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Overview of e-Cigarettes and e-Liquids

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ABSTRACT

Electronic cigarettes (ENDS) were introduced to the market particularly for addicted smokers to quit the habit of conventional tobacco smoking. The process behind e-cigarettes is heating an e-liquid/juice using a battery to generate an aerosol or vapor. There are four generations of electronic cigarettes in the market; cigar like, tanks, mods and pods. The evolution of these models of electronic cigarettes has affected the young generation for two decades. Most electronic cigarette manufacturers add nicotine, flavors, other addictive chemicals and sometimes illicit products to e-liquids; thus, e-cigarettes have become a global health issue. Scientists have revealed that the content of e-liquids can create many long-term and short-term health problems including EVALI. Thus, many countries are in the process of regulating the market of electronic cigarettes. e-Cigarettes are new to the Sri Lankan society and they can be easily embraced by the younger generation due to unawareness of the dark side of these products. In this overview, components of e-cigarettes, chemicals present in e-liquids, generation of e-cigarettes, growth of e-cigarette market, and health concerns associated with vaping of e-cigarettes are presented.

Introduction

Since 1950s, the smoking of tobacco has risen as a habit that reflected the status and emotions to others, until scientists revealed the dangers of it. One tobacco cigarette consists of or produces more than 50 toxic chemicals [1,2]. Some toxic chemicals include alkaloids (nicotine, anatabine); non-volatiles: 4-(N-nitroso-N-methyl aminobutyric acid); volatiles: (N-nitrosoethylmethyl amine, N-nitrosodiethylamine); polyaromatic hydrocarbons (PAHs), acetonitrile, acrylonitrile, and heavy metals, Pb, As, Cd etc. [2].

More people are dying from conventional tobacco smoking than from wars, accidents, and natural disasters. Thus, the introduction of Electronic Nicotine Dispensing Systems (ENDS), commonly known as electronic cigarettes (e-cigarettes), is considered as a "savior" for addicted tobacco smokers [3]. They appeared on the market more than a decade ago. Nowadays e-cigarettes are available in Sri Lanka and public awareness is mandatory before it becomes a threat to our younger generation.

Conventional puff to electronic puff

Tobacco cigarettes are simply known as conventional cigarettes. All types of tobaccos (e.g., cigar, pipes, smokeless tobacco - chewing tobacco and snuff) are dangerous. It is a famous secret that these cause all kind of health risks including; cardiovascular diseases, lung diseases, cancers,

infertility, miscarriages, low bone density, gum diseases, tooth loss, immune system dysfunction, sexual impotence in men, increase risk for hip fracture in women etc. [2,4].

According to World Health Organization, smokers are more susceptible to be infected by both bacteria and viruses. Therefore, Covid 19 virus can easily affect the smoker's weak respiratory and immunity systems due to his/her smoking behaviors such as smoker's hand to mouth action, sharing of pipes etc. [5].

e-Cigarettes and vaping are novel alternatives for ex-smokers and smokers who want to give up smoking. Most of these devices have in-built tank or cartridge, and the nicotine levels can be changed according to the nicotine doses prescribed by the doctor. The ultimate goal of using e-cigarettes is to quit the more harmful tobacco smoking forever. However, nowadays, most of the non-smokers specially teenagers are trying out e-cigarettes due to peer pressure and get themselves exposed to this dangerous experiment. Vaping can lead to nicotine addiction and increased risk for addiction to other drugs.

What is an "e-cigarette"?

Vaping is the inhalation of a heated aerosol (i.e., vapor). e-Cigarette is a hand-held electronic device that can produce an aerosol by heating an "e-liquid"

using a battery. Vaping is probably safer than combustible tobacco use, although the long-term health impacts of vaping are unknown [3].

There are more than 7000 flavored e-liquids available in the market [3,6] and fruit and mint flavors are popular among US youth [7]. JUUL (USA) is the leading company that provides more than 19% of e-cigarettes and related products to the global market. e-Cigarettes are produced by more than 400 companies all over the world (e.g., China - Aleadar, Artery, Asvape, Ovanty, Freemax, Eleaf, VooPoo, Wismec, Rincoe, Mimo; USA - Asmodus, dotMod, Hexohm, Vgod, Volta; UK - Nanostix, Relx, RevTech; Korea - Just fog, Lil; Malaysia - NCIG; Taiwan - Suorin etc.) [8].

Components of an e-cigarette

An e-cigarette is composed of five main parts; mouthpiece, e-liquid chamber, battery, atomizer and a switch [9,10].



Figure 1 Main components of an e-cigarette

(<https://www.vapebrothers.com/in-focus/what-is-an-electronic-cigarette/>)

The atomizer plays a vital role in energy transition and making the aerosols. That means it transmits and converts electricity (which is supplied by a battery) into heat. Sometimes, heating wires (e.g., nichrome, pure Ni and Ti, stainless steel etc.) act as atomizers and these may enhance the metal toxicity [9,10].

There are several techniques that can be used to produce the vape, such as dripping, dabbing etc. Dripping method is the most common technique applied in many e-cigarettes, since it gives a thick aerosol cloud, a stronger throat hit and an intense flavor. In this method, e-liquid drips directly on to the heating coil. Generally, the cotton wool-like material (ekowool, silica fiber, and rayon fibers) called "wick" is soaked by the e-liquid, thus facilitating dripping. Dabbing is one of the methods that produce vapor from cannabis [10].

Evolution of e-cigarette

All e-cigarettes can be categorized into four generations (Figure 2). The first generation of e-cigarettes appeared like a ciga. Its cartridge and

atomizer are molded into one piece; thus, it is known as cartomizer. This type of e-cigarettes is reusable [9,10].



- (A) - 1st Generation - Disposable/cig like
 (B) - 2nd Generation - Medium size/rechargeable/refillable
 (C) - 3rd Generation - MOD
 (D) - 4th Generation - POD

Figure 2 Four generations of e-cigarettes

(<https://www.ncbi.nlm.nih.gov/books/NBK555596/figure/ch6.fig1/>)

Tank type e-cigarettes belong to the second generation. This product is composed of more attractive features such as having a battery with larger capacity which can be controlled by on/off switch, separate refillable e-liquid cartridge etc. This is much effective towards the cessation of smoking as the nicotine concentration can be reduced by varying the heat generated by the power output [9,10].

"MOD" (modified or modular e-cigarette) represents the third generation of e-cigarettes and it consists of adjustable atomizer, cartridge and modifiable battery which can adjust the voltage. This refillable and rechargeable mod can control the release of aerosol. But the main disadvantage of this product is production of carcinogenic carbonyls by hotter e-liquids [8-10].

Fourth generation is represented by "POD". Its battery, atomizer and mouthpiece are combined into one piece, and cartridge is replaceable. It produces higher nicotine concentration compared to that of mods, even though it generates less carbonyl content as it needs less power [7,9]. Pods are popular among young people in US, while adults and older people in England prefer tanks [9].

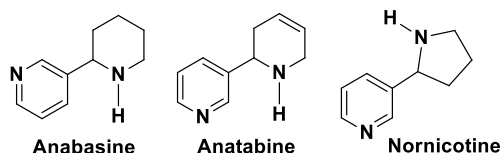
Constituents of "e-liquid"

Main constituents that can be found in an e-liquid are,

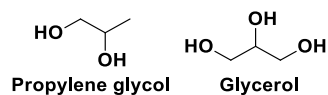
- Propylene glycol or glycerine (solvent)
- Nicotine (not always)
- Particles - Silicate (size < 2.5 μm , e.g., PM_{2.5}) [3]
- Heavy metals - Pb, Cr, Ag, Ni, Al, Sn

- Flavorings (e.g., taste like menthol, mint, clove or spice, alcohol (wine, cognac), candy, fruit, chocolate, etc.) [3, 7]

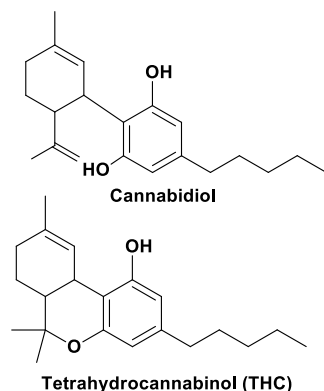
The other constituents found in the vape are aldehydes (acetaldehyde or formaldehyde), alkaloids (anabasine, anatabine, nornicotine), butadiene, diacetyl and acetyl propionyl, ethanol, N-nitrosamine, polyaromatic hydrocarbons, propylene glycol, glycerin sucrose, propyleneoxide, flavors (menthol), volatile organic compounds (VOCs) (methanol, ethanol, acrylamide, acrylonitrile, benzene, acrolein, pyrazine, pyridine, styrene, toluene, xylene), vanillin, limonene, and vitamin-E acetate [3,11-15].



Generally, propylene glycol and vegetable glycerin or glycerol play the role of the solvent in e-liquid [5,12,16].



Sometimes e-liquid may contain cannabidiol, tetrahydrocannabinol (THC), or synthetic cannabinoids [10].

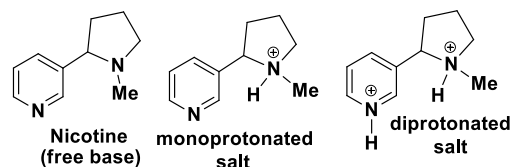


Cannabis oil (hash oil) can be extracted by using different organic solvents such as naphtha, petroleum ether, olive oils etc. It is added to e-liquids containing limonene or lecithin to enhance the miscibility and to mask the characteristic strong odor of the cannabis oil [10].

Nicotine and Nicotine Salt

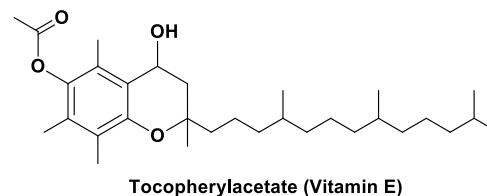
Nicotine is one of the most addictive chemicals to human beings and it is a weak base ($pK_a = 8$), which is capable of producing excessive metabolites in the liver. Nicotine stimulates the adrenal glands to release the hormone epinephrine (adrenaline) which increases the levels of a chemical messenger in the

brain called dopamine. In a conventional tobacco cigarette, 10-15 mg of nicotine is present while 6-24 mg/ml in an e-cigarette. According to EU-TPD (European Tobacco Product Directive) regulation limits, maximum nicotine concentration in an e-liquid should be 20 mg/ml [9]. Some researchers have revealed that e-cigarette companies are misleading the society by displaying less nicotine concentrations on their labels than the actual nicotine concentration present in the e-liquid. Reports suggest that non-nicotine e-liquids can also be topped up with nicotine shots [3,11].

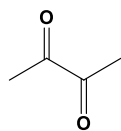


Not only nicotine stimulates the release of adrenaline but also increases the blood pressure. Dizziness, irregular and disturbed sleep, depression, anxiety, indigestion, diarrhea, dry mouth and nausea are common symptoms of the nicotine toxicity. Nicotine can go through to a child from a breastfeeding mother as it circulates through the blood stream. Hence, the child will suffer from restless, rapid increase of heartbeat, vomiting, interrupted sleep and diarrhea [11,12,17].

Vitamin-E or Tocopherol acetate is another component present in illicit e-liquids. Though Vitamin-E is safe to use as a dermatological product (skin cream) and in food, the vape of vitamin-E may turn into a sticky oil substance inside the lungs. e-Liquids containing Marijuana oil can be potentially fatal [13].



PM_{2.5} sized particles (particles that are 2.5 microns or less in diameter) in e-liquids can pass through the air sacs and circulate in the body causing heart attacks, lung cancer and asthma. Heavy metals and other VOCs are bio-hazards. Components in e-cigarette aerosols can interact with each other to produce harmful substances such as formaldehyde, acetaldehyde etc. Diacetyl is a food sweetener which is not harmful to the digestive system but its vapor can cause "popcorn worker's lung disease". Recently scientists have discovered that e-cigarettes are causative to cytotoxicity, diseases in pulmonary and cardiovascular systems etc. [11,14,15,22,23]. Passive vaping may cause short term lung obstructions [14,16].



