QED Disinfection of Drinking Water in China

T. Prevenslik
QED Radiations, Hong Kong, China

ABSTRACT: In China, perhaps half of the population drinks water that is contaminated by human or animal waste. Moreover, bottled waters, even if available are not always safe. QED induced UV radiation using hand-held nano-coated bowls is proposed to allow the individual to disinfect water at the point of use using body heat alone – no electrical power. QED stands for quantum electrodynamics. QED disinfection is a consequence of quantum mechanics that forbids the atoms under the TIR confinement inherent in the nanocoating to have the heat capacity to increase in temperature. TIR stands for total internal reflection. By selecting the proper coating thickness, the heat from the hand is conserved by QED inducing conversion to UV-C radiation. EPA guidelines for disinfection require a UV-C dose of 16 to 38 mJ / cm^2. With body heat of about 6 mW / cm^2, the hand-held drinking bowl disinfects drinking water in 3 to 6 seconds.

1 INTRODUCTION

China's massive population poses difficult environmental challenges for a nation of some 1.2 billion people. Indeed, water pollution and waste management are among the most pressing issues (Natl Acad Scie 2007). Over 3.5 million tons of sewage waste per day requires extensive treatment facilities. Perhaps half of all Chinese — 600 million people— drink water that is contaminated by human waste are subjected to waterborne pathogens and a myriad of human health concerns.

But contaminated drinking water is not unique to China. WHO/UNICEF estimates (WHO/UNICEF, 2012) almost 1 billion people do not have access to safe drinking water. Although visitors to China generally do not stay long to expose themselves to health risks from heavy metals, they almost all will meet "La Dudza" - the Chinese version of diarrhea within their first days after arrival.

The WHO estimates (Collins 2013) that 64% of all premature deaths in China are related to waterborne toxins consumed on a regular basis by a majority of the nation's population that cannot afford bottled water, and even if bottled water is available the consumer at the point of use never knows if it is indeed safe. The most direct disinfection is by boiling at the point of use, but except for water boiling units in restaurants is not available to the individual consumer.

Unfortunately, there are no known low-cost alternatives to purifying water for the individual other than by boiling. Even if tap water becomes drinkable, few people will stop boiling drinking water, a habit that is ubiquitous in China. Boiling kills or deactivates (Classen et al. 2008) all waterborne pathogens, including protozoan cysts such as cryptosporidium that can be resistant to chemical disinfection including viruses such as rotavirus and norovirus that are too small to filter out. Even if the water is turbid, boiling can remove microorganisms and volatile organic compounds such as benzene and chloroform.

Unequivocally, water purification by filtration at the point of use is desirable. In Kenya, Bolivia and Zambia, water purifiers have been shown (Sobsey, et al. 2008) to reduce diarrheal diseases by 30–40%. Fewer than 5% of Chinese homes currently have filtered purifiers, despite a unit costing only around 1,500 to 2,000 renminbi. The water purifiers require pumping through ceramic or resin filters (Mpenyana-Monyatsi et al., 2012) coated with silver NPs. NP stands for nanoparticle. Silver NPs are known to provide antimicrobial action by damaging the DNA of bacteria, but NPs that come off the filter and enter the body also (Prevenslik, 2010) damage human DNA that if not repaired, leads to cancer.

In contrast, UV disinfection of drinking water outside the body avoids the danger of cancer posed by NPs in filters. Currently, LEDs in the UV-C are thought (Ferrero 2014) to provide the individual with point of use disinfection of drinking water, but still require a source of electrical power. LEDs stand for light emitting diodes.

Even in the Western world, the individual can never be sure if the drinking water is safe. A simple way of allowing the individual to purify the water just before drinking at the point of use is desirable.

2 THEORY

QED induced UV radiation using hand-held nano-coated drinking bowls is proposed by which drinking water is disinfected with body heat depicted in Figure 1.

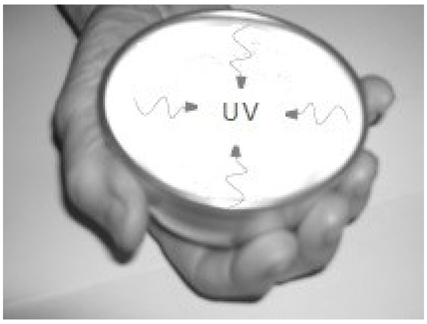

Figure 1. QED induced UV radiation from body heat disinfecting drinking water

QED induced disinfection of drinking water is a consequence of QM that precludes the atoms in nano-coatings to have the heat capacity to conserve body heat by an increase in temperature. Instead, the heat is induced by QED to produce UV radiation.

