IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 7, March 2026
Impact Factor: 8.2

Electronic Cigarettes A Review On Health Effects and Public Awareness

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Abstract: *Electronic cigarettes (e-cigarettes), or vapes, have gained substantial attention as alternatives to conventional tobacco products by delivering nicotine through aerosolization instead of combustion. Despite being marketed as harm-reduction devices, accumulating scientific evidence suggests notable adverse effects on respiratory, cardiovascular, and systemic health, alongside a high potential for nicotine dependence. In India, the proliferation of e-cigarettes initially generated public curiosity but soon raised serious public health concerns, particularly due to their growing use among adolescents and young adults. In response, the Government of India implemented the Prohibition of Electronic Cigarettes Act (PECA), 2019, prohibiting their manufacture, sale, and distribution. Nevertheless, online accessibility and limited public awareness continue to undermine effective enforcement. This review critically examines the health impacts, addiction potential, and public perception of e-cigarettes, with emphasis on the Indian regulatory framework. The analysis underscores the necessity for comprehensive public education, robust enforcement mechanisms, and further research to inform evidence-based policy and protect population health.*

Keywords: Electronic cigarettes; Vaping; Nicotine; Health effects; Public awareness

I. INTRODUCTION

Tobacco use continues to be a major public health problem worldwide, contributing to more than eight million deaths each year. India alone accounts for over one million of these deaths, making it one of the largest consumers of tobacco products globally [1]. In recent years, electronic cigarettes (e-cigarettes) also known as electronic nicotine delivery systems (ENDS) have emerged as an alternative to conventional smoking. These battery-operated devices vaporize a liquid mixture containing nicotine, propylene glycol, glycerin, and flavoring agents, which is then inhaled by the user. Since they do not involve the burning of tobacco, manufacturers and some users believe they are a safer substitute for traditional cigarettes [2], Globally, e-cigarettes have witnessed rapid growth in popularity, particularly among young adults and adolescents. Marketing strategies, appealing flavors, and the perception of reduced harm have played key roles in their widespread adoption. According to the World Health Organization, the number of e-cigarette users has increased steadily over the past decade, raising major public health concerns [3]. However, the emergence of e-cigarettes threatened to undermine these efforts, especially among the youth population. Studies conducted among college students and adolescents in cities like Mumbai, Delhi, and Bengaluru revealed rising awareness and curiosity about vaping. Many respondcats believed e-cigarettes were safer and less addictive, even though scientific evidence does not support these assumptions [4]. Recognizing the potential dangers, the Government of India adopted a preventive approach. In 2019, the Prohibition of Electronic Cigarettes Act (PECA) was enacted, banning the production, sale, storage, distribution, and advertisement of e cigarettes across the country. The decision was based on growing international and domestic evidence suggesting that e-cigarettes could serve as a gateway to nicotine addiction and conventional smoking among non-smokers. Despite this prohibition, enforcement challenges persist, with reports of illegal online sales and unauthorized imports [5]. While some researchers argue that ecigarettes may help existing smokers reduce or quit tobacco use, this potential benefit remains unproven in India. Moreover, the risk of youth initiation and nicotine dependence outweighs the uncertain cessation advantages. The long-term health effects of vaping are still being studied, but current findings associate e-cigarette use with respiratory irritation, cardiovascular stress, and potential cellular damage. Public awareness campaigns and continued monitoring are essential to ensure that the younger population does not fall victim to misleading claims of safety and modernization. In conclusion, e-cigarettes represent a complex challenge for India's public health system. Balancing innovation and prevention requires careful consideration of scientific evidence, regulatory enforcement, and public education. This review aims to explore the health impacts, public awareness, and policy implications of e-cigarettes in India to provide insights for future research and effective tobacco control strategies.

