarette (e-cigarette) is an electronic device that works by heating a liquid containing flavoring, propylene glycol or vegetable glycerin, and possibly nicotine. The user inhales the vapor created from the heated liquid to simulate smoking traditional cigarettes. Their design includes: most often a built-in battery, a tank for the liquid, an atomizer and, in addition, electronic components often allowing control of the temperature of the heater, or the flow of vapor produced [1].

The idea of an electronic cigarette dates back to the 1960s, but the first patent for a modern e-cigarette was registered in China in 2003 by Hon Lik [2] [3]. Since then, the e-cigarette market has begun to grow and evolve rapidly, becoming an alternative to traditional cigarettes.

Electronic cigarettes have grown in popularity mainly in the last decade, thanks to increased awareness of the harms of smoking traditional cigarettes and the healthy lifestyle trend [4]. E-cigarettes offer an alternative form of nicotine delivery without producing smoke, which has contributed to their popularity among those focused on reducing the health harms associated with smoking.

## **2. Substances contained in e-cigarettes and their effects on health**

The composition of e-cigarette liquid can vary greatly, as there are many different flavors, manufacturers and types of liquid available on the market. Depending on the flavor and manufacturer, the composition of the liquid can vary in the amount of substances present in the liquid. An additional problem is, the formation of new chemicals with different properties when heating the liquid, so the "composition of electronic cigarettes" should be considered in two ways: the composition of the e-cigarette liquid and the composition of the resulting aerosol after heating. Other things that can affect the substances produced during heating include the way the e-cigarette is used, the used heating element, the modification of the e-cigarette by the user, such as increasing the power of the heating element.

Based on a study of 54 different liquids, from different manufacturers by Jürgen Hahn et al, we can conclude that the main ingredients that are present in most e-cigarette liquids are: propylene glycol (propane-1,2-diol), glycerol, nicotine and flavorings. Substances that may be present in smaller amounts are: ethylene glycol, propane-1,3-diol, ethylvanillin, thujone [5]. Of course, these are compounds contained in liquid that has not been heated. According to a study by Herrington and Myers (2015), 18 new substances were created during the heating process in addition to the products contained in the fluid itself [6].

In summary - the substances that are contained in the liquid and in the aerosol are nicotine, propylene glycol, glycerol, flavorings, ethylene glycol, propane-1,3-diol, ethylvanillin, thujone, aldehydes, metals, volatile organic compounds, phenols, tobacco-specific nitrosamines (TSNA), tobacco alkaloids, and dozens of other substances whose health effects in this form have not been studied [5] [6] [7]. The health effects of the most important components of e-cigarettes will be presented below.

## **2.1. Propylene glycol**

Propylene glycol (propane-1,2-diol) is an organic chemical compound from the dihydroxy alcohol group. It is a colorless, odorless, oily liquid. It is used extensively in the pharmaceutical, cosmetic and food industries as a humectant, as a flavor carrier or as a solvent for dyes. Propylene glycol is also used in medicine as a solvent for medicinal substances administered orally and even those administered intravenously. So it would seem to be a relatively safe substance. That's what the Food and Drug Administration (FDA) said in 1973, recognizing propylene glycol as a safe substance (GRAS) [8][9]. GRAS substances are considered safe in the food and medical industries, but not necessarily safe during long-term effects on humans by inhalation.

Some e-cigarette users complain of dry mouth and nasal mucous membranes, which may be related to the properties of propylene glycol. This also seems to be supported by a study by Moline JM et al. and Wieslander et al. who studied theater actors who were in cyclical contact with theater fog (propylene glycol is also used to make theater fog). In the Wieslander et al. study, there were no changes in lung function parameters, but the actors reported eye and throat irritation. In the Moline JM et al. study, actors in contact with theater fog also reported irritation of the throat and nasal mucosa [10][11]. Animal studies have also been conducted to test the effects of chronic exposure to propylene glycol on the organs of

rats and dogs, but they did not show the effects of propylene glycol on any organ system [12][13].

According to the available studies, we cannot conclude that chronic use of propylene glycol is associated with adverse health effects, but most of the studies involve taking propylene glycol orally. We can conclude that some people may experience irritation of mucous membranes after contact with propylene glycol. However, we cannot unequivocally state that propylene glycol taken in aerosol form with an e-cigarette is harmless, as we still do not have enough data.

## **2.2. Glycerol**

Glycerin, glycerol, propane-1,2,3-triol - an organic chemical compound from the triol group. It is an oily colorless liquid with no odor. Glycerol is used in food products, pharmaceuticals, medical products. Glycerol, like propylene glycol, is recognized by the Food and Drug Administration (FDA) as a safe substance (GRAS) [14][15].