2.1 *QM Restrictions*

Classically, the atoms in coatings always have the heat capacity to increase in temperature upon the absorption of heat irrespective of their thickness. QM differs in that the heat capacity of the atom vanishes in nano-coatings, and therefore heat cannot be conserved by an increase in temperature. Figure 2 shows the thermal kT energy (or the heat capacity) of the atom as a harmonic oscillator (Einstein & Hopf 1910) to vanish at coating thicknesses < 1 micron.

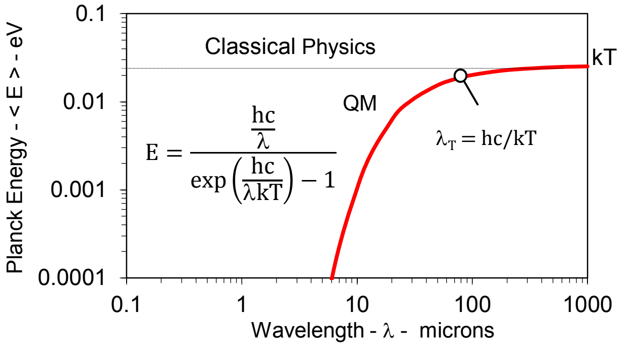

Figure 2 Heat Capacity of the Atom at 300 K
In the inset, E = Planck energy, h = Planck's constant, c = speed of light, k = Boltzmann's constant, T - temperature, and λ = wavelength

2.2 *EM Confinement and QED Radiation*

TIR has a long history. In 1870, Tyndall showed light is trapped by TIR in the surface of a body if its RI is greater than that of the surroundings. RI stands for refractive index. Tyndall used water to show TIR confinement allowed light to be observed moving along the length of transparent curved tubes. TIR may confine any form of EM energy, although in the nano-coating of the drinking bowl the confined EM energy is the body heat from hands holding the bowl

TIR confinement requires the deposited heat to be concentrated in the coating surface that is a natural consequence of nanoscale coatings having high S / V ratios, i.e., surface to volume ratios. Hence, QED creates standing wave photons within the TIR confinement formed between the coating surfaces, the number of photons conserving the heat absorbed. The wavelength λ of the standing photons is, λ = 2 d, where d is the coating thickness.

However, TIR confinement by the coating surfaces is not permanent, sustaining itself only during heat absorption, i.e., absent absorption there is no TIR confinement for QED to conserve the heat by creating standing photons in the coating.

QED relies on complex mathematics as described by Feynman (Feynman 1985) although the underlying physics is simple to understand, i.e., EM radiation of wavelength λ is created by supplying heat to a QM box having sides separated by $\lambda/2$. In this way, QED conserves absorbed EM energy by frequency up-conversion to the TIR resonance described by the thickness d of the coating. The Planck energy E of the QED radiation,

$$E = h\upsilon, \quad \upsilon = \frac{c/n}{\lambda}, \quad \lambda = 2d \tag{1}$$

where, n is the RI of the coating.

2.3 *UV Disinfection*

UV light as a disinfectant penetrates the cell wall of an organism to scramble the genes thereby precluding reproduction. Research has shown that the optimum UV wavelength range to destroy bacteria is between 250 and 270 nm (NDWC 2000).

The US HEW set guidelines for UV light disinfection to require a minimum dose of 16 mJ / cm^2 at all points throughout the water disinfection unit, but recently the National Sanitation Foundation International set the minimum UV light requirement at 38 mJ / cm^2 for treat visually clear water.

Currently, LED's in the UV-C are limited to EQE of a few percent (Mukish 2015) and not expected to impact the disinfection market until 2017/2018. EQE stands for external quantum efficiency. In contrast, the QED drinking bowl has 100% efficiency, but is limited by low body heat.

3 ANALYSIS

The wavelength of QED radiation emission from the conservation of heat in nanoscale coatings having n = 2 and 4 is shown in Figure 3.

