https://docs.google.com/presentation/d/1Z0jPd_HgXz0YD7s3m9HhhU1OGgZgGPiow0rZ0H99zXg/edit?usp=sharing

Ellie Kasradze, Richard Lin, Andrei Mitrofan, Danny Nguyen, Vivian Wong

Prompt

~~**Design a UV or Ozone based Car Sanitizer**: In the midst of a global pandemic caused by a highly infectious disease which is known to linger in air and on surfaces, people still need to be transported by ambulance and automobile. Design a realistic method for sanitizing an entire automobile interior (with nobody present in the car!). Use Ozone, UV, or some other method. Explain how nooks and crannies will be sanitized. Develop a research plan for this effort. What needs to be researched, as opposed to what can be reasonably predicted to work?~~

After conducting more research, we found out that one of the most important aspects of clearing pathological germs from an automobile is good air ventilation, and that is sufficient for removing pathogens in most cases. As ambulances already have highly effective HVAC systems that are can remove more than 99.9% of germs in the air, and opening windows in an automobile allows for good ventilation of the air inside, we didn't consider that the benefits of a technological sterilization solution would prove significantly better than other simple behavioral solutions. After discussing with our mentor about other solutions like improving air cycling via rolling down the windows during or after a ride, reducing the need for an UV/ozone car sterilizer solution), we pivoted the research we had already done to design an **Inline UV sterilizer.**

Inline UV sterilizer: Design or build a UV airway sterilizer. The sterilizer should fit in-line in a standard 22mm adult airway hose with taper-fit connections. If designing, model flux well enough to convincingly assert sanitizing ability. The device should ideally be small and fit directly into an airway, for example to sanitize the output of a ventilator patient. The device should admit ZERO dangerous UV radiation outside of itself (even in the airway.) WARNING: UVC radiation is inherently dangerous to human eyesight and skin; if building a device, serious precautions and safe practices are absolutely required and the team will be disqualified if it does not demonstrate safe practices. SKILLS: BioMe, Biology, Physics, EE, optics.

Early Prototype:

We created a proof of concept prototypes with materials that we had readily available to demonstrate how the actual device would function. We illustrated how the device would attach to existing ventilator tubing and how the UV LEDs would be placed to allow for sterilization of the exhaled air.

Materials:

- 22 mm tubing
- Ventilator mask
- PVC corner tube
- Blue LEDs (closest wavelength we had to the UV)

- Resistors
- Black-out tubing (we used a black foam tube)
- Power source (we used a 9V battery)
- Wires

Build instructions:

1. Connect the PVC corner tube to the exhalation port on the ventilator mask, and connect the 22mm tubing to both the PVC corner tube and the inhalation port on the mask.
2. Insert the blue LEDs facing inwards in the black-out tubing, and wire them in parallel to the power source. Wire the power source in series with an appropriate resistor for the LEDs you are using. Our LEDs had a 3.3V drop and maximum rating of 30 mA, so we used a 300 Ohm resistor.
3. Attach the black-out tubing to the end of the 22mm exhalation tube.

Background research on sterilization methods (UV, Ozone, and other types)

UV:

- What wavelengths do we need for UV-C sterilization?
    - 100 - 280 nm
- UV bulbs vs. LED
    - https://www.fda.gov/medical-devices/coronavirus-covid-19-and-medical-devices/uv-lights-and-lamps-ultraviolet-c-radiation-disinfection-and-coronavirus
    - Numerical comparison: https://klaran.com/intensity-comparison-uvc-leds-vs-lamps
        - Assume only 10-30% of input power into UV lamp is output due to heat losses and inefficiencies
- Time frame: how long does it take to properly kill microorganisms?
    - 8 foot biosafety cabinet ~ 30 min
    - https://abionline.com/is-uv-sterilization-effective-for-viruses-and-bacteria/
    - “60 seconds of UV-C LED light exposure has been shown to sterilize 90% of coronavirus germs”
- Need: UV works best on smooth surfaces - limited in that it penetrates superficially so can’t get into crevices
- Dose of 75mJ/cm2 is needed to kill >99.9% of the COVID-19 virus.
    - At a distance of 10cm from average (6W) UV bulb, light would need to shine for at least 12.5 sec to sterilize >99.9%
        - At 2cm away, would only need 0.5 sec
    - https://smartairfilters.com/en/blog/uv-light-air-purifiers-uvgi-far-uv-covid-delta-virus/
- UV dose calculator: https://uv-light.co.uk/uv-dose-calculator/
- The Inverse Square Law states that the doubling of the distance between the UV light and surface will quadruple the time required for disinfection

    - https://www.researchgate.net/figure/Visual-propagation-of-light-following-the-inverse-square-law_fig2_320926645#:~:text=10%20The%20Inverse%20Square%20Law,efficacy%20of%20UV%20room%20disinfection.
- Price of 60W UV lights (assuming 10% efficiency -> functionally 6W): 2 pack for $50
    - Cross-sectional area = 8.1"x6.3" = 51.03 in^2
    - With 2 panels & 2cm (0.787 in) away, volume sterilized in 0.5 sec = 40.16in^3
        - Using approximated ambulance air volume, time required for entire ambulance at max efficiency (only unsterilized air passing over light) is about 3.4 hours
        - This number is linearly correlated to # of UV lights. With $100 worth of lights (4 lamps), time would be about 1.7 horus

Approximated volume of ambulance: 739cm x 241cm x 279cm = about $50m^3$ = about $3.05*10^6$ in^3

- https://www.demers-ambulances.com/model-comparison-chart/
- Important when calculating sterilization time for a given flow rate (though this number obviously includes seats and other non-air items in the car)
- From this image, assuming ⅓ of ambulance is occupied by furniture/cabinets (about $1{,}000{,}000$ in^3 air)
    - About 16.4 m^3 of air in ambulance

ETFE film, like F-Clean Clear, has high (>80%) transmission to UVC light.

- https://www.researchgate.net/post/Which_plastic_has_the_highest_transmittance_of_optical_wavelength_from_250-300_nm_PET_PEN_PS_PMMA_PI
- $1.32/$ft^2$=0.917 cents/$in^2$ https://www.friendlyaquaponics.com/docs/ETFE%20Pricing%202014.pdf

Human Exhale: 5-7 L/min

- Average 6 L/min used in calculations
- https://unit.aist.go.jp/ieco/ect/pdf/Nishi_Masterthesis.pdf

Other Methods:

- https://arxiv.org/ftp/arxiv/papers/2005/2005.11443.pdf - review (from 2005) of covid/related virus transmission and disinfection methods: couple things to look into would be spraying chemical disinfection and plasma disinfection (mostly the latter maybe, since sprays probably won't cover nooks and crannies)

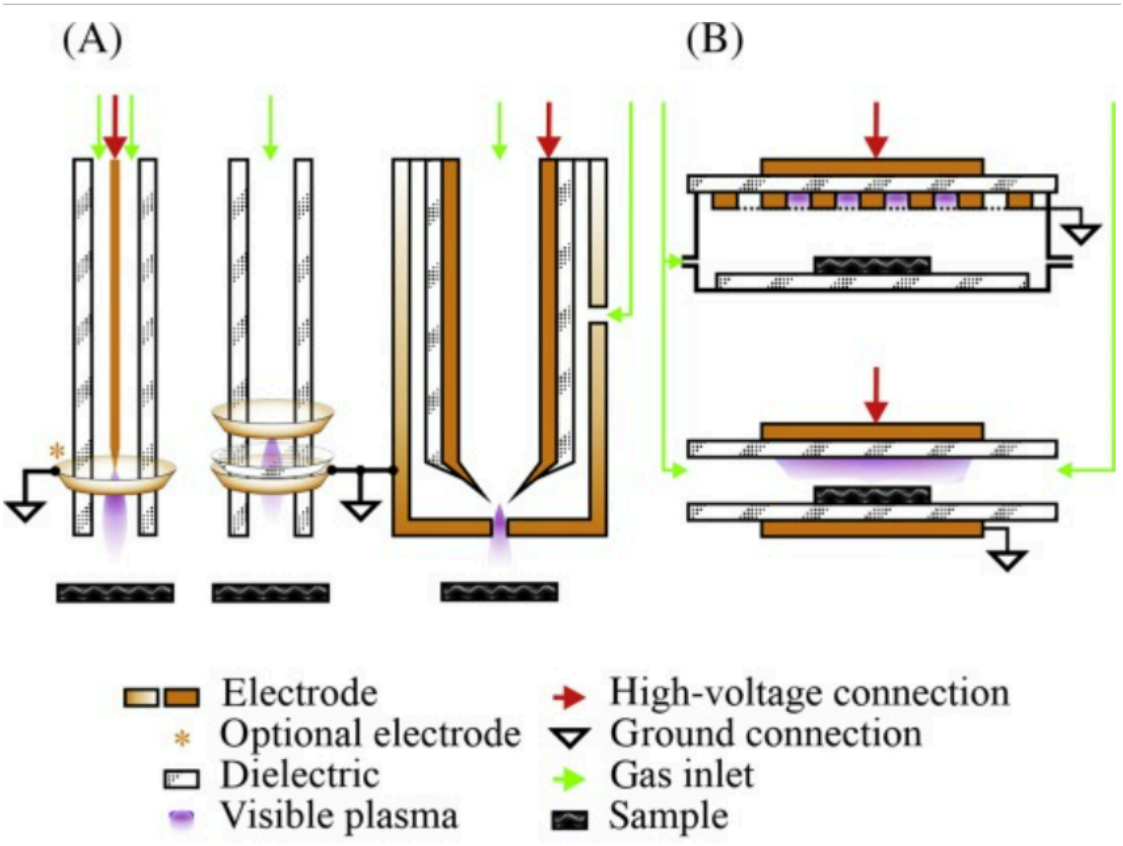
    - "In order for a virus to be infective, it must fuse with a host cell, insert its genome into the cell, and replicate. These processes require an enveloped virus to have an intact envelope and nucleocapsid. To inactivate a virus, at least one of these components needs to be disrupted."
    - mentions uv/solar radiation
    - chemical disinfectants: ethanol and detergents disrupt the lipid layer, chlorine and glutaraldehyde modify important protein sites on the envelope/capsid, and chlorine reactions with nucleotides/amino acids to degrade genetic material

        - chemical agents reviewed generally inactivate covid within 5 minutes or less, but may evaporate too fast/be incompatible with metals
        - dispersing disinfectants: wiping (manual), and spraying (more feasible for a device); spraying, or atomization, comes in the form of a variety of droplet sizes, spray distances, and flow rates
    - plasma disinfection: cold atmospheric plasma (CAP) is low-temp, non-thermal (electron temp is much higher than heavy species [ions/neutrals]) has been considered for disinfection in dentistry, oncology, food processing; reactive oxygen and nitrogen generated in non-thermal plasma are thought to damage DNA/proteins (inactivated potato virus Y in 1 minute); plasma-activated water (PAW) is water+non-thermal plasma, inactivated newcastle disