Electronic Cigarettes and DNA Damage

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Abstract

Electronic e-cigarettes are common throughout the world. E-cigarettes deliver the nicotine stimulant through aerosols to the lungs without burning tobacco. Recently, e-cigarette smokers have mysteriously expressed nicotine poisoning symptoms including nausea and vomiting, excessive salivation, headache, and dizziness followed by a period of central nervous system depression, paralysis, difficulty in breathing and even death. Unlike the immediacy of nicotine poisoning, the potential of cancer developing decades later from e-cigarette use was assessed with DNA tests that showed nicotine enhanced the UV-induced DNA mutation frequency in human lung and bladder epithelial cells by two- to fourfold. Enhanced DNA damage is consistent with simple QED that predicts nanoparticles (NPs) produced from the metal heater in the e-cigarette emit UV radiation well known to cause DNA mutations that may lead to cancer. The mystery of nicotine poisoning is solved by removing the heater producing the NPs, but then the nicotine would remain in the ground state and not enhance the stimulation of the smoker's senses

Keywords — *e-cigarettes, nanoparticles, DNA damage, cancer.*

I. INTRODUCTION

In September 2019, more than 200 people [1] across the US have come down with a mysterious illness linked to smoking e-cigarettes and a few deaths have been reported. The CDC believes their illness is associated with vaping, but cannot determine the ingredient causing the problem. Absent a known cause, doctors are treating the mystery illness as a disease of unknown origin. The patients suffered from respiratory symptoms of nicotine poisoning including: coughing, shortness of breath, chest pain, and difficulty breathing. Unlike nicotine poisoning, cancer does not appear until decades later which is of concern in that young people in their early 20s smoke e-cigarettes.

One explanation for the mystery illness is e-cigarettes produce NPs from heating metals [2,3] in the coil heater. In nanotechnology, NPs are linked to many illnesses similar to nicotine poisoning as illustrated in Fig. 1

Fig. 1. Nanoparticle linked illnesses

In smoking e-cigarettes, puffing activates a battery that heats a liquid to produce an aerosol stimulant containing flavoring, vegetable glycerin, and nicotine. However, metal NPs are found [2,3] in the e-cigarette aerosols.

E-cigarettes produce Fe, Al, Cu, Cr, Ni, and Zn in high NP concentrations. The size of Sn, Cr, and Ni from [2] are shown in Fig. 2. Peak concentrations occur for 50 - 70 nm NPs. One puff of an e-cigarette is estimated to contain about 2 million NPs / cm^3. For Ni and Sn, the NPs are spherical at ~ 50 nm. The Cr NP is irregular with minimum dimension ~ 100 nm. In the simple QED of irregular NPs, the EM wave stands across the minimum dimension consistent with Fermat's principle of minimum time in conserving absorbed heat by EM emission. For spherical NPs, the minimum dimension is the diameter.

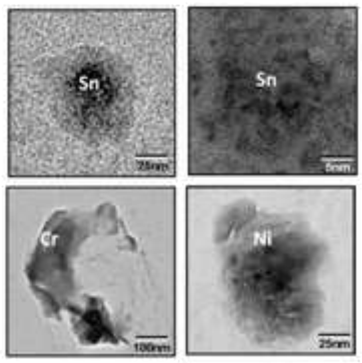

Fig. 2. NP Size - Sn, Cr, and Ni

An e-cigarette generation system [3] was developed for inhalation toxicology studies of size, number, and chemical compositions of metallic NPs. The Kanthal e-cigarette coil was tested without a nicotine solution to characterize the size distribution and chemical composition of the metallic NPs generated from heating of a dry e-cigarettes. Kanthal is an Fe, Cr, and Al alloy including a trace of Mn, Si, and C. Fig. 3 shows NP shapes of Fe to vary from irregular to spherical. The minimum irregular NP size is < 50 nm and spherical shapes ~ 50 nm. EDX maps show Fe and O to be dominant.