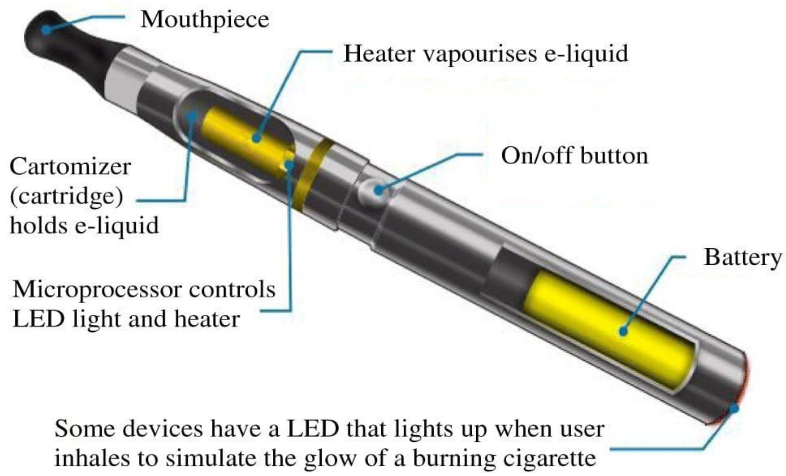

Fig 1. Electronic cigarette

History and Development of Electronic Cigarettes

The evolution of electronic cigarettes (e-cigarettes) represents one of the most significant technological shifts in nicotine delivery methods over the past two decades. The concept of inhaling vaporized substances rather than burning tobacco dates back to the mid-20th century, In 1963, Herbert A. Gilbert, an American inventor, designed and patented a "smokeless non-tobacco cigarette" that produced flavored, heated air instead of smoke. Although his prototype was never commercialized, it laid the foundation for future developments in vapor-based nicotine delivery systems [6]. The true inception of modern e-cigarettes occurred in 2003 when Chinese pharmacist Hon Lik developed a device that used a piezoelectric ultrasonic atomizer to vaporize a nicotinecontaining solution. His invention was marketed by the Chinese company Ruyan, which introduced the first generation of e-cigarettes to the global market, Hon Lik's motivation stemmed from his desire to quit smoking after losing his father to lung cancer a fact that highlights the device's original intent as a smoking cessation tool [7]. By 2006-2007, e-cigarettes began to spread rapidly to European and American markets, driven by aggressive online marketing and claims of being a "healthier alternative" to traditional cigarettes. These early. devices, often called "cigalikes," closely resembled conventional cigarettes in shape and size, containing a battery, heating coil, and cartridge filled with e-liquid. Their appeal lay in the ability to simulate the sensory and behavioral aspects of smoking without producing smoke or tar. However, limited battery life and nicotine delivery inconsistency restricted their popularity to a small group of users [8]. The second generation of e-cigarettes, commonly referred to as "vape pens," emerged around 2010. These devices were larger, rechargeable, and featured refillable e-liquid tanks. They provided users greater control over vapor production and nicotine concentration, Soon after, third generation "mods" and fourth-generation "pod systems" were developed, incorporating adjustable wattage, temperature control, and a wide range of flavors These innovations transformed vaping into a global lifestyle trend, especially among younger demographics [9]. Parallel to the technological evolution, the composition of e-liquids diversified. Initially, formulations included nicotine, propylene glycol, and glycerin. Over time, thousands of flavoring agents were introduced, ranging from fruit and candy to menthol and cola. Although these flavors increased product attractiveness, they also raised public health concerns regarding youth initiation and potential toxicity from inhaled flavoring chemicals. The World Health Organization (WHO) and other regulatory bodies began highlighting these risks, prompting several countries to tighten controls over e-cigarette advertising and sales [10]. In India, e-cigarettes appeared in urban markets and online stores around 2010. At first, there were no specific regulations, and devices were often promoted as safe smoking alternatives. However, growing public health concerns soon led to increased scrutiny, Reports from the Indian Council of Medical Research (ICMR) and the Ministry of Health and Family Welfare (MoHFW) emphasized the lack of evidence supporting the safety or efficacy of ecigarettes for smoking cessation. In 2019, India took a decisive stance by implementing the Prohibition of Electronic Cigarettes Act (PECA), banning the production, import, sale, and advertisement of e-cigarettes nationwide [11]. The Indian government's decision was based on the recognition that e-cigarettes could serve as a gateway to nicotine addiction, particularly among youth. The ban positioned India among the first major countries to take a comprehensive legal approach against vaping products. Despite this, challenges persist in curbing illegal imports and online sales, Continuous awareness campaigns and strict enforcement remain crucial to ensuring that vaping does not re-emerge as a social trend among adolescents. Globally, the history of ecigarettes reflects both innovation and controversy. While proponents emphasize their potential role in harm reduction, critics highlight the risks of dual use (vaping alongside smoking), youth addiction, and long-term health uncertainties. The evolution of e-cigarettes demonstrates how rapidly technology can outpace public health regulation. For countries like India, the lesson lies in maintaining proactive surveillance, promoting public awareness, and aligning tobacco control policies with emerging global evidence. In summary, the development of e-cigarettes from a 1960s prototype to a global phenomenon illustrates a complex intersection of science, commerce, and public health.

Types of Electronic Cigarettes

Electronic cigarettes (e-cigarettes), also known as Electronic Nicotine Delivery Systems (ENDS), have undergone significant technological evolution since their introduction in the early 2000s. This evolution has resulted in a wide range of devices that vary in design, nicotine delivery efficiency, and user experience. The classification of e-cigarettes can be broadly based on device design, generation of technology, nicotine delivery mechanism, and user customization features. Understanding these types is crucial for assessing their health effects, market dynamics, and regulatory challenges.

Fig 2. Types of Electronic Cigarette

DOI: 10.48175/IJARSCT-32214

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First Generation: "Cigalikes"

The first generation of e-cigarettes, commonly referred to as cigalikes, were designed to closely resemble conventional cigarettes in both appearance and use. They were the earliest form of commercially available e-cigarettes and generally consisted of a small battery, an atomizer, and a cartridge containing e-liquid. The term "cigalike" was coined because of their physical similarity to tobacco cigarettes and their simplicity of use users could inhale directly from the device without the need for any prior setup. These devices were typically disposable or semi-disposable. Some models had replaceable cartridges while others were single-use. Cigalikes used automatic batteries that activated upon inhalation and produced limited vapor volume. Nicotine was delivered inconsistently due to small battery capacity and weak atomizer performance, making the nicotine absorption rate much lower than that of traditional cigarettes. Despite their limitations, cigalikes gained popularity among early adopters and individuals attempting to quit smoking, as they mimicked the physical act of smoking while reducing exposure to certain combustion-related toxicants. However, as technology advanced, users demanded devices with higher vapor production and more control over nicotine delivery, leading to the evolution of the second generation [12].