Diacetyl

JUUL was the first company that introduced the nicotine salt, instead of free-base nicotine. Newly arrived Pods contain nicotine salts produced by mixing nicotine and benzoic acid [12]. It has a pH similar to the extravascular fluid in the lung, thus, puffs with higher concentration of nicotine can be taken in without any throat irritation. Nicotine salts are found to be more harmful than free-base nicotine, because they increase the absorption of nicotine into the blood stream immediately [12].

Global Threat

The global market for e-cigarettes has multiplied from around 50 million USD in 2005 to over 20 billion in 2019 and is expected to grow to 34 billion by 2024 [18]. Today, e-cigarette companies are targeting teenagers and they are introducing eye-catching e-cigarette models with different flavors [12,19]. Because of these misleading labels and mesmerizing advertisements, the young generation is lost among the clouds.

In 2020, e-cigarette use among high school students (grade 9-12) and middle school students (grade 6-8) in US were 19.6% and 4.7%, respectively [7]. Many teenagers do not even realize that vaping-cartridges contain nicotine, and assume the pods contain only flavors. The easy availability of these electronic devices, alluring advertisements, various sweet e-liquid flavors, and the belief that they are safer than cigarettes have helped make them appealing to this age group [13].

Under U.S. Food and Drug Administration (FDA) regulations designed to protect the health of young Americans, minors can no longer buy e-cigarettes in stores or online. The FDA now regulates the manufacture, import, packaging, labeling, advertising, promotion, sale, and distribution of e-cigarettes [12,13].

In 2019, sixty-eight (68) US e-cigarette users died and over 2800 consumers were hospitalized due to lung injuries and acute pneumonia (EVALI) associated with vaping of e-cigarettes [8].

Teenagers can easily get addicted to illicit e-liquid products containing THC (the main psychotropic ingredient in marijuana), butane and hash oils (concentrated THC) etc., although under the Federal Law in US, cannabis products over 0.3% THC are illegal [10].

In 2019, e-cigarette market in Southeast Asia was worth 595 million USD and projected to grow to

766 million by 2023 [8]. The youth in Southeast Asian countries such as Malaysia, Indonesia, Philippine, Vietnam, Taiwan, Hong-Kong has become the victims of e-cigarettes. Singapore, Laos, Cambodia have imposed a ban on import and sale of e-cigarettes in 2020 [8,18]. We are not aware of any reports on the use of e-cigarettes by Sri Lankan youth.

Meaning of new words and abbreviations

Atomizer - A compartment of an e-cigarettes where the electric energy is converted into heat to produce vapor from e-liquids

Cartomizer - It is a type of atomizer that is pre-filled with e-liquid which can be replaceable. Cartomizer is usually the easiest type to operate [10]

Electronic cigarette - A hand-held electronic device that can produce an aerosol by heating an "e-liquid" using a battery.

e-Liquid - A liquid used to produce aerosol in e-cigarettes.

MOD - Short for modified e-cigarette, that can be modified according to user preferences. They are larger than a vape pen and produce more vapor

POD - It is a mini vape based on a two-part system: a pod filled with vape juice that snaps into a small battery [10]

Vaping - Inhalation of a heated aerosol (*i.e.*, vapor)

ENDS - Electronic Nicotine Dispensing Systems

EVALI - E-cigarette, or vaping, product use associated lung injury [20]

THC - Tetrahydrocannabinol is the main psychoactive component of cannabis

Conclusion

There are four generations of electronic cigarettes in the market; cigar like, tanks, mods and pods. The proper use of e-cigarettes may help lower nicotine-cravings in addicted smokers which may lead to quitting of the habit of smoking. However, e-cigarettes are not an FDA-approved quit aid, and there is no conclusive scientific evidence on the effectiveness of vaping for long-term smoking cessation. Addition of nicotine, flavors, other addictive chemicals and illicit products to e-liquids made the e-cigarette a potential health problem, particularly for the younger generation. Strict regulatory actions should be taken by governments and health authorities to prevent e-cigarette use from becoming a health issue in Southeast Asia and Sri Lanka in the future. People must understand that e-cigarettes and vaping are as dreadful as conventional cigarettes.

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