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Review

HEALTH RISK FACTORS ASSOCIATED WITH USE OF ELECTRONIC CIGARETTES (ANALYTICAL REVIEW)

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The article examines health risks associated with use of electronic cigarettes (vaping) and the spread of EVALI (E-cigarette or Vaping Product Use-Associated Lung Injury).

The study aims to systematically analyze and comprehensively assess medical-biological, socio-behavioral, and environmental risks associated with e-cigarette use given their rapidly growing popularity across diverse population groups evidenced by surging sales. Special attention is paid to dynamics of the electronic nicotine delivery systems (ENDS) market in Russia, which reached 170 billion RUB in 2023 (+18.7 %), with the share of retail outlets increasing from 7 % (2021) to 35 % amid a decline in traditional smoking.

To achieve the goal, we analyzed 63 scientific publications (41 international and 12 Russian) from PubMed, MEDLINE, eLIBRARY, and CyberLeninka. Publications were selected using PICO criteria: Population (P) – e-cigarette users, including adolescents and young adults; Intervention (I) – regular vaping; Comparator (C) – traditional smoking or non-smoking; Outcomes (O) – development of EVALI, nicotine dependence levels, cognitive impairments, and environmental impacts of device disposal.

The study revealed that rising popularity of e-cigarettes (vaping) among youth correlates with social factors (peer influence, stress, and fashion trends), misconceptions about e-cigarette safety, and aggressive marketing targeting adolescents. A direct link between vaping and EVALI was emphasized. Special attention was paid to environmental risks, including improper disposal of devices containing lithium-ion batteries, plastics, and heavy metals.

Despite anti-smoking campaigns, vaping prevalence continues to grow, particularly among youth. Emerging evidence on EVALI raise an obvious concern about adverse health effects of vaping and this requires a comprehensive approach to evaluating health impacts of e-cigarettes. Priorities include studying EVALI epidemiology, disease manifestations across populations, long-term health effects, and developing strategies for early diagnosis, treatment, and enhanced smoking prevention programs.

Keywords: *electronic cigarettes, vaping, nicotine dependence, youth health, social factors of addiction, toxic aerosols, long-term effects of vaping, cardiorespiratory risks, oncological risks, neurocognitive impairments.*

Active spread of electronic nicotine delivery systems (ENDS), which are more known as electronic cigarettes, has become a most significant phenomenon in public health over the last decade. Since they were first introduced on the market in early 2000ties, these devices have become very popular due to their image as a ‘less harmful’ option to traditional tobacco smoking. However, a drastic growth in ENDS consumption, especially among young people, is raising a great concern among healthcare experts and the medical society in general. Up-to-date toxicological and epidemiological studies are revealing substantial gaps in the methodology for assessing risks associated with using ENDS and electronic cigarettes (EC). When it comes to traditional cigarettes, such an indicator as ‘pack – years’ allows objective estimation of cumulative health harm. In contrast, similar standardized risk measuring techniques have not been developed for electronic cigarettes so far and this makes it difficult to assess their long-term health effects.

In addition, any consensus has not been reached among experts yet as regards integrative assessment of ENDS harmfulness, which covers not only nicotine-addiction outcomes

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but also synergic effects produced by auxiliary components as well as potential cardiorespiratory, oncological and neurocognitive risks. A difficulty in creating an evidence base results from absent standardized protocols for clinical studies *in vivo* and *in vitro* as well as from longitudinal data being rather limited.

Our research object is represented by electronic cigarettes and medical, social and ecological outcomes associated with their use and described in literature over the period between 2014 and 2024.

The research subject is a comprehensive analysis of health risk factors including development of specific pathologies (primarily, EVALI), sociodemographic peculiarities related to spread of vaping in various age groups, as well as ecological outcomes resulting from manufacture and utilization of electronic cigarettes.

The study **aims to** systematically analyze and comprehensively assess medical, social, and environmental risks associated with e-cigarette use given their rapidly growing popularity across diverse population groups evidenced by surging sales.

Materials and methods. Within this study, we have performed a systemic review of research publications with their focus on effects produced by electronic cigarettes on health, social aspects and the environment relying on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) principles. Publications were selected using PICOS criteria where Population (P) was e-cigarette users, including adolescents and young adults; Intervention (I) was regular vaping; Comparator (C) was traditional smoking or non-smoking; Outcomes (O) were development of EVALI and other pathologies and finally Study Design (S) included cohort studies, clinical tests and meta-analyses.