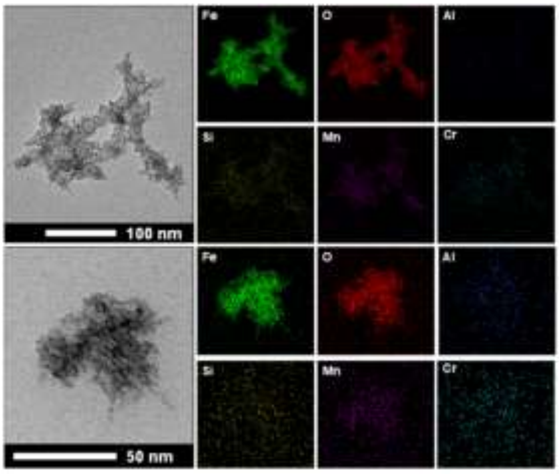

Fig. 3. NP shapes and EDX maps from Kanthal e-cigarette coil

Chemical carcinogenesis [4] assumes metabolism into an electrophilic metabolite that binds covalently to DNA and, if not enzymatically repaired, mutations occur, the accumulation of mutations in the genomic landscape may lead to cancer and/or damage DNA repair enzymes. Nicotine is rapidly metabolized *in vivo* to cotinine and other metabolites. In this regard, nicotine induces DNA damage and further inhibits DNA repair in human cell types.

However, chemicals are not necessary to bind DNA and induce DNA damage as UV light alone directly damages DNA to induce mutations. Of relevance to e-cigarettes is whether carcinogenesis is enhanced by nicotine irradiated with UV light in human cells. In this regard, the potential of cancer developing decades later was assessed [5] in mice showing e-cigarette aerosol enhanced UV-induced DNA mutation frequency in lung and bladder epithelial cells. Otherwise, epidemiology studies over decades would be required to assess carcinogenesis from e-cigarettes.

II. PURPOSE

The purpose of this paper is to show the DNA mutagenesis of nicotine is enhanced by irradiated UV light produced from heated NPs. The UV light is endogenous to the e-cigarette aerosol. Exogenous UV from solar radiation is not considered.

III. ANALYSIS

Endogenous UV light from NPs depends on simple QED - a method of analysis applicable [6,7] to nanoscale heat transfer. Simple QED is not the complex light and matter interaction advanced by Feynman and others. Instead, simple QED is readily understood by the Planck law of quantum mechanics that requires the heat capacity of constituent atoms in NPs to vanish under EM confinement. In contrast, classical physics always assumes the atom has heat capacity that produces an increase in temperature upon the absorption of heat. Simple QED differs as the NP conserves heat by the creation of standing EM radiation inside and across the diameter of the NP is illustrated in Fig. 4.

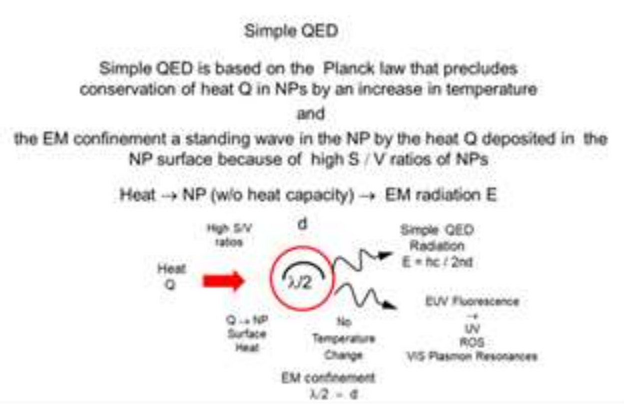

Fig. 4. Simple QED - Conversion of heat to EM radiation

The temperature of the e-cigarette aerosol is increased by the heat Q of the coil, the aerosol transferring the heat Q to the NP. Because NPs have high surface-to-volume (S/V) ratios, the heat Q is almost totally absorbed in the NP surface. The NP temperature cannot conserve the surface heat Q by an increase in temperature, and instead a standing wave is created inside and across the diameter d of the NP having half-wavelength $\lambda/2 = d$. Correcting the velocity of light c for the refractive index n of the NP gives the time $\tau = 2d/(c/n)$ for 1 cycle. Hence, the frequency of the standing wave $c/\lambda = 1/\tau = c/2nd$ gives $\lambda = 2nd$.

