Electronic Cigarette (EC): Basic Design, Working Principle and Harmful Effects

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Abstract—Electronic cigarette (EC) is an electronic nicotine delivery device. It is considered that EC is healthier alternative of conventional cigarette and use of EC that deliver nicotine containing vapours has increased rapidly across the world. So there should be proper development of EC. It can cause lots of harmful effect on human health and on future generation also. This study highlights the basic principle of EC, with their basic components. Key words: Electronic cigarette, Atomizer, nicotine, Aerosol, E-liquid.

Key words: Hospital Bed Management, Hospital Capacity Planning, Decision Support Systems, Decision Support Models

I. INTRODUCTION

Electronic Cigarette (EC) is a battery-powered Electronic Nicotine Delivery Device (ENDD) resembling as regular cigarette [1]. It is used to deliver nicotine in a toxin free vapours [2]. This device was invented by Ruyan Group (holdings) limited, China in 2003, and the company patented EC in Canada in 2004 [3]. An EC have several parts, the main components of it are a plastic tube, battery, atomizer (heater), microprocessor, indicator light (LED), and E-liquid (nicotine, propylene glycol, glycerine, water and flavours).

Electronic cigarette is designed to reduce the harmful effect of conventional cigarette, but its appearance is just like a regular cigarette. A conventional cigarette produces smoke when it burns, but EC generates vapours that contain nicotine. They are popular in market as they can help people to quit smoking [1], and are often marketed as the healthier version of the conventional cigarette.

II. COMPONENTS OF E-CIGARETTE

There are many components of an Electronic Cigarette and sometime they can vary according to manufacturing companies (Brands). Main components of EC are:

A. Atomizer

It is heating element that vaporizes the liquid [4], connected with battery for power. It is made up of nickel chromium wire and coupled with thick copper wire coated with silver [5]. It gets heated while current passes through it because of high resistance. Most of them seem to have around 1-3 ohms of resistance and the batteries are of 3-6 volt.

B. E-liquid

E-liquid is a mixture of nicotine and some other chemicals which is present in EC. A replaceable cartridge with a liquid soaked porous material is used to store E-liquid. The porous material [6] (Polly fill fabric) is used to deliver E-liquid to atomizer via capillary action and converts it into aerosol [8]. E-liquid mainly comprises of:

1) Propylene glycol

It is a non-toxic organic compound which is used to generate artificial “smoke” for theatrical production. It is easily absorbed by the Polly fill fabric inside the cartomizer (atomizer + cartridge) and has low density, so, it doesn’t build up gunk while heated, therefore it is added as liquid vehicle to stimulate the appearance of using “real” cigarette [3][6].

2) Glycerine

It is also a non-toxic organic compound with slightly sweet taste which also makes the e-liquid sweeter and the flavour is a little difficult to detect. It produces significantly more vapours than propylene glycol [6][9].

3) Flavours

These are additive liquids added in E-liquid to provide different flavours or taste like candy, menthol etc. Most of our EC flavour choices come in bottles from 7.5 ml to 30 ml and can be customized to have double E-liquid flavours.

C. Battery

The batteries used in EC are Nickel-Cadmium (NiCad), Lithium-polymer (Li-poly), Nickel metal-hydride (NiMh), Lithium ion (Li-ion), alkaline and Lithium Manganese (LiMn) battery [10] and operated between 3.5 – 4.8 volts. The rechargeable batteries can also be used [4].

D. LED

LED (Light Emitting Diode) indicates the signal activation of the device with each puff [25].

E. Sensor

A pressure sensor, flow sensor, acoustic sensor, touch sensor, capacitive sensor, optical sensor, Hall Effect sensor and an electromagnetic field sensor are used in EC [4]. They get activated at negative pressure/air flow and then complete the circuit of EC. The cigarette starts working.

F. Microprocessor

Microprocessor shows the level of E-liquid present in EC and amount of dose taken, amount of dose remaining in EC, battery life, safety warning and use of EC frequency per day. One patent describes Bluetooth communication protocol integration and multiple smoking software programs based on fluid type and user preference. [10]
III. BASIC PRINCIPLE OF ELECTRONIC CIGARETTE

When a regular cigarette is lighted, the tobacco present in it starts burning. The person starts drawing the cigarette, the smoke goes inside the blood stream. Tobacco smoke contains tar, nitrogen oxide and carbon monoxide and some other poisonous gases which are carcinogenic, so to remove all these harmful effects EC is generated. The major difference in a regular cigarette and EC is that, regular cigarette produces smoke with harmful particles but EC produces aerosol of nicotine not the smoke. Some of different types of EC are shown in fig.1.

Now, the question arises that, how EC works? The basic principle of first generation–EC is given bellow:

1) The sensor of EC is activated when the user draws it [4][10].
2) The pressure change is detected by the airflow sensor which transfers the power to LED, heating element and other elements.
3) The E-liquid saturates a wick via capillary action and is aerosolised by the heating element.[8][10]
4) The aerosolised droplets of E-liquid subsequently flow into the user’s mouth and lungs.

The cigarette starts working when it gets signals from sensor or when the user turns on the button. A switch is present in some cigarette to turn on [11]. It initiates the power supply to the atomizer, LED and other elements [11] [12]. Air holes are present in EC near the battery to air flow for puffing and also control pressure drop [10] [13] [14] as shown in Fig.2. The air hole size is equal to the size of pen led size to prevent child choking hazards associated with pen led [10]. The basic principle of EC is shown by the flow chart in Fig.4.