An initial search was conducted in five electronic databases including PubMed/ MEDLINE, Web of Science, Scopus, eLIBRARY and CyberLeninka, which insured covering both foreign and Russian publications. The search period was ten years (2014–2024), which corresponds to the time when first research data were reported about EVALI and a considerable growth in popularity of electronic cigarettes. Our search strategy involved using combinations of keywords both in English and Russian languages ('e-cigarettes', 'vaping', 'ENDS' 'EVALI', 'e-liquid', 'vape-associated lung injury').

The initial search yielded 18,437 results, which then underwent multi-stage processing. At the first stage, 5121 duplicates were excluded by using automated tools and manual checking. The remaining 13,316 publications went through double independent screening per headings and abstracts; it was accomplished by two researchers with subsequent agreement as regards any discrepancies. As a result, 8940 publications were excluded since they did not correspond to the research subject. After duplications, studies with insufficient evidence bases and works not meeting the PICO criteria were excluded, 63 relevant publications remained to be included in the analysis considering the extended reference list (51 foreign studies and 12 Russian studies). We conducted full-text analysis and structured the available data per three main subject areas: medical aspects (including clinical manifestations, diagnostic criteria and EVALI pathophysiology); social and behavioral factors (prevalence in various age groups and motivation to use e-cigarettes); and environmental damage (toxic wastes and utilization issues). We assessed authenticity of the results by analyzing possible sources of the systematic bias including publication bias, any influence exerted on studies due to funding provided by e-cigarette manufacturers or limitations found in the design of some studies. Special attention was paid to finding any contradictions between different sources and analyzing likely reasons for their occurrence.

Methodological strictness of the study was ensured by several taken measures such as using standardized forms for data extraction and cross-checking the results by independent experts. Limitations of the study include possible incompleteness of the data per some regions across the globe, language limitations (the study covers only publications in English

and Russian) as well as rapid data deterioration due to very dynamic development of the e-cigarette market and new studies appearing in the sphere. All stages in the analysis were documented in accordance with the principles of scientific research reproducibility.

The current state of the issue. In Russia, most adults have a negative attitude towards smoking and consider it bad for health; still, smoking remains quite prevalent among the country population [1, 2]. Nicotine addiction and tobacco smoking have been a well-known health issue for the humanity over a very long time. In its turn, use of electronic cigarettes is a rather new challenge for public health.

EVALI was first mentioned in medical literature in 2019 when an outbreak of acute respiratory diseases was detected among e-cigarette users in the USA. Despite many warnings made by the WHO since 2014, systemic research on the issue was initiated only after a CDC publication in 2019 [3].

The COVID-19 pandemic had a rather paradox effect since quarantine measures (lockdowns) were expected to result in a temporary decline in e-cigarette sales. But in reality, an opposite picture was observed as stress and social isolation provoked a growth in 'home vaping' and the e-cigarette market grew tenfold, from 0.002 % in 2017 to 0.02 % in 2020. People most likely started to use such devices more often due to COVID-19-related anxiety [3].

By February 2020, CDC had already registered more than 2800 hospital admissions and 68 deaths caused by EVALI [3, 4].

In Russia, the first EVALI cases were detected in 2019 [4]. According to the WHO statistics (2023), 30 % of Chinese students use electronic cigarettes. In Russia, Rospotrebnadzor reported in 2024 that vaping was a regular habit for 25 % young people aged 18–24 years [1, 3].

The COVID-19 pandemic created certain difficulties for collecting statistical data. In 2020–2021, 45 % of the disease cases were incorrectly diagnosed as COVID-19 due to similar symptoms typical for both diseases (cough and shortness of breath) thereby distorting the global statistics [4, 5].

At present, the geographical aspect of the issue is quite diverse. EVALI incidence is typically 2.5 times lower in countries where regulatory measures are strict in this respect (for example, Australia and Japan, where only one EVALI case was officially registered in 2020) against the USA (2558 hospitalized patients with non-fatal outcomes and 60 deaths) [5–8]. For example, sales of nicotine-containing liquids without a prescription have been prohibited in Australia since 2021; in Japan, only heat-not-burn products are allowed, which seriously decreases the risk associated with inhaling toxic aerosols [9, 10].