Simple QED creates standing EM waves from the EUV to UV to VIS and NIR. EUV is common in biological NP diameters d < 30 nm, otherwise the UV to the NIR are produced. The EM confinement necessary to create the standing EM wave is the momentary surface heat of the NP. EUV waves fluoresce down to lower quantum states: UVA to UVC, reactive oxygen species (ROS), and VIS plasmon resonances. Upon absorption in water surroundings, the EUV fluoresces down to lower states, but is inefficient. Fluorescence data is scarce, e.g., EUV at 120 nm in water is available from astronomy in Lyman-α fluorescence [8] to UVB (330 nm) and UVC (254 nm) but only about 8 and 13 percent efficient, respectively

The simple QED wavelength λ = 2nd for various NP metals is given in Fig. 5. The refractive index n is taken from the literature at wavelengths near the UVC at 254 nm. The Sn data is the exception at 730 nm, but was the lowest wavelength data available. The Ag, Cu, and Ni data give about the same response. Data for Fe is reasonably correct. The red lines give the NP diameter d range from 37 to 80 nm corresponding to the UVC. Experimentally, simple QED is consistent with the higher number of NPs and the NP range 50 - 70 nm reported in [2]. Also, Fig. 3 giving the average NP diameter of ~ 50 nm is near the ~ 60 nm average of the 37 to 80 nm range given by simple QED. Fig. 5 shows simple QED radiation wavelengths produced for NP diameters d < 100 nm.

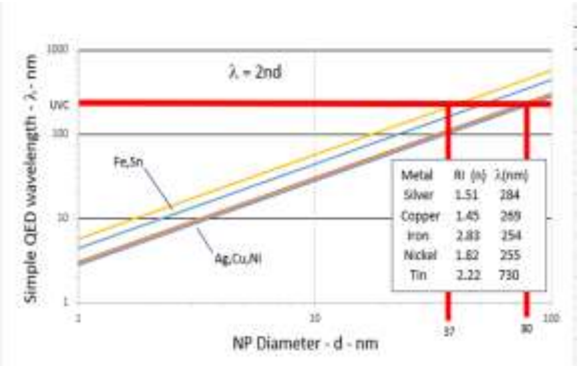

Fig.5. Simple QED wavelength v. NP material and diameter

Since the 1940's, UVC irradiation (225-305 nm) of nicotine is known [9] to produce oxynicotine, methylamine and nicotinic acid. Recent spectroscopy [10] shows the UVC provides a representative measure of the first excited state of nicotine in relation to water as illustrated in the absorption spectrum in Fig. 6.

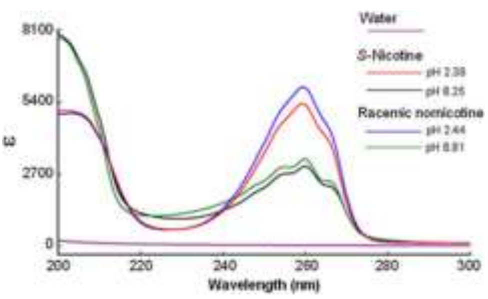

Fig. 6. Nicotine absorption in the UV

Similar to nicotine, the UV absorption spectrum [11] of native DNA follows the UVC peak at 254 nm depending on folded structure modified by glycation in ribose as shown in Figure 7.

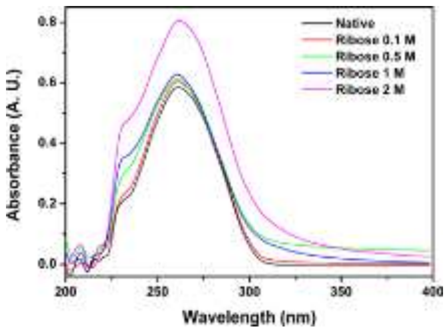

Fig. 7. UV absorption spectra DNA (black) and glycated in D-ribose.

