INSIGHTS INTO THE SUSCEPTIBILITY OF CORONAVIRUSES TO UV IRRADIATION AS EFFECTIVE DISINFECTION OPTION

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1. BACKGROUND

- The highest energy spectrum of ultraviolet radiation, that extends from wavelength of about 200 to 280 nm (UVC radiation), has been shown for decades to inactivate or destroy bacteria, viruses and fungi.
- UV-based disinfection techniques have been largely used to reduce the spread of microorganisms in living spaces, medical units or other contaminated locations. The inactivating effect of UV radiation is not the same on all microorganisms but it strongly depends on the species type, irradiation wavelength and doses, exposure time and sample condition.
- Recently, an increasing attention has been focused on the susceptibility of coronaviruses to UV irradiation, as well as on identifying the exposure conditions to effectively limit the spread of infection.

2. UV-INDUCED STRUCTURAL CHANGES ON VIRAL RNA

- UV light is absorbed by RNA strands of the virus and causes their nucleotide sequences to clump together, thus preventing the cells from reproducing or killing them.
- UV light may cause several types of damage to viral RNA: photochemical modification (e.g. dimerization), crosslinking or oxidative damage, as shown in Fig. 1.

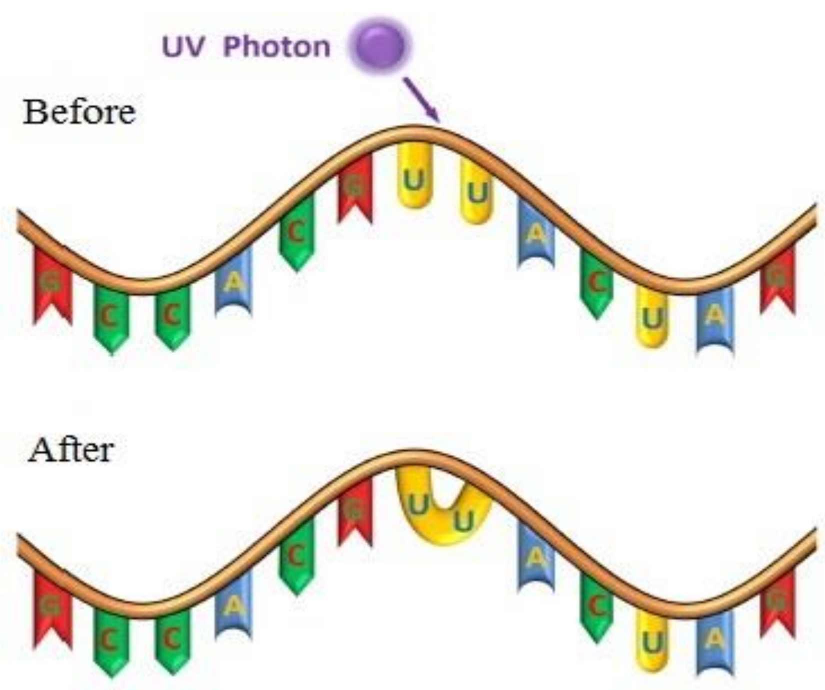

Fig. 1 UV-RNA-damaging mechanism by dimer formation

- RNA viruses' conformation partly dictates the type of photoproducts produced by UV irradiation, that are mainly pyrimidine hydrates and cyclobutadipyrimidines, as well as other photoproducts (e.g. purines and pyrimidine dimers) occurred at much lower rates. Some of the viral RNA photoproducts under UV light exposure are shown in Fig. 2.