At present, there is an obvious trend for growing use of electronic cigarettes among population groups of all ages. According to statistical reports, tobacco smoking prevalence was 26.2 % among adults in Russia in 2017. The overall share of smokers in Russia declined a bit down to 21.5 % but people who used ENDS accounted for 14.8 % among them [11, 12].

Electronic cigarettes were first invented by Hon Lik, a Chinese pharmacist, in 2003. The innovation appeared at a time when people were getting more aware of health harm caused by traditional smoking and there was a demand to create an alternative way to consume nicotine without harmful effects associated with tobacco burning. Hon Lik, a smoker himself, strived to create a device, which could help him to give up smoking. He used the basic principle of an inhalator functioning and elements similar to ordinary cigarettes. The first electronic cigarettes were made of a battery, heating element and a cartridge (tank) with nicotine-containing liquid, flavorings and other components. When this device was activated, the heating elements turned the liquid into vapors inhaled by smokers thus allowing them to consume nicotine without smoke and its toxic side products [12]. Introduction of electronic cigarettes became a real revolution in the world of smoking. They rapidly gained popularity among smokers, who tried to reduce health harm caused by tobacco as well as among people who were trying to quit smoking. Electronic cigarettes offered a wide choice

of various taste additives; this attracted young people's attention and promoted a new lifestyle wiping off a thin boundary between smoking and vaping.

Smokers' age went down when electronic cigarettes appeared on the market.

As electronic cigarettes started to become more and more popular, discussions started about their safety and long-term health effects. Various countries introduced regulatory measures as regards their use and the public opinion got divided. Smoking is among primary reasons for health deterioration and leads to decline in smokers' quality of life. Multiple studies give evidence of smoking having a negative effect on both physical health and mental state. According to the World Health Organization (WHO), smoking is stated as the cause of more than 8 million deaths per year; of them, 7 millions are directly caused by long-term tobacco consumption [13].

Spread of vaping among young people and adolescents is especially disturbing since the bad habit becomes not only a part of their social practices and self-expression but also promotes new behavioral patterns [14]. Developing nicotine addiction among young people is further aggravated by the fact that electronic cigarettes are pictured as a 'safe' alternative to traditional smoking. Nicotine in e-liquids, including its salts, accelerates the addiction development. Social networks and marketing campaigns conducted by EC manufacturers actively create a vaping culture by making its use look 'romantic'. Fashionable trends, easily available devices and flavored e-liquids as well as impacts exerted by social networks and influencers are becoming the key factors stimulating people to start using electronic cigarettes [15, 16]. Mane people make a grave mistake considering them a safe alternative to traditional smoking. Marketing campaigns that emphasize diversity of available tastes and attract popular bloggers to participate in them create a false idea that vaping is harmless; they keep silence about potential health risks [14, 17]. For example, certain challenges have become popular in social networks, such as #CloudChasing, where users compete in creating the biggest vapor clouds. These challengers are viewed by millions thereby spreading vaping as a practice among young people [17]. Statistical reports show that 45–70 % of adolescents aged 15–18 years have tried vaping and 12–30 % of them use such devices regularly [16]. Likelihood of e-cigarette use is 72 % higher among students with attention deficit / hyperactivity disorder (ADHD) and this is often associated with stimulating effects produced by nicotine [18]. An early start of vaping accelerates formation of nicotine addiction and toxic aerosol components (formaldehyde and heavy metals) pose a serious threat for a developing body by inducing cognitive disorders, bronchial asthma and creating risks of cancer [16, 19–21]. Vaping is associated with elevated anxiety and depression levels among young users: according to some studies, 45 % of adolescents-vaping users have clinically significant anxiety symptoms ($p < 0.01$), and 32 %, depression symptoms (OR = 1.5; 95 % CI: 1.3–1.8). In addition, combining EC with alcohol and other psychoactive substances creates an elevated risk of poly-drug addiction: 18 % of regular vaping users also smoke cannabis (RR = 2.1; 95 % CI: 1.8–2.5) [15]. Despite that, up to 50 % of young people still consider vaping a safe alternative to smoking and have no idea of its long-term health effects [16]. The key role in the development of this habit belongs to the closest people, including friends and relatives, and this emphasizes the necessity to reinforce preventive measures [17]. It should be noted that vaping as a health issue does not concern only health but also affects the environment since vaping devices contain heavy metals (lead and mercury), lithium-ion batteries and plastic cartridges, which practically do not decay naturally and contaminate soils and water [22, 23].

Some studies reveal that smokers face higher risks of chronic diseases including lung cancer, cardiovascular diseases, and chronic obstructive pulmonary disease, which deteriorates quality of their life. Nicotine causes vasoconstriction and raises blood pressure thereby creating elevated risks of infarctions and strokes even for young vape users.

Statistical data confirm that exclusive vaping is not associated with most cardiometabolic disorders but its combined use with traditional cigarettes increases atherosclerosis risk by 2.2 times. Stimulation of the sympathetic nervous system induces arrhythmias as they have been found in 15 % of vape users ($p < 0.05$) [24, 25].

A large-scale longitudinal study within the All of Us program ($N = 249,190$) has established that exclusive use of electronic cigarettes is significantly associated with developing chronic obstructive pulmonary disease (COPD) (OR = 2.29; 95 % CI: 1.42–3.71) and hypertension in people aged 30–70 years (OR = 1.39; 95 % CI: 1.09–1.77). Combined use of vapes and traditional cigarettes created elevated risks of all cardiometabolic outcomes, especially atherosclerosis (OR = 2.18; 95 % CI: 1.82–2.62). The latest data emphasize that vaping, apart from EVALI, increases the risk of COPD and hypertension in adult users, which requires some revision as regards approaches to estimating its long-term effects. As reported in a longitudinal study ($n = 2100$), which involved assessing the lung function (FEV1/FVC), 40 % of regular EC users had chronic bronchitis symptoms (against 12 % among non-smokers). Therefore, the risk of respiratory diseases grows as a time of using vapes exceeds one year (OR = 2.3, 95 % CI: 1.8–3.0) [25].

In addition to health effects, vaping has considerable influence on social behavior. As reported in a study conducted in Great Britain, 22 % of smokers are more often discriminated at their workplaces and this may undermine their career development [26]. In addition, studies conducted in 2005 found some neurotoxic effects produced by nicotine on the central nervous system; pathological effects were the most pronounced in those smokers who started to consume tobacco at an early age. Tobacco-addicted adolescents tend to have persistent cognitive disorders; in particular, their working memory is less accurate and effective regardless of the duration of exposure to tobacco. Moreover, during withdrawal, such adolescents usually suffer from considerable difficulties in functioning of both working and verbal memory, which is evidence of long-term nicotine effects on neurocognitive processes [19]. A decline in the grey matter volume has been discovered in tobacco smokers; its density also tends to decrease in them as compared to non-smokers [20]. Smoking is considered a significant factor that makes for the development of cerebral atrophy and declining perfusion in cortical and subcortical structures. These processes are associated with accelerated neuron degeneration and increase likelihood of cognitive dysfunction [21].

Some open sources provide survey data about smoking affecting social perception and status. A study published in *American Journal of Public Health* has revealed that smokers have higher depression levels against non-smokers. Smoking is also linked to social contacts: smokers can have certain difficulty in establishing and maintaining social contacts. As reported in some studies, expenditures on treating smoking-associated diseases are much higher than those spent on other prevention and treatments, which further aggravates smokers' financial situation [27]. The authors conclude that 'vaping' is an addiction, which leads to nicotine addiction and issues affecting certain behavioral aspects. Addiction to electronic cigarettes develops much more rapidly that addiction to ordinary cigarettes. ENDS use becomes a routine thereby making for the development of a deviant behavioral practice [28]. Special concern is raised by the fact that children and adolescents are becoming more and more vulnerable to marketing campaigns promoting electronic cigarettes. As reported, 45–70 % of adolescents aged 15–18 years have tried vaping and 12–30 % of them use such devices regularly; likelihood of electronic cigarette use is 72 % higher among people with attention deficit / hyperactivity disorder (ADHD) (OR = 1.72; 95 % CI: 1.65–1.79) [16, 18].

An American study, which was conducted in April 2021, revealed a significant relationship between ADHD and e-cigarette use among respondents aged 18–39 years. In particular, 7.89 % (15,863 people) out of 195,443

undergraduate and postgraduate students used electronic cigarettes. Likelihood of using e-cigarettes turned out to be 72 % higher among students with diagnosed ADHD against those who did not have this disorder. Interestingly, this relationship between ADHD and EC use was more pronounced among postgraduate students against undergraduates, which might be due to elevated stress levels and higher academic demands for senior students. These findings also showed a similar trend in using other tobacco products, which indicates possible common effects produced by nicotine as the key factor. The authors believe that people with ADHD can use nicotine as a self-treatment method since its stimulating effect can temporarily improve attention concentration [18]. Long-term cognitive disorders, including a decline in the grey matter volume, are detected 1.5 times more frequently in people who use vapes regularly ($p < 0.001$) against those who do not smoke with an apparent correlation between an early start of vaping and progressing working memory deficiency. Reproductive risks are also significant since nicotine and heavy metals affect male spermatogenesis (sperm cells become 40 % less mobile, $p < 0.01$) and create elevated risks of premature birth (OR = 1.7; 95 % CI: 1.4–2.0) and fetus hypoxia for pregnant women [19–21].

Addiction to electronic cigarettes is developing among young people given this whole set of dominant negative factors.

Although many people believe vaping to be a safe alternative to traditional smoking, multiple studies report that e-cigarette aerosols contain the same carcinogens such as formaldehyde and heavy metals [14, 28]. An inhaled aerosol contains not only nicotine but also ultra-dispersed particles, carbonyl compounds (formaldehyde and acetaldehyde) and heavy metals (lead, cadmium, and nickel), which damage the epithelium in the airways thereby increasing the risk of bronchitis, asthma and COPD. Chromatography performed on 50 EC models identified several adverse chemicals in EC aerosols including formaldehyde (up to 15 μg/inhalation, when heated up to > 250 °C), nickel and lead (thrice as high as MPC when cheap products are used). Therefore, carcinogen levels correlate with a device capacity ($r = 0.72$, $p < 0.001$) [29].

Environmental risks include environmental pollution with heavy metals (lead and mercury) and lithium-ion batteries, which account for up to 40 % of the total electronic wastes. Disposable EC (for example, Puff Bar, Elf Bar) contain non-removable lithium-ion batteries and plastic cases, which cannot be recycled (90 % go to dumps). When decaying, they release toxic substances, such as lithium and lead. E-liquids (containing nicotine, propylene glycol, and glycerin) are toxic for water organisms; when they enter water objects, they affect fish by damaging gills (mortality reaches 60 % upon exposure to a concentration of 0.1 mg/l). They can also accumulate in soils and underground waters. Composition of 1000 e-cigarettes was analyzed in another study; as a result, it was established that 90 % of disposable EC were not fit for recycling and a single cigarette contained 0.5 grams of lithium plus 10 grams of plastic. Therefore, if e-cigarette consumption grows at the same rate, 500 thousand tons of toxic wastes will have accumulated in dumps by 2030 [29].

Flammability risk is an additional concern since EC batteries can explode due to overheating or short circuit and this may result in burns or injuries among consumers. About 65 % of such devices are utilized unsafely and this results in toxicants accumulating in soils and water [22, 23].

Social and economic aspects. As we continue to analyze vaping and EVALI, we should pay attention to social and economic aspects of this global issue. Vaping has become not only a way to intake nicotine but also a self-expression method for young people, which makes its prevention much more difficult. Wide EC spread undermines decades spent on anti-tobacco propaganda by creating a false idea of their harmlessness. Vaping in public places promotes return to smoking among former smokers and stimulates a wish to try it among non-smokers. Some studies report that EC use is frequently

associated with creating a certain lifestyle, which attracts adolescents and young people [14]. This lifestyle includes fashionable accessories, stylish packing of e-cigarettes and a wide selection of flavors, which makes smoking e-cigarettes more attractive in comparison with traditional ones.

Tobacco advertising frequently uses bright colors. Popular bloggers and influencers are often involved in promotion. E-cigarettes are run all through such campaigns as a modern, fashionable and safe type of smoking. Although some companies declare they have decreased levels of harmful chemicals in vaping liquids, scientific data indicate that such liquids still contain potentially hazardous components including diacetyl, benzaldehyde and other chemicals, which can induce chronic respiratory inflammation [30–34].

Despite growing attention to medical and environmental risks of vaping, the economic dynamics on the market remains the key driver stimulating its further spread. Active implementation of electronic nicotine delivery systems into the consumer environment is closely connected to transformations in legislation, marketing strategies and changes in retail trade. These factors create solid basis for realizing how grave the issue is and getting an insight into its socioeconomic roots, which requires profound analysis of market trends and regulatory challenges.

In Russia, the ENDS market, including vapes and e-cigarettes, has been growing steadily due to transformation of consumer preferences and regulatory changes. As reported in the NeoAnalytics study, the e-cigarettes market reached 170 billion rubles in 2023 having grown by 18.7 % against the previous period due to both wider distribution (the share of retail outlets selling ENDS grew from 7 % in 2021 to 35 % in 2023) and regulatory measures aimed at making the market ‘step out of the shadow’ including digital marking introduced in December 2022 and step-by-step prohibition on turnover of unmarked goods [35, 36]. Simultaneously, rapid expansion of specialized retail outlets was observed as the number of points for selling ENDS reached 16.9 thousand in cities with over a million residents by March 2023, which was 32 % higher than in 2022. Over the period from 2019 to 2023, the number of such outlets doubled as it grew from 2.6 to 5.2 thousand as reported by the 2GIS and Yandex Business. This growth is supported by considerable profitability of the segment (200–400 % against 5–10 % in traditional tobacco sales), which motivates entrepreneurs to open retail outlets even if rent is high and competition is severe [37, 38]. However, the market dynamics is closely connected with spread of illegal products: as estimated by the Ministry of Industry and Trade of Russia, the share of unmarked nicotine-containing liquids reached 93 % in the second half of 2022, and counterfeit devices, mostly produced in China (HQD brand) accounted for 80–90 % of sales, which was due to absence of mandatory import certification and poor quality control. A true paradox is the fact that when the share of traditional smokers went down in Russia (from 39 % in 2009 down to 21 % in 2023 as reported by Rosstat), a growth in ENDS use did not result in the overall decline in nicotine addiction prevalence, which is partially due to a part of consumers switching from traditional cigarettes to their alternatives [39]. Regulatory measures, including a steady growth in excise taxes imposed on liquids for vaping (up to 21 ruble per ml by 2024) and wider requirements to marking, are aimed at reducing black market turnover; however, their effectiveness is still limited due to remaining gaps in the legislation, such as absent safe standards for such products and insufficient control of sales to minors. Therefore, the ENDS marker in Russia is undergoing major restructuring where commercial attractiveness of the sector contradicts high risks associated with low legality and insufficient transparency of supply chains [40–43].

These market processes have direct influence on population health as ENDS availability, especially counterfeit products, aggravates nicotine addiction and makes anti-tobacco campaigns less effective. Growing e-cigarettes consumption among young peo-

ple, stimulated by aggressive marketing and poor control, creates a vicious circle, where commercial benefits conflict with public healthcare goals. This emphasizes the necessity to not only introduce stricter regulatory measures but also to integrate epidemiological data into strategist for controlling the market in order to reduce long-term risks for health and the environment.

Social networks play an important role in spreading information about vaping. Such platforms as Instagram, TikTok and YouTube, often become a place where vaping culture is demonstrated and where young people download videos with beautiful vapor clouds or with their participation in various challenges. This creates an illusion that vaping is quite normal, which can pose a threat for susceptible population groups. Therefore, there should be active cooperation between social platforms and healthcare experts so that vaping-related content would be controlled [44, 45].

Moreover, the economic aspect of vaping also requires serious attention. Sales of e-cigarettes and liquids for them are a multibillion industry, which strives to expand its markets. This creates a conflict of interests between commercial goals pursued by companies and healthcare tasks. Socioeconomic analysis has revealed that aggressive marketing targeted at young people increases likelihood of them starting to use vaping threefold (RR = 3.0; 95 % CI: 2.7–3.4). EVALI incidence is 2.5 times lower in countries where vaping is strictly regulated (Australia and Japan) than in the USA (1 case against 2558), which confirms effectiveness of introduced legislative restrictions [5–8].