Second Generation: "Vape Pens"

The second generation of e-cigarettes, known as vape pens, emerged around 2010. These devices were larger and resembled fountain pens or markers, offering improved performance and longer battery life compared to cigalikes. Vape pens introduced refillable tanks (clearomizers) that allowed users to manually refill e-liquid, reducing operational costs and environmental waste. Vape pens operated using a manual activation button and rechargeable lithium-ion batteries, allowing for better control over vapor production. The use of wick-and-coil heating systems improved acrosol generation, resulting in higher nicotine delivery per puff. This generation marked the beginning of user customization different coil resistances, voltages, and e-liquid nicotine concentrations allowed users to tailor their vaping experience. Flavors became an essential selling point for vape pens, with thousands of varieties emerging globally. These included fruit, dessert, mint, and beverage-inspired options. However, such flavor availability led to public health concerns due to increased youth attraction. Several Indian and international studies indicated that flavored e-cigarettes were disproportionately preferred by adolescents and young adults, contributing to experimental use and eventual nicotine dependence [13]

Third Generation: "Mods" or "Advanced Personal Vaporizers (APVs)"

The third generation of e-cigarettes, often referred to as "mods" (short for modifications) or Advanced Personal Vaporizers (APVs), represented a significant technological leap. Mods were larger, bulkier devices with removable batteries, variable wattage, and adjustable airflow systems. They allowed users to modify almost every aspect of vaping from power output to coil resistance resulting in massive vapor clouds and intense throat hits. Mods typically used sub-ohm coils (resistance below 1 ohm), which produced more vapor and delivered higher doses of nicotine or flavor per puff. Many enthusiasts began engaging in "cloud chasing," a recreational activity where users compete to produce large vapor clouds. While this culture contributed to the social popularity of vaping, it also raised health concerns due to excessive inhalation of aerosolized substances. Another significant feature introduced in mods was temperature control technology, which helped prevent overheating and the production of harmful carbonyl compounds such as formaldehyde. Despite these safety advancements, improper use or modification by inexperienced users sometimes resulted in battery explosions or overheating incidents, leading to regulatory scrutiny. In India, before the 2019 ban, mod-style devices were available in urban vape shops and online markets, attracting both hobbyists and smokers seeking customizable nicotine delivery. However, the higher vapor production and stronger nicotine doses increased dependence potential, raising public health alarms [14].

Fourth Generation: "Pod Systems"

The latest evolution in e-cigarette technology is represented by pod-based systems. These compact devices use pre-filled or refillable pods instead of tanks, offering convenience, portability, and ease of use. The JUUL system, introduced in 2015, revolutionized the e-cigarette market globally. It employed nicotine salt e-liquids, which allowed for smoother inhalation of higher nicotine concentrations, closely mimicking the nicotine hit of traditional cigarettes. Pod systems are small, lightweight, and discreet, making them particularly attractive to students and young adults. However, their high nicotine delivery efficiency has sparked significant concern among regulatory bodies. In India, although JUUL and similar products were not officially launched, imported and counterfeit variants became available online prior to the national ban. Pod systems marked a major shift in the nicotine landscape, leading to widespread youth experimentation in countries like the United States and raising fears of a similar trend in India. Research suggests that the combination of flavor availability, modern design, and nicotine salt formulation contributes significantly to youth initiation and continued use [15].

Market and Regulatory Overview

Globally, e-cigarettes are marketed under thousands of brand names, varying in design, power output, and e-liquid formulations. The market is dominated by companies such as JUUL, Vuse, Blu, and SMOK. In India, prior to the 2019 ban, major urban centers like Delhi, Mumbai, and Bengaluru witnessed a rapid growth of vape stores and online sales platforms offering a wide array of devices. However, the Indian government's decision to prohibit e-cigarettes under the Prohibition of Electronic Cigarettes Act (PECA), 2019, curtailed their formal availability. The Act classified all ENDS products including e-hookahs and heat-not-burn devices as illegal for sale, manufacture, and import. Despite the ban, occasional online availability of imported pods and disposable vapes persists, posing regulatory enforcement challenges. Public health experts in India have emphasized that understanding the types and technical features of e-cigarettes is vital for policymaking, surveillance, and educational campaigns. Identifying devices that deliver higher nicotine concentrations or appeal to youth can aid in framing targeted interventions to reduce experimentation and addiction [16].

Mechanism of Nicotine Delivery:

The mechanism of nicotine delivery through electronic cigarettes (e-cigarettes) is fundamental to understanding their pharmacological impact, addiction potential, and risk profile. Nicotine is the principal psychoactive compound responsible for the reinforcing effects of smoking, and its delivery dynamics greatly influence user satisfaction and dependence. In e-cigarettes, nicotine is aerosolized and inhaled rather than combusted, and this process involves several technological and physiological stages, including aerosol generation, absorption through the respiratory tract, and systemic distribution. Studies have reported that the aerosolized particles generally range between 100 and 600 nanometers, enabling them to penetrate deep into the pulmonary alveoli where rapid absorption into the bloodstream occurs [17]. Device design features play a crucial role in determining the amount of nicotine delivered per puff. Variations in coil resistance, battery voltage, and airflow mechanisms directly influence the heat generated and the density of aerosol produced. Low-resistance coils, often termed sub-ohm coils, allow higher current to pass through, producing greater heat and larger vapor volumes, which in turn enhance nicotine delivery. Devices with adjustable wattage or voltage settings further allow users to control vapor density and nicotine yield. However, higher temperatures may also promote the formation of thermal degradation byproducts such as formaldehyde and acrolein, which can pose toxicological risks. The Central Drugs Standard Control Organization (CDSCO) in India reported that depending on design parameters, e-cigarettes can deliver nicotine doses ranging from 0.5 mg to over 2 mg per puff, illustrating the variability introduced by device engineering [18]. Once the aerosol is inhaled, nicotine absorption primarily occurs through the lungs, with additional uptake via oral and nasal mucosa. The alveolar region of the lungs provides a vast surface area with rich capillary networks, allowing rapid diffusion of nicotine into the bloodstream. Within 5 to 10 minutes after inhalation, nicotine concentrations in plasma typically reach peak levels. A smaller

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ISSN: 2581-9429 Volume 6, Issue 7, March 2026 Impact Factor: 8.2

proportion of aerosol deposits in the upper airways and oral cavity, where nicotine is absorbed more slowly through mucosal tissues. After systemic absorption, nicotine is distributed throughout the body and crosses the blood brain barrier within seconds. It binds to nicotinic acetylcholine receptors in the brain, stimulating dopamine release, which reinforces rewarding sensations and promotes dependence. Hepatic metabolism, primarily via the cytochrome P450 enzyme CYP2A6, converts nicotine to cotinine, the main metabolite used to measure exposure in biological studies [20]. User behavior also significantly modulates nicotine delivery. Unlike cigarette smokers, e-cigarette users can alter puff duration, inhalation depth, and puff frequency to control nicotine intake. Longer and more frequent puffs increase aerosol production and maintain coil temperature, leading to higher nicotine yields. Behavioral adaptation or self-titration, where users unconsciously modify their puffing patterns to achieve desired nicotine satisfaction, is commonly observed. Findings from the National Institute of Mental Health and Neurosciences (NIMHANS) indicate that experienced users often extend their puff duration over time, resulting in substantially higher plasma nicotine levels than estimated by device specifications [21]. Such behavioral flexibility makes it challenging to standardize nicotine exposure among e-cigarette users. When compared to conventional cigarettes, the efficiency of nicotine delivery from e-cigarettes varies depending on the device type and usage pattern. Traditional cigarettes generally yield about 1 to 2 mg of absorbed nicotine per stick, while e-cigarettes may deliver between 0.5 and 2.5 mg per vaping session. Early cigalike models produced substantially lower plasma nicotine levels, leading to limited satisfaction among smokers seeking alternatives. However, third-generation devices and modern pod systems have achieved delivery efficiencies approaching those of combustible cigarettes. A comparative pharmacokinetic study conducted by the all India Institute of Medical Sciences (AIIMS) revealed that while older devices provided slower and less intense nicotine absorption, newer models with optimized coils and nicotine salt formulations produced plasma nicotine peaks nearly equivalent to traditional smoking. Despite the absence of combustion-related toxins, the physiological consequences of nicotine exposure such as increased cardiovascular workload, oxidative stress, and neural adaptation remain concerning [22].

Pharmacokinetics of Nicotine via Electronic Cigarettes

Pharmacokinetics describes how a substance is absorbed, distributed, metabolized, and eliminated by the body. In the case of nicotine, pharmacokinetics determine the intensity, duration, and reinforcing effects that lead to dependence. The pharmacokinetic profile of nicotine delivered through electronic cigarettes (e-cigarettes) is influenced by multiple factors such as device design, aerosol characteristics, puffing behavior, and the chemical form of nicotine used in the e-liquid. Although the fundamental processes resemble those associated with traditional cigarette smoking, several differences exist in absorption rate, plasma nicotine concentration, and systemic clearance patterns. Understanding these distinctions is crucial for evaluating the addictive potential and health risks of e-cigarette use. When an e-cigarette is activated, the heating element vaporizes the e-liquid, producing an aerosol of fine droplets containing nicotine and solvents such as propylene glycol and vegetable glycerin. Upon inhalation, these particles enter the respiratory tract, and nicotine is rapidly absorbed across the alveolar epithelium into the pulmonary circulation. The lung provides a large surface area and thin alveolar membrane, enabling efficient diffusion of nicotine into the bloodstream. This mechanism mirrors that of combustible cigarette smoke, although the rate and magnitude of absorption depend heavily on particle size, vapor concentration, and the nicotine concentration of the e-liquid. Studies have shown that optimal particle size for alveolar absorption lies between 100 and 500 nanometers, a range typically achieved by modern pod systems and sub-ohm devices [23]. Once in the bloodstream, nicotine rapidly distributes throughout body tissues, particularly in the brain, where it binds to nicotinic acetylcholine receptors (nAChRs). This receptor activation triggers the release of dopamine, serotonin, and other neurotransmitters that contribute to the sensation of pleasure and reward. The time taken to reach peak plasma nicotine concentration, often referred to as Tmax, is a critical determinant of the addictive potential of any nicotine-containing product. Conventional cigarettes usually achieve peak levels within 5-7 minutes, whereas early generation e-cigarettes required up to 20-30 minutes due to lower aerosol production and inefficient delivery systems. However, with the advent of nicotine salt formulations and high-efficiency pod systems, the Tmax for e-cigarettes has reduced to under 10 minutes, approximating that of traditional smoking [24]. This improvement has significantly increased their capacity to induce dependence, especially among first-time users. Nicotine absorption also occurs through the oral mucosa and upper airways when aerosol droplets deposit in these regions during inhalation. This pathway contributes to slower but sustained nicotine uptake, prolonging systemic exposure. The combined pulmonary and mucosal absorption results in biphasic plasma nicotine levels: an early sharp rise from alveolar diffusion followed bya prolonged phase from mucosal absorption. This pharmacokinetic pattern is one reason users report both immediate satisfaction and prolonged craving suppression after vaping. The total nicotine dose absorbed per session depends not only on the concentration in the e-liquid but also on user behavior longer puff duration, deeper inhalation, and higher puff frequency all enhance systemic delivery. Observational studies in India have shown that experienced users often modify their puff profiles to maintain plasma nicotine levels comparable to smokers, a behavior consistent with nicotine self-titration [25]. Following absorption, nicotine undergoes extensive distribution across highly perfused tissues such as the brain, liver, and kidneys. The compound is lipophilic and easily crosses biological membranes, including the blood brain barrier and the placenta. The apparent volume of distribution (Vd) for nicotine averages 2-3 L/kg, indicating wide tissue penetration. Once inside the central nervous system, nicotine's interaction with nAChRs not only mediates acute psychoactive effects but also triggers long-term neuroadaptations responsible for tolerance and dependence. The reinforcement cycle created by repeated receptor activation explains why frequent e-cigarette use can rapidly lead to addiction even in individuals who have never smoked before. This has been of particular concern in India, where young adults and college students are among the most frequent users of modern pod devices [26]. Metabolism of nicotine occurs predominantly in the liver via cytochrome P450 enzymes, primarily CYP2A6 and, to a lesser extent, CYP2B6 and CYP2E1. The major metabolite formed is cotinine, which accounts for more than 70% of nicotine's metabolic products and serves as a reliable biomarker for nicotine exposure in biological fluids such as plasma, saliva, and urine. The metabolic conversion of nicotine to cotinine involves oxidation followed by conjugation with glucuronic acid, facilitating excretion. The average plasma half-life of nicotine is approximately two hours, while cotinine exhibits a longer half-life of about sixteen hours, making it a suitable indicator of chronic exposure. Comparative metabolic studies indicate that e-cigarette users show similar nicotine half-lives to smokers, suggesting comparable hepatic metabolism pathways despite differences in delivery mechanisms (27). Elimination of nicotine and its metabolites occurs primarily through renal excretion. Urinary pH significantly affects the excretion rate acidic urine enhances ionization and facilitates faster clearance, whereas alkaline urine prolongs retention. Chronic use of high-nicotine e-cigarettes may lead to accumulation of cotinine and minor metabolites such as trans-3hydroxycotinine and nicotine-N-oxide, reflecting sustained systemic exposure. Additionally, gender, genetic polymorphisms in CYP2A6, and concurrent use of medications or alcohol can influence nicotine clearance rates. Indian pharmacogenetic studies have identified interindividual variability in nicotine metabolism, with slower metabolizers showing greater dependence tendencies and higher withdrawal severity when abstaining [28]. The overall pharmacokinetic profile of e-cigarettes varies across different device generations. First-generation cigalikes deliver relatively low nicotine concentrations with gradual absorption, leading to suboptimal satisfaction and limited substitution potential for smokers. Second-generation vape pens improve efficiency through higher power output and refillable tanks, resulting in faster absorption and higher plasma nicotine peaks. Third-generation mods and sub-ohm devices can deliver nicotine doses comparable to or exceeding traditional cigarettes, particularly when combined with nicotine salt formulations. Fourth-generation pod systems, exemplified by JUUL and similar devices, provide rapid systemic absorption with plasma nicotine levels equivalent to or higher than combustible products, making them particularly concerning from an addiction standpoint. Data from the Indian Council of Medical Research suggest that pod users achieve peak plasma concentrations between 15 and 25 ng/mL. within ten minutes of use, values nearly identical to those of cigarette smokers [29]. Understanding the pharmacokinetics of nicotine delivered via e-cigarettes has major public-health and regulatory implications. The efficiency and rapidity with which nicotine is absorbed determine not only the potential for addiction but also cardiovascular and neurological risks. Rapid spikes in plasma nicotine can increase heart rate, blood pressure, and catecholamine release, contributing to sympathetic activation and potential cardiovascular strain. Chronic exposure