A. E-liquid transportation

The transportation of E-liquid to aerosol generator is via capillary action, through a wick. To control the transportation of E-liquid the transport is controlled by microprocessor. The other possible transport of E-liquid to aerosol generator is mechanically controlled pump, nozzle and diaphragms [10].

![Fig. 2: EC with basic components](image)

B. Aerosol Generation

From the above process the E-liquid is transported to heating element and in some cases through mechanical processing, in which an ultrasonic vibration generator or other mechanical devices are also used to produce an aerosol by mechanical dispersion [10] [13] [15]. The ultrasonic vibrator generates aerosols of size 0.5-1.5 µm [10] [17] [18]. In some EC pumps and nozzles (jets) are also used to generate aerosols. The heating of atomizer is determined by the material, element’s resistance, voltage across it. It also determines the current flow in atomizer. The change in temperature and duration of heating of atomizer influences the aerosols [10]. Element degradation, fouling and other factors also influence the heating element temperature [10]. Arrangement of heating element is shown in Fig. 3.
After the whole process aerosols are generated, and there temperature constantly reduces while travelling through respiratory tract when the customer draws it. The large particles of aerosol got attached to the central passage of EC. These large particles may be removed from the passage and reused [10] [20]. The use of EC nowadays become very common and popular as its design got advanced. Microprocessors, programmable logic units, integrated circuits and other electronic components may be incorporated into some EC [6]. It can also be connected with Bluetooth [21]. The presence of microprocessors and memory chips in EC raises concerns about the collection and use of personal privacy information. The microprocessor also facilitate customer to exchange data with the third party while charging through universal serial bus (USB) and through Bluetooth [10] [12].

IV. TYPES OF E-CIGARETTE

EC has many types with small vernation in components of it, but the purpose is same to deliver nicotine.

A. Disposable EC

This looks like an ordinary cigarette shaped. Device consist a battery and a cartridge containing an atomizer to heat a solution (with or without nicotine). Not rechargeable or refillable and is intended to be discarded after product stops producing aerosol. Sometimes it called an e-hookah [19].

B. Rechargeable EC

It is Cigarette-shaped device consisting of a battery that connects to an atomizer used to heat a solution typically containing nicotine. Often contains an element that regulates puff duration and/or how many puffs may be taken consecutively [19]. There batteries are rechargeable due to which these can be used again and again.

C. Pen-Style, Medium-Sized Rechargeable EC

These are Larger than a cigarette. They have a higher capacity battery, which are rechargeable. They may contain a prefilled cartridge or a refillable cartridge (often called a catomizer). These devices often come with a manual switch allow the customer to regulate length and frequency of puffs [11] [19].

D. Tank-Style, Large-Sized Rechargeable EC

These are much larger than a cigarette. They have a higher capacity battery and typically contain a large, refillable cartridge. They also contain manual switches for regulation of length and frequency of puffs. They have a battery casing for customizing battery capacity. These can be easily modified according to customer requirement [19].

V. DIFFERENT BRANDS OF E-CIGARETTE AND THEIR PROPERTIES

The demand of EC in market is too much due to the erroneous concept that they are helpful for people to quit smoking. There are many brands of EC are available in market. Some of them are given in ‘Table 1’

<table>
<thead>
<tr>
<th>Brand models</th>
<th>Relative nicotine content</th>
<th>Nicotine (mg)</th>
<th>Puffs per cartridge</th>
<th>Flavours</th>
</tr>
</thead>
<tbody>
<tr>
<td>NJOY NCIG</td>
<td>Regular</td>
<td>18</td>
<td>No information</td>
<td>Regular (traditional), Menthol, vanilla, strawberry and apple.</td>
</tr>
<tr>
<td></td>
<td>Light</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zero</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liberty Stix</td>
<td>Regular</td>
<td>24</td>
<td>60-80</td>
<td>Tobacco, mint, vanilla, cherry, chocolate,</td>
</tr>
</tbody>
</table>
VI. HARMFUL EFFECTS OF E-CIGARETTE

1) Propylene glycol is known to cause allergic reactions in some EC users. These can vary from minor reactions, like a tingling sensation in the throat, to serious irritations on various parts of the body. If user experience the unusual symptoms after vaping PG e-liquid, it is best to stop using it immediately and switch to vegetable glycerine [6].

2) Propylene glycol in the form of aerosol may be a pulmonary irritant and increases dynamic airway resistance, EC use could be detrimental to people with asthma and chronic obstructive pulmonary diseases.[3]

3) The aerosol of EC having heavy metals (nickel, copper) and silicate (silicon, calcium, aluminium, magnesium) which goes into the lungs and can cause carcinogenic effects. So, it is required to improve the design and manufacturing of EC [5] [21][22].

4) EC can also be used for inhalation of other drugs, medicines or substance that can vaporize [4]. So, EC should be regulated as tobacco products only, it should not be used for any other delivery system or drugs.

5) EC is mostly used by youngsters as it looks like a regular cigarette; suggest them that smoking behaviour is socially acceptable. And the flavours used in EC like menthol, candy, chocolate etc. attract youngsters to start smoking.[3]

6) EC causes hazards to neonate through inhalation, dermal and oral contact. It adversely impact weight and lungs development and altered development of cerebral cortex in the neonate [23][24].

VII. CONCLUSION

All the brands of EC share a basic design with little bit difference in some components like atomizer, E-liquid (amount of nicotine and flavours). There are lots of harmful effects of EC but these are lower than convention cigarette. Additional research will improve the current understanding of basic e-cigarette design to reduce the harmful effects of EC. Standardised EC testing should be developed so that EC can be tested before it comes in hands of customers.

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