A growing number of studies report potential hazards of vaping related to DNA damage, chronic inflammation and cancer. EC aerosols contain carcinogenic chemicals such as formaldehyde, acetaldehyde, acrolein as well as heavy metals (nickel, cadmium, and lead) and toxic flavorings. When introduced to the body via inhalation, these chemicals induce genotoxic damage to cells, activate inflammatory pathways and support mutations in gene hotspots associated with cancer such as TP53 [46–52].

The chemical composition of EC aerosols directly depends on heating conditions for liquids containing propylene glycol, glycerin, nicotine, and flavorings. Under high temperatures (> 200 °C), these components decompose and this leads to formation of carbonyl chemicals, including formaldehyde and acrolein classified as carcinogens. Acrolein, for example, forms DNA-adducts similar to those observed in lung cancer caused by tobacco smoking. In addition, heavy metals emitted from spiral-like heating elements of electronic devices enhance oxidative stress and epithelium damage. Clinical observations give evidence of a relationship between long-term EC use and head and neck cancer, lung cancer and urinary bladder cancer. Thus, IV stage tongue cancer was diagnosed in a male aged 19 years who had been using ENDS daily for 4 years [46–53].

However, contemporary studies face several limitations. First, most data have been obtained in short-term experiments or observational studies, which does not allow exact assessment of health risks after decades of using EC. Second, it is rather difficult to standardize research results due to great variability of e-liquid composition and device capacity. Third, many EC users used to smoke traditional cigarettes and this creates distortions when an effort is made to analyze solely vaping effects. Despite all that, experimental data show that even low levels of carcinogens in aerosols are able to accumulate in the airways thereby increasing likelihood of mutations and tumor progression [52–59].

Practical recommendations following the analysis include restrictions imposed on EC use by adolescents and pregnant women; stricter regulatory control of liquid composition; prohibition on marketing targeted at young people. The authors emphasize that nicotine-replacing therapy and behavioral support remain much safer ways for quitting smoking. In clinical practice, doctors should take vaping into account when they assess risk factors causing cancer and cardiovascular dis-

eases. Long-term investigations including cohort studies and molecular analysis of pathways responsible for interactions between chemicals and DNA will provide a better insight into the complete picture of EC-related health risks [46, 48, 49–51].

Therefore, although ultimate data about long-tern EC effects are still absent, we can hardly ignore warnings about their potential carcinogenicity. While the technology market is developing more rapidly than regulatory measures, a cautious attitude towards vaping and search for safe alternatives remain top priority for public health [60–63].

Results and discussion. Our analysis has revealed a whole set of medical, social and environmental risks associated with using electronic cigarettes (EC). The major adverse health outcome of vaping is EVALI, a disease associated with acute lung damage. Hospital admissions due to it are much more frequent in countries with liberal regulation (for example, the USA) than in regions where vaping is restricted severely (Australia and Japan). Longitudinal studies have confirmed the relationship between regular vaping and elevated risks of COPD (OR = 2.29) and hypertension (OR = 1.39); combined use of EC and traditional cigarettes aggravates cardiometabolic disorders (OR for atherosclerosis is = 2.18). Toxic aerosols that contain formaldehyde, heavy metals and ultra-dispersed particles induce respiratory pathologies including chronic bronchitis (40 % among EC users against 12 % among non-smokers), as well as cognitive disorders associated with the declining volume of grey matter ($p < 0.001$).

Social factors, such as aggressive marketing, creating a romantic image for vaping in social networks and the erroneous concept of EC being safe for health, have become the key drivers of their popularity among young people. More than 45 % of adolescents aged 15–18 years have tried vaping and likelihood of EC use is 72 % higher among people with ADHD (OR = 1.72), which indicates that they use nicotine as a self-treatment method. Environmental risks include accumulation of toxic wastes (lithium-ion batteries and plastic) and environmental pollution. About 90 % of disposable devices are not fit for recycling and this means that up to 500,000 tons of hazardous wastes will have accumulated by 2030.

The Russian market for electronic nicotine delivery systems is showing a rapid growth having reached 170 billion rubles by 2023. This is due to wider distribution and partial legalization of the segment through product marking. However, high profitability (up to 400 %) stimulates development of specialized retail outlets simultaneously aggravating counterfeit-related issues: up to 93 % of e-liquids and 80–90 % of devices remain unmarked. The paradox is that a decline in the share of traditional smokers (from 39 % in 2009 to 21 % in 2023) is not accompanied with a decline in overall prevalence of nicotine addiction since young people switch to alternative products. To minimize these risks, it is necessary to introduce stricter control over product quality, prohibit EC sales to minors and enhance prevention activities making an emphasis on aerosols being toxic and on long-term health effects of vaping. A complex approach that combines regulatory, educational and medical activities will become a key to reducing socioeconomic and epidemiological threats associated with this segment.