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 6, Issue 7, March 2026 Impact Factor: 8.2

alters brain reward circuitry and enhances tolerance, making cessation more difficult. For these reasons, the similarity in pharmacokinetic behavior between advanced e-cigarettes and traditional cigarettes challenges the perception that vaping is a safer alternative. It emphasizes the need for strict control over nicotine concentration in e-liquids, user education, and enforcement of national policies such as

India's 2019 Prohibition of Electronic Cigarettes Act. In conclusion, the pharmacokinetic behavior of nicotine via e-cigarettes encompasses rapid pulmonary absorption, extensive distribution, hepatic metabolism to cotinine, and renal elimination. Modern e-cigarette designs have significantly improved nicotine delivery efficiency, achieving plasma levels and absorption rates comparable to combustible cigarettes. While the absence of tar and carbon monoxide may reduce certain toxic exposures, the underlying addictive potential driven by nicotine pharmacokinetics remains virtually unchanged. Comprehensive understanding of these pharmacokinetic dynamics is essential for healthcare providers, policymakers, and researchers working toward effective tobacco harm-reduction and cessation strategies.

Advantages of Electronic Cigarettes

Electronic cigarettes (e-cigarettes) have been promoted as a potentially less harmful alternative to traditional tobacco products. Their development was driven by the desire to reduce exposure to toxic combustion by-products while maintaining nicotine delivery for smokers. Although debates on their long-term safety continue, several advantages have been reported by researchers and public health experts.

1. Reduced Exposure to Harmful Chemicals

E-cigarettes operate by vaporizing a liquid containing nicotine, propylene glycol, and flavoring agents rather than burning tobacco. This eliminates combustion, which is the primary source of toxicants in cigarette smoke, such as tar, carbon monoxide, and polycyclic aromatic hydrocarbons. Consequently, users are exposed to significantly lower concentrations of carcinogens and toxins compared to traditional smoking [30].

2. Harm Reduction and Smoking Cessation Aid

E-cigarettes have been widely discussed as tools for tobacco harm reduction and smoking cessation. For chronic smokers who struggle to quit, switching to vaping can lower toxic exposure while addressing both the behavioral and psychological aspects of addiction. The hand-to-mouth action, inhalation sensation, and visual cues associated with vaping mimic the smoking experience, helping smokers gradually transition away from cigarettes [31]. Randomized clinical trials have shown that e-cigarettes can be as effective as or even superior to nicotine replacement therapies such as patches or gums. In India, some tobacco cessation centers reported that smokers who adopted e-cigarettes demonstrated higher quit rates than those using traditional nicotine therapies [32].

3. Reduced Second-Hand Smoke Exposure

Traditional cigarettes are a significant source of second-hand smoke (SHS), which contributes to passive smoking-related diseases such as asthma and cardiovascular disorders among nonsmokers. E-cigarettes, on the other hand, emit an aerosol rather than smoke. This aerosol primarily consists of water vapor and trace amounts of volatile compounds, resulting in much lower levels of environmental contamination [33].

4. Economic and Environmental Advantages.

E-cigarettes may offer cost savings in the long term. Although the initial investment in a vaping device can be relatively high, the recurring cost of e-liquids and maintenance is generally lower than the cost of purchasing cigarettes regularly [34].

5. Controlled Nicotine Intake and Flavor Options

E-cigarettes provide users with the flexibility to choose e-liquids of varying nicotine concentrations, ranging from nicotine-free to high-strength formulations. This enables users to tailor their intake according to their dependence level and even gradually taper down nicotine consumption [35].

DOI: 10.48175/IJARSCT-32214

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Volume 6, Issue 7, March 2026
Impact Factor: 8.2

6. Reduced Odor and Greater Social Acceptance

Unlike cigarette smoke, which leaves a persistent odor on clothes, hair, and surroundings, ecigarette vapor dissipates quickly and typically carries mild or pleasant scents depending on the flavor used. This characteristic makes vaping more socially acceptable, particularly in family and professional environments where smoking is stigmatized [36].

7. Absence of Tar and Improved Respiratory Outcomes

One of the key harmful substances in cigarette smoke is tar, which contributes to chronic lung diseases such as bronchitis and emphysema. Since e-cigarettes operate without combustion, they eliminate tar exposure entirely [37].