Glycerol is a well-studied compound. The most common complaints when taking glycerin orally are: diarrhea, increased thirst, headache, vomiting. There have been a number of studies that have shown no harm to glycerin, even during long-term use. One of them is a study conducted by the Organization for Economic Co-operation and Development in which 14 volunteers were given oral glycerol for 50 days at a dose of 1.3 to 2.2 g/kg/day [16]. Another study that can be cited is one in which rats were exposed to inhaled glycerol at doses of 0, 1000, 1930 and 3910 mg/m<sup>3</sup> for 6 hours a day, 5 days a week for 2 weeks. At the end of the study, minimal squamous metaplasia of the epiglottis was found in 2/25, 1/19, 4/20 and 10/21 rats at doses of 0, 33, 167 and 662 mg/m<sup>3</sup>, respectively, and mild squamous metaplasia was found in one male in the high-dose group. The researchers noted no macroscopic or systemic effects or changes in organ weights [17]. A study that seems important in terms of smoking is one that tests the carcinogenicity of glycerin. In this study, glycerin was administered to rats for a period of two years at a dose of up to 10mg/kg. The study in rats showed no increased incidence of cancer [18].

Analyzing the cited examples, we cannot conclude that glycerin is harmful, however, glycerin under the influence of contact with the heating element in the e-cigarette and other

substances contained in the aerosol can transform into other compounds that may not be inert to the body.

### **2.3. Nicotine**

Nicotine is an organic chemical compound from the pyridine alkaloid group. It occurs naturally in the leaves and roots of the noble tobacco (*Nicotiana tabacum*). The first documented contact with tobacco is believed to be the meeting of Christopher Columbus with the Arawak people who gave the crew of his ship dried tobacco leaves in 1492. Nicotine itself, contained in tobacco leaves, has a history of nearly two hundred years because it was isolated in 1828, its chemical structure was known in 1843 and synthesized in 1904 [19][20].

Nicotine has many biological effects. As for the positive effects of nicotine, we can mention such as stress relief, decreased appetite, improved learning ability, increased concentration. A study that can attest to the positive effects of nicotine is a study of people with Alzheimer's disease, which found improved cognitive function in patients after using nicotine [21]. In addition, there are studies that show positive effects in autoimmune diseases; nicotine has been proven to slow down demyelinating processes in multiple sclerosis, in inflammatory bowel disease it reduces levels of inflammatory cytokines, in sarcoidosis it reduces the expression of TLR2 and TLR9 and increases levels of T.reg [22]. However, despite these positive effects, it seems that chronic nicotine use has many more negative effects. There are a large number of studies that show harmful effects on the cardiovascular, nervous and immune systems [22] [23] [24]. The effect of nicotine on the development of cancer has also been proven [25] [26] [27]. From the above studies, we can conclude that nicotine has significant effects on the cardiovascular system: it induces vascular remodeling and accelerates vascular smooth muscle aging, which leads to acute conditions such as myocardial infarction, stroke and sudden cardiac death, and chronic conditions: vasculitis, thrombogenesis, endothelial dysfunction, hemodynamic stress, arrhythmogenesis, insulin resistance and lipid disorders[24]. The immune system is also adversely affected by nicotine intake. Nicotine impairs both innate and acquired immunity, also prolonged nicotine intake interferes with neutrophil recruitment processes which can lead to easier development of cancer [22]. One of the most important aspects when it comes to nicotine is its addictive potential. It has been proven that nicotine indirectly initiates the release of dopamine,

serotonin, norepinephrine, acetylcholine, glutamate and endorphins. These substances are responsible for feelings of pleasure.

Unlike the previous two substances, studies clearly indicate that there are negative effects of taking nicotine. Nicotine affects the cardiovascular system, the immune system, leads to atherosclerosis, vasculitis and even strokes and heart attacks. Nicotine has also been shown to have positive effects, but in this work we are considering nicotine as a component of e-cigarette liquids and the aerosols they produce, so we cannot consider nicotine as a single substance.

### **3. Electronic cigarettes and addiction**

#### **3.1. Nicotine content in e-cigarettes vs. risk of addiction**

According to many scientific studies, the nicotine content of e-cigarettes can significantly increase the risk of addiction to the substance. Nicotine is a highly addictive chemical that acts on the central nervous system, causing feelings of pleasure and arousal [28]. Therefore, people who use e-cigarettes with a high nicotine content can quickly become addicted to the drug.