The simple QED induced EM radiation analysis suggests 50-70 nm NPs of various metals produced in e-cigarettes tends to produce an average UVC radiation that excites nicotine to higher energy states coincident with absorption peak of native DNA. The UVC produced by NPs therefore enhances DNA damage above that of nicotine in the ground state. Indeed, DNA damage from NPs is not limited to e-cigarettes. Vaccinations containing NPs of aluminum adjuvants are used [12] to stimulate antigens in vaccines, the DNA damage in the vaccines more severe than e-cigarettes as the NPs reach the brain directly upon injection into the blood stream.

Unlike tobacco smoke, e-cigarette aerosols are thought to contain nicotine and relatively harmless organic solvents, and therefore e-cigarettes are considered [5] non-carcinogenic and a safer [13] substitute for tobacco. But this is questionable.

Although NPs are not the major component in e-cigarette aerosol, NPs are the most important to consumer health. NPs by emitting UV radiation excite nicotine to high electronic states to enhance mutagenic DNA and inhibit DNA repair in human lung and bladder epithelial cells, all of which are unlikely for nicotine in the ground state. NPs make e-cigarette smoking far more serious in future cancers than normal cigarettes.

IV. CONCLUSIONS

Simple QED [6,7,12] based on the Planck law denies constituent atoms in metal NPs of e-cigarette aerosols the heat capacity to conserve absorbed heat by an increase in temperature. Because NPs have high S/V ratios, the absorbed heat is deposited in the NP surface, the surface heat itself providing the brief, but necessary EM confinement to convert the surface heat to UV radiation standing inside the NP, at which time the EM confinement vanishes and the UV is free to excite nicotine and/or damage DNA in the surroundings.

Unlike discrete electron quantum states of the atom, the simple QED quantum state depends only on the size of the NP allowing UV photon creation by simply immersing NPs in an ambient thermal bath that otherwise is precluded unless a photon having an energy state equal or greater than the UV is absorbed.

E-cigarettes produce NPs [2,3] from the metal heating coils. Once the NPs are free in the aerosol, simple QED predicts further heating induces the NPs to emit EM radiation in the EUV-UVC-UV-VIS-NIR depending on NP size. NPs > 100 nm producing VIS and NIR are harmless. Irrespective of the NP metal, the average EM radiation of 50-70 nm NPs in the UV coincides with the UVC absorption peak of nicotine and DNA spectra. EUV produced in < 50 nm NPs produce UVC by fluorescence, but inefficiently.

Whether vaping is safer than smoking conventional cigarettes is an issue of great interest. Conventional cigarettes were found [14] to contain approximately 9000 million NPs per cigarette having diameters d from 6–50 nm. Assuming 100 puffs/day, estimates [2] suggest e-cigarettes produce about 100 million NPs which is far less than smoking one conventional cigarette per day. Based on the number of NPs alone, the e-cigarettes appear safer than conventional cigarettes as 9000 e-cigarettes puffs / day are required to inhale the same number of NPs as the one conventional cigarette.

However, the UVC from 50-70 nm NPs in e-cigarettes excites nicotine to electronic states above the ground state. Nicotine in the ground state may be considered similar to ordinary cigarettes absent NPs. On this basis, DNA damage from the higher electronic state of nicotine in e-cigarettes compared to conventional cigarettes poses a larger potential for decades later cancer.

The difficulty with the latter argument is that although the NPs in e-cigarettes include metals while conventional cigarettes do not, both emit UV radiation. Differences between metallic and non-metallic NPs are the refractive index which are not significant for the same NP diameters. What is important is the extent of DNA damage which is not assessed here or available in the literature. The FDA is recommended to conduct DNA testing of both conventional cigarette smoke and e-cigarette vapor to resolve the merits of e-cigarettes over conventional cigarettes.

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