8. Technological Adaptability and Safety Features

Modern e-cigarette devices are technologically advanced and include safety features such as temperature control, puff counters, and short-circuit protection. These innovations help prevent overheating and accidental exposure to high temperatures. Some devices also connect to mobile apps, allowing users to monitor nicotine consumption, track progress, and set reduction goals [38]

9. Potential for Tobacco Harm Reduction Policies

From a public health perspective, e-cigarettes may play a role in comprehensive tobacco control strategies when regulated effectively. Countries such as the United Kingdom have integrated e cigarettes into harm reduction policies, showing a decline in smoking prevalence as adult smokers shift to vaping. Although India banned the sale and advertisement of e-cigarettes under the 2019 Prohibition of Electronic Cigarettes Act, ongoing discussions among researchers suggest that controlled medical supervision could help assess their benefits for chronic smokers resistant to quitting. Such policy-level evaluations must balance harm reduction with youth protection to maximize public health outcomes [30][31][38].

Disadvantages and Health Risks of Electronic Cigarettes

Although electronic cigarettes (e-cigarettes) have gained popularity as alternatives to conventional tobacco products, growing evidence highlights significant health risks and disadvantages associated with their use. These concerns relate not only to the chemical composition and physiological effects of e-cigarette aerosols but also to social, behavioral, and policy implications. The notion that vaping is a completely safe alternative is increasingly being challenged by scientific studies and public health authorities.

1. Health Effects and Respiratory Risks

E-cigarette aerosols contain harmful substances such as formaldehyde, acetaldehyde, acrolein, and heavy metals, albeit in lower concentrations than conventional cigarettes. When inhaled repeatedly, these compounds can cause oxidative stress, inflammation, and cellular damage in the respiratory tract [39]. Studies have linked chronic e-cigarette use with symptoms of bronchitis, coughing, and reduced lung function, even among young, non-smoking users. Additionally, exposure to fine particulate matter and metal nanoparticles (including nickel, lead, and chromium) released from heating coils may induce pulmonary toxicity. A 2022 study from the All India Institute of Medical Sciences (AIIMS) reported early signs of airway inflammation and oxidative injury among daily Indian vapers [40]

2. Cardiovascular Concerns

Nicotine, regardless of its delivery method, exerts well-documented cardiovascular effects. It increases heart rate, blood pressure, and myocardial oxygen demand while promoting endothelial dysfunction and arterial stiffness [41]. E-cigarette aerosols may also contain ultrafine particles that enter systemic circulation and contribute to vascular inflammation. Experimental studies have shown acute elevations in sympathetic nervous activity following vaping sessions, leading to increased cardiac workload. Long-term use has been associated with heightened risks of hypertension and atherosclerosis. Indian cardiologists have expressed concern that e-cigarettes, though marketed as safer, can exacerbate cardiovascular disease in individuals with preexisting conditions [42].

3. Nicotine Addiction and Dependence

One of the most significant disadvantages of e-cigarettes is their potential to sustain or even intensify nicotine addiction. Modern devices deliver nicotine efficiently, often matching or exceeding the levels obtained from traditional cigarettes [43]. The use of nicotine salts in newer pod-based systems enhances absorption and provides a smoother throat hit, making them especially appealing to adolescents and first-time users. This easy and pleasurable delivery mechanism has led to widespread dependence, particularly among young populations. Behavioral surveys conducted in Indian universities revealed a rising trend of nicotine dependence among youth who had never smoked conventional cigarettes but started vaping recreationally [44].

4. Risk of Dual Use and Relapse

Many individuals who switch to e-cigarettes continue to smoke conventional cigarettes simultaneously, a behavior known as dual use. Dual users often maintain or even increase their overall nicotine exposure instead of reducing harm [45].

5. Toxic and Carcinogenic Exposure

Although e-cigarettes eliminate combustion, the vaporization process can still produce toxic byproducts. High-voltage devices may generate formaldehyde-releasing agents and acrolein, both known carcinogens [46].

6. Gateway to Youth Addiction

One of the most alarming issues with e-cigarettes is their appeal among adolescents. Attractive flavors, sleek designs, and social media marketing have contributed to a surge in experimentation among youth. Studies across Indian cities like Delhi, Mumbai, and Bengaluru have found that over 30% of students who had tried vaping had never smoked tobacco before [47].

7. Misleading Marketing and Lack of Regulation

The marketing of e-cigarettes often portrays them as safe, modern, and socially desirable. Such messages, especially when disseminated through social media platforms, mislead consumers about actual health risks [48].

8. Potential for EVALI and Acute Lung Injury

An outbreak of E-cigarette or Vaping-Associated Lung Injury (EVALI) in the United States in
2019 raised global concern over the safety of vaping. The condition was linked to vitamin E acetate and other additives in e-liquids that cause severe lung inflammation. Although large-scale EVALI cases have not been widely reported in India, isolated incidents of acute respiratory distress and hospitalization following e-cigarette use have been documented [49].

9. Environmental and Waste Concerns

While e-cigarettes reduce cigarette butt litter, they introduce new environmental issues through electronic waste. Disposable e-cigarettes and used pods contain lithium batteries, plastic casings, and residual e-liquids, which can contaminate soil and water if not disposed of properly [50].