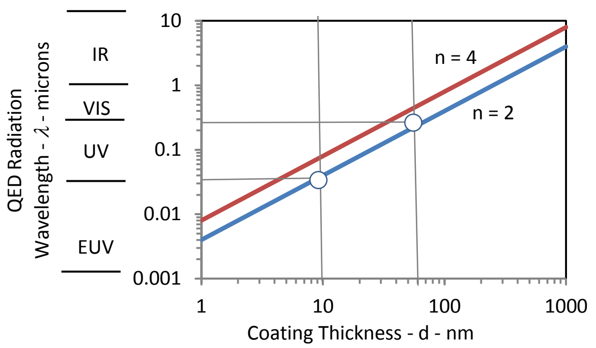

Figure 3 Wavelength of QED Emission v. Coating Thickness

Insuring TIR confinement requires the RI of the coating to be greater than that of the substrate. Most RI vary from, 1.5 to 3. For the coating having = 2, the QED emission from 10 – 60 nm coating thicknesses produces EM radiation from UV-C to the near EUV. In water, the near UV-C at 254 nm may be transmitted over distances comparable to the size of the drinking bowl without any absorption. For n = 4, smaller coating thicknesses are required to produce UV-C.

Taking λ = 260 nm UV as the optimum wavelength for disinfection in a coating of n = 2, the coating thickness is 65 nm and a substrate having n < 2. Materials should be selected that are resistant to corrosion and readily cleanable. The RIs of the coating and substrate depend on wavelength and require evaluation at λ = 260 nm. Total human body heat is about 100 W. Since the average surface area (Wiki 2014) for adult men and women is about 1.75 m^2, the heat flow Q = 5.71 mW / cm^2. Hence, the dose to destroy water pathogens of 16 to 38 mJ / cm^2 may be provided by keeping the water in the drinking bowl from 3 to 6 seconds.

4 RESULTS

The QED induced disinfection of drinking water is currently under development. Prototypes comprise a 1 mm thick half-sphere aluminum bowls (100 mm diameter x 50 mm high) that fit into the palm of one hand. Melamine and glass bowls were considered, but have a low thermal conductivity compared to aluminum to take advantage of the 12 C differential between body temperature (32 C) and ambient (20 C). Moreover, melamine and glass are fragile compared to the ductility of aluminum to avoid fracture upon accidental dropping. According to Eqn.(1), a 53 nm ZnO nano-coating consistent having a refractive index of 2.4 therefore converts 100% of body heat 5.71 mW / cm^2 to UV-C. Test results for the UV-C zinc-oxide coated bowls are expected for the WRE Conference.

In addition, proof of principal test of QED radiation at UV-A levels for titanium dioxide is planned for the WRE Conference. For UV-A (330 – 400 nm), the TiO_2 having RI = 2.6 requires thicknesses (63 – 73 nm). The TiO2 coatings are applied to flat 20 mm x 20 mm aluminum samples and heated on the backside by an insulated electrical heater.

5 CONCLUSIONS

A hand-held QED drinking bowl comprising a 53 nm ZnO coating on aluminum is presented allowing the individuals in developing countries to disinfect water at the point of use just before drinking.

Disinfection occurs by UV-C radiation created as the body heat from the hand holding the QED drinking bowl passes through the ZnO coating.

Prototypes are in a state of development and are planned to be presented at the WRE Conference.

6 REFERENCES

Collins, G. 2013. Beijing Tap Water - Safe or Not? *The Beijinger*, January 23, 2013

Einstein A & Hopf L. 1910. Statistische Untersuchung der Bewegung eines Resonators in einem Strahlungsfeld. *Ann. Physik* 33:1105-1120.

Ferrero, G. 2014. UV disinfection in developing Countries. UNESCO IHE, Delft, The Netherlands, November 6, 2014.

Feynman R: QED: The Strange Theory of Light and Matter, Princeton University Press, 1985.

Mpenyana-Monyatsi L, et al., 2012. Cost-Effective Filter Materials Coated with Silver Nanoparticles for the Removal of Pathogenic Bacteria in Groundwater. *Int J Environ Res Public Health* 9: 244–271.

Mukish, P. 2015. UV LED - Technology, Manufacturing and Application Trends in disinfection, Yole Developpement.

National Academy of Sciences. 2007. Safe Drinking Water is Essential. *Global Health & Education Foundation.*

Prevenslik, T. 2010. Cancer by Nanoparticles. NanoSafe 2010, November 18-20, Minatec, Grenoble

NDWC. 2000. Ultraviolet Disinfection, National drinking water clearinghouse (NDWC) fact sheet, Tech Brief: Fifteen September 2000.

Wikipedia, Body Surface Area. Wikipedia, the free encyclopedia 2014.

WHO/UNICEF, 2012. Progress on Drinking Water and Sanitation: 2012 Update.

.