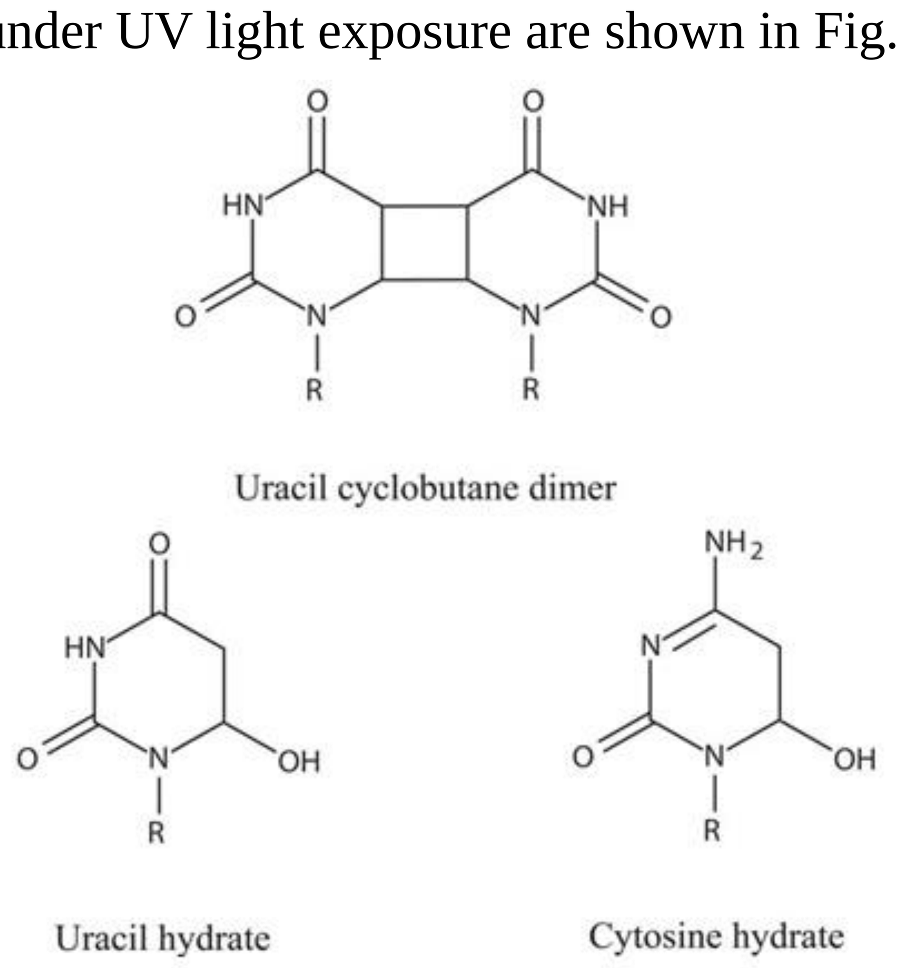

Fig. 2 UV-induced commonly formed viral RNA photoproducts

- Apart from the effect of UV radiation on the viral RNA, the virus coat protein itself may suffer UV photo-damage and may become cross-linked to RNA, thus contributing to virus inactivation.
- UV damage to RNA has been carried out *in vitro* but very few studies suggest that RNA damage may also occur *in vivo* under physiologic conditions.

3. UV-PHOTOINACTIVATION OF SOME CORONAVIRUSES

- Several scientific investigations identified the irradiation wavelength and the UV-photoinactivation for various coronavirus strains. Almost all experiments were performed with mercury vapour lamps, with a peak emission at 254 nm (UVC). In all experiments and for all coronaviruses, a successful virus inactivation was observed, as summarized in Table 1.

Table 1 Susceptibility of some coronaviruses to UV irradiation

Coronavirus	Irradiation wavelength (nm)	Log-reduction dose (mJ/cm^2)	Sample condition
Human Coronavirus (HCoV-229E)	222	0.56	aerosol
Human Coronavirus (HCoV-229E)	254	NA / successful innactivation	liquid (cell culture medium with serum)
Human Coronavirus (HCoV-OC43)	222	0.39	aerosol
Human Coronavirus (HCoV-OC43)	254	NA / successful innactivation	liquid (cell culture medium with serum)
Murine Coronavirus (MHW)	254	0.66	aerosol
Middle East Resp. Syndrome Coronavirus (MERS-CoV)	254	NA / successful innactivation	droplets
Infectious Bronchitis Coronavirus (IBV)	254	13.84	surface
Murine Coronavirus (MHV A59)	254	NA / successful innactivation	surface
Severe Acute Resp. Syndrome Coronavirus (SARS-CoV)	254	NA / successful innactivation	liquid (salt solution)
Canine Coronavirus (CcoV I-71)	254	10.55	liquid (cell culture medium with serum)
Murine Coronavirus (MHV 2)	254	1.54	liquid (cell culture medium with serum)
Infectious Bronchitis Coronavirus (IBV-10 strains)	254	NA / successful innactivation	liquid (cell culture medium)
Middle East Resp. Syndrome Coronavirus (MERS-CoV EMC 2012)	254	27.47	liquid (blood plated concentrate)
Murine Coronavirus (MHV)	254	6.67	liquid (cell culture med. without serum)
Porcine Epidemic Diarrhea Virus (PEDV)	254	NA / successful innactivation	liquid (blood plasma)
Severe Acute Resp. Syndrome Coronavirus (SARS-CoV Frankfurt 1)	254	17.54	liquid (blood platelet concentrate)
Severe Acute Resp. Syndrome Coronavirus (SARS-CoV Hanoi)	254	22.67	liquid (cell culture medium with fetal bovine serum in MTP)
Severe Acute Resp. Syndrome Coronavirus (SARS-CoV P9)	254	40.5	liquid (cell culture medium with fetal bovine serum in MTP)

- Experiments have shown that the irradiation doses required are lower for viruses on surfaces, aerosols and pure salt solutions.
- The organic compounds contained in the cell culture medium may exhibit very high absorption of the applied UV light, resulting in much lower irradiances for the viruses inside the sample.

4. CONCLUSIONS

- UV light has antiviral effect against coronaviruses but it is yet premature to draw conclusions on the UV light virucidal effect on SARS-CoV-2, as the experimental data released so far are quite few.
- Given the similar structure of coronaviruses containing a single-stranded RNA and the mechanism of inactivation by inducing structural changes to the RNA chain, it can be assumed that UV irradiation is an advantageous option for disinfecting surfaces and enclosures, applicable also for SARS-CoV-2 contamination, including any future RNA mutations.

References:

Heßling M. *et al.*, Ultraviolet irradiation doses for coronavirus inactivation – review and analysis of coronavirus photo inactivation studies, GMS Hygiene and Infection Control, 2020, Vol.15, pp. 1-8;

Buonanno M. *et al.*, Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses, Scientific Reports, 2020, DOI: 10.1038/s41598-020-67211-2;

Kowalski W. Ultraviolet Germicidal Irradiation Handbook. UVGI for Air and Surface Disinfection, Springer, 2009, DOI: 10.1007/978-3-642-01999-9;

Yuanyuan Qiu *et al.*, UV inactivation of human infectious viruses at two full-scale wastewater treatment plants in Canada., Water Research, 2018, Vol. 147, pp. 73-81, DOI: 10.1016/j.watres.2018.09.057.

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