10. Unclear Long-Term Health Impact

E-cigarettes are relatively new products, and comprehensive long-term studies are limited. The majority of available data focus on short-term outcomes, leaving uncertainties about chronic health consequences such as cancer, reproductive harm, or neurological disorders. Since many users are young, potential effects may not manifest for decades. Public health experts in India and globally caution that without extensive longitudinal research, claims of e-cigarette safety remain premature. The lack of consistent, long-term evidence underscores the need for ongoing surveillance and controlled clinical studies [41][45][48].

Regulatory Aspects and Factors Perspective of Electronic Cigarettes

The regulation of electronic cigarettes (e-cigarettes) varies widely across nations, reflectingdifferences in health priorities, public perception, and industry influence. In India, the government has adopted one of the world's strictest regulatory frameworks, emphasizing the prevention of nicotine addiction, particularly among youth. Understanding these regulatory aspects and factors influencing such policies helps clarify how nations balance public health protection with evolving harm-reduction debates.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 7, March 2026
Impact Factor: 8.2

1. Global Regulatory Overview

Globally, e-cigarette policies differ based on the classification of these devices as tobacco products, consumer goods, or pharmaceutical tools [51]. In the United States, the Food and Drug Administration (FDA) regulates e-cigarettes under the Tobacco Control Act, requiring manufacturers to obtain premarket approval before introducing new products. The European Union (EU) enforces the Tobacco Products Directive (2014/40/EU), limiting nicotine concentration (to 20 mg/mL), mandating child-resistant packaging, and restricting advertisements [52].

2. Indian Legal Framework

India has taken a preventive and prohibitive stance through the Prohibition of Electronic Cigarettes Act, 2019, banning the production, sale, import, and advertising of e-cigarettes [53]. The law aims to curb nicotine addiction and protect youth from potential health hazards. Key provisions include: Complete prohibition on all forms of e-cigarette trade. Penalties: Up to 1 year imprisonment or 21 lakh fine for first-time offenders; up to 3 years and 25 lakh fine for repeat offenses. Seizure and search powers granted to authorized officers. The government based its decision on recommendations from the Indian Council of Medical Research (ICMR) and Ministry of Health and Family Welfare, citing insufficient scientific evidence of e-cigarettes as safe cessation aids [54].

3. Public Health and Policy Rationale

The Indian government's policy is grounded in a precautionary public health approach, prioritizing population safety over unverified harm-reduction claims. The main policy drivers include [55]: Preventing youth initiation and nicotine dependence. Addressing misleading marketing targeting students and young adults. Limiting exposure to toxic chemicals in e-liquids. Upholding commitments to the WHO Framework Convention on Tobacco Control (FCTC). India's policy aligns with WHO-SEARO recommendations urging developing nations to restrict electronic nicotine delivery systems until sufficient evidence confirms their long-term safety [56].

4. Enforcement and Practical Challenges

Despite the legal ban, practical enforcement faces several obstacles Online sales and covert imports continue through social media and e-commerce platforms. Lack of technical expertise among enforcement officers to identify vaping products. Uneven state-level enforcement, with differing interpretations of the Act. Black market expansion, driven by consumer curiosity and limited awareness of legal consequences [57].

5. International and Ethical Perspectives

Internationally, regulatory strategies vary between restrictive and harm-reduction-oriented approaches. Countries like India, Thailand, and Brazil emphasize prohibition to safeguard public health, while UK and New Zealand support controlled availability as cessation aids [58]. From an ethical perspective, India's stance reflects a population-centered precautionary principle. prioritizing societal welfare over individual freedom of choice. Surveys in Indian cities indicate that over 70% of adults support the ban, perceiving it as necessary to protect youth from nicotine addiction [59].

II. CONCLUSION

Electronic cigarettes have emerged as a significant development in the field of nicotine delivery systems, offering both opportunities and challenges for public health. While they were initially introduced as a safer alternative to conventional smoking, scientific evidence increasingly highlights their potential health risks, particularly concerning nicotine dependence, respiratory harm, and cardiovascular effects. The perception of e-cigarettes as harmless has contributed to their rapid popularity, especially among youth, raising serious concerns about long-term addiction and gateway behavior toward tobacco use. In the Indian context, the government's strong regulatory stance through the Prohibition of Electronic Cigarettes Act, 2019 reflects a preventive approach focused on safeguarding public health rather than promoting harm reduction. Despite enforcement challenges, this policy underscores India's commitment to controlling nicotine addiction and preventing the re- normalization of smoking behavior. Overall, the review indicates that while e-cigarettes may pose fewer immediate toxic risks compared to traditional cigarettes, they are far from risk-free. A balanced understanding of their pharmacological, behavioral, and societal impacts is essential for informed policymaking. Public awareness, strict enforcement, and continued research are crucial to mitigating potential harm and ensuring that public health remains the top priority in addressing the global challenge of electronic cigarette use.

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