Our discussion highlights the necessity to revise the existing regulatory measures. Despite EC being declared ‘less harmful’, their long-term effects remain largely uninvestigated and the available data are contradictory due to methodological limitations (80 % of studies are based on self-reporting). In future, researchers’ attention should be paid to investigating EVALI epidemiology; developing standardized diagnostic protocols including creation of a risk scale similar to that used in estimating traditional cigarettes and known as ‘pack – day’; and estimating effects produced by vaping on mental health and reproductive function. Stronger regulatory restrictions similar to Australian and Japanese models as well as educational campaigns aimed at destroying the myth about EC safety can also become an effective instrument for risk mitigation.

Complex analysis of risks associated with using electronic cigarettes. Health risks include EVALI (E-cigarette or Vaping Product Use-Associated Lung Injury) confirmed in 8 studies [3, 5–9, 19, 33] as well as respiratory diseases and COPD reported in 7 studies [24, 25, 33, 51, 52, 57, 59]. Other health threats include hypertension and cardiometabolic disorders reported in five publications [24, 25, 46, 52, 57]; cancer risks due to exposure to carcinogens and genotoxicity, 9 publications [29, 34, 46, 47, 50, 52, 55, 58, 60]; neurocognitive disorders (a decline in the grey matter volume, memory deficit), 5 studies [19–21, 25, 48]; reproductive risks, 3 studies [19, 21, 25].

Social and behavioral aspects cover growing popularity of vaping among young people influenced by aggressive marketing and social networks [10, 14–18, 28, 37–39, 44], developing nicotine addiction and poly-drug addiction [2, 15, 18, 27, 35, 48, 52], as well as social stigmatization [26, 27].

Environmental risks include accumulation of toxic wastes (lithium-ion batteries, plastic, and heavy metals reported in six studies [22, 23, 29, 31, 53, 59]), soil and water pollution (4 publications [21, 22, 31, 53]) and flammability of electronic devices (2 publications [22, 29]). These data emphasize the necessity to work out an inter-disciplinary approach to regulation and prevention.

Vaping as a challenge requires not only a medical but also socioeconomic approach. It is necessary to examine what effects vaping produces on a developing body including children, adolescents and pregnant women. Special attention should be paid to possible transfer of toxicants with breast milk and their effects on newborns' health. This will make it possible to identify potential health risks for future generations and take relevant actions to minimize them.

It is also noteworthy that vaping as an issue does not concern only users' physical health but their mental welfare as well. Nicotine addiction can be aggravated by other factors such as stress, anxiety, and depression.

A new disease has emerged in the present world called EVALI and this is a serious health threat for smokers. The EVALI risk has been established to equal 1.8 (95 % CI: 1.5–2.1) among vape users as compared to non-smokers and EVALI case fatality rate reaches 2.4 % (68 cases out of 2800 hospital admission in the USA by 2020) [2, 4, 9]. Novelty of the pathology means absence of a unified scientifically substantiated approach to treating patients with diagnosed EVALI. At present, there are no effective measures for preventing nicotine addiction associated with using electronic cigarettes and this makes it difficult to prevent development of the disease. Addiction to vaping is spreading rapidly among young people due to impacts exerted by social factors and aggressive marketing and this fact is especially disturbing.

Critical assessment of research methods has revealed that at present there are certain limitations of the study since 80 % of the analyzed publications rely on using data collected by self-reporting in surveys with a certain risk of underestimation.

Conclusion. Therefore, our study has shown that vaping is associated with elevated risks of respiratory diseases, cognitive dysfunctions and environmental problems quantitatively confirmed by epidemiological and clinical data. At present, there are hardly enough studies with their focus on long-term effects of electronic cigarettes on future generations including potential impacts on addicted people's offspring. The research results cover selective vaping risks (COPD and hypertension) and a crucial role that belongs to double addiction, which should be used as grounds for introducing stricter regulatory measures.

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