Studies have shown that e-cigarettes with high nicotine content can be more addictive as traditional cigarettes [29] . Users of e-cigarettes with high amounts of nicotine can experience strong cravings for a cigarette and withdrawal symptoms when they are unable to use an e-cigarette.

In addition, excessive nicotine intake can also cause a number of harmful health effects, such as an increased risk of cardiovascular disease, cardiac arrhythmias, respiratory diseases and the risk of developing cancer [30][31].

Therefore, it is important for e-cigarette users to control nicotine content and be aware of the risk of addiction associated with it. It is also worth remembering that the best way to avoid addiction is to avoid using nicotine-containing products altogether.

#### **3.2. Comparison of the addictive potential of electronic with traditional cigarettes**



Electronic cigarettes are often advertised as less harmful than traditional cigarettes, mainly due to the absence of burning tobacco and other chemicals but there is no long term data to prove it. The research suggests that people who use electronic cigarettes can develop nicotine addiction more as those who smoke traditional cigarettes [29]. However, differences in the way nicotine is delivered may affect the differences in the addictive potential of electronic cigarettes compared to traditional cigarettes.

Nonetheless, electronic cigarettes still pose health risks, especially for nonsmokers and young people who may start using electronic cigarettes as a first step toward nicotine addiction. Therefore, it is important to take measures to prevent the use of both traditional and electronic cigarettes to protect public health.

### **3.3. Potential help to quit or reduce traditional cigarettes**

Scientific research confirms that the use of alternative tobacco products, such as e-cigarettes and tobacco warmers, can help people addicted to traditional cigarettes to quit or reduce the habit [32] [33].

According to a study published by Britain's Public Health England, e-cigarettes are 95% less harmful than traditional cigarettes [34]. In addition, an analysis by the Royal College of Physicians in the UK indicates that using e-cigarettes may even be more effective than traditional smoking cessation methods, such as nicotine replacement therapy [35].

Similar conclusions have also been drawn from other scientific studies, which have shown that people who use alternative tobacco products are more likely to succeed in quitting. E-cigarettes and tobacco warmers allow nicotine addicts to gradually reduce their nicotine intake, making quitting easier and more successful [36].

Therefore, helping people quit traditional cigarettes can be made effective by using alternative tobacco products that are less harmful to health and can help reduce nicotine addiction. Therefore, it is worth considering choosing such products as a support in the fight against smoking addiction.

## **4. Regulations on electronic cigarettes**

#### **4.1. Current regulations on the advertising and sale of e-cigarettes**

Current regulations on the advertising and sale of e-cigarettes vary from country to country. Some countries have placed restrictions on the advertising and sale of e-cigarettes due to public health concerns, especially among young people. Examples of regulations on e-cigarette advertising and sales include:

- United Kingdom - e-cigarettes are regulated by the Tobacco and Related Products Regulations 2016, which place restrictions on e-cigarette advertising. It is not allowed to promote e-cigarettes on television, radio or in the press [37].
- United States - e-cigarettes are regulated by the US Food and Drug Administration (FDA). In 2019, the FDA banned the sale of e-cigarettes with flavors other than menthol and tobacco in stationary stores to limit youth access [38].
- Canada - E-cigarettes are regulated under the Tobacco and Vaping Products Act, which places many restrictions on e-cigarette advertising, including a ban on advertising them in places where youth are present [39].

Scientific studies conducted in various countries confirm the harmfulness of e-cigarettes to health, especially to young people. According to a U.S. Surgeon General report, e-cigarettes can be harmful to health, and young e-cigarette users have a higher risk of nicotine addiction [40].

As a result, regulating the advertising and sale of e-cigarettes is important to protect public health and limit youth access to these products.

#### **4.2. Proposals to change the law to limit access to e-cigarettes, especially for young people**

One of the most important steps to be taken is a statutory ban on the sale of e-cigarettes to minors. This ban is already in place in much of the country, but is not always respected by vendors. Many young people reach for e-cigarettes without realizing the potential damage they can do to their health.

Banning e-cigarette advertising in the media - Banning e-cigarette advertising in traditional media, as well as on online platforms, could significantly limit young people's

access to these products. Advertisements for e-cigarettes often target youth and may encourage minors to use them.

Introduce special outlets for e-cigarettes - Introducing special outlets for e-cigarettes with strict rules on selling only to adults could limit youth access to these products.

Increasing penalties for selling e-cigarettes to minors - Introducing stiffer penalties for vendors who sell e-cigarettes to minors should deter dealers from breaking the law.

Education on the harms of e-cigarettes - It is also important to increase educational efforts about the harms of e-cigarettes so that young people are aware of the dangers of using these products. Improving public awareness of the health effects of e-cigarettes can help reduce the demand for them among young people.

## **5. Prevention and education activities**

Prevention and education activities regarding electronic cigarettes are aimed at increasing public awareness of the negative effects of using these devices and reducing their prevalence in society.

One of the preventive measures may be an information campaign aimed at various groups in society, including young people, parents, teachers and health professionals. The campaign could include, among other things, educational spots, posters or informational brochures that outline the harmful effects of smoking electronic cigarettes, such as nicotine addiction, harmful chemicals and the risk of respiratory diseases.

Another measure could be the introduction of regulations restricting the advertising and sale of electronic cigarettes, especially to young people. For example, banning the sale of devices to minors, restrictions in public places where e-cigarettes can be used, and tightening controls on the composition and safety of these products.

In addition, organizing workshops, trainings and lectures for young people on the harmfulness of electronic cigarettes and promoting healthy lifestyles to raise awareness of the negative effects of smoking e-cigarettes and encourage healthy choices.

An important part of prevention and education efforts is also to cooperate with community organizations, health services and government institutions to work together to reduce the use of electronic cigarettes and improve public awareness of their harmfulness.

## **6. Summary and conclusions**

### **6.1. Summary of the dangers of electronic cigarettes**

Electronic cigarettes pose a threat to public health for a number of reasons. The first important factor is that e-cigarettes contain many harmful chemicals, including toxic heavy metals such as lead and cadmium, and carcinogenic compounds such as formaldehyde and acetaldehyde. In addition, some e-cigarettes contain nicotine, which is an addictive substance and can negatively affect users' mental and physical health.

Another major risk associated with e-cigarettes is that they can cause damage to the lungs and respiratory system. Scientific studies have shown that long-term use of e-cigarettes can lead to chronic lung diseases such as pneumonia and obstructive bronchitis. In addition, chemicals present in e-cigarettes can cause respiratory irritation and allergies in users.

Another risk associated with e-cigarettes is the risk of nicotine poisoning, especially in children and adolescents, who may accidentally ingest e-cigarette liquid or over-consume nicotine cartridges. Nicotine poisoning can lead to serious health problems such as nausea, vomiting, seizures and even death in extreme cases.

It is also worth noting that e-cigarettes can be used to inhale drugs, which poses an additional public health risk. Using e-cigarettes for drug consumption can lead to addiction and serious health problems, such as mental disorders and heart disease.

In view of the above risks, there is a need to take control and educational measures to reduce the use of e-cigarettes and minimize the negative health effects associated with them. This is a key issue to protect public health and prevent the epidemic spread of the harmful effects of e-cigarette use.

### **6.2. Recommendations for the public, health care providers and policymakers to reduce the harms of e-cigarettes**

E-cigarettes bring with them many potential harms, so it is important to take measures to reduce their negative impact on society. The public should be educated about the harms of e-cigarettes and the benefits of quitting smoking. Awareness campaigns can raise public awareness of the dangers of e-cigarette use.

The health service should increase efforts to diagnose and treat health complications associated with e-cigarettes and conduct scientific research to learn about the effects of long-term use of these devices. Professional health workers should be trained to identify symptoms associated with e-cigarette use and to provide treatment for nicotine addiction.

Policymakers should place restrictions on e-cigarette advertising, especially targeting youth, and tighten regulations on the sale and distribution of these products. In addition, it is important to take legislative action to control the quality and composition of substances used in e-cigarettes and limit the availability of flavors that attract younger users.

Implementing these recommendations can help reduce the harmfulness of e-cigarettes and contribute to improving public health.

## **Disclosure**

Authors contribution:

Conceptualization: Kamila Giżewska, Konrad Białogłowski, Michał Dacka, Karol Bochyński

Methodology: Konrad Białogłowski, Katarzyna Molenda, Kamila Giżewska, Paulina Dąbrowska

Formal analysis: Michał Żuber, Katarzyna Ciuba, Barbara Borodziuk, Michał Dacka

Investigation: Kamila Giżewska, Konrad Białogłowski, Filip Borodziuk

Writing–roughpreparation: Konrad Białogłowski, Michał Żuber, Katarzyna Ciuba

Writing review and editing: Kamila Giżewska, Barbara Borodziuk, Filip Borodziuk

Visualization: Karol Bochyński, Katarzyna Molenda, Paulina Dąbrowska, Konrad Białogłowski, Kamila Giżewska

All authors have read and agreed with the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Funding statement: No external funding was received to perform this review.

Board statement: Not applicable–this review included analysis of the available literature.

Statement of informed consent: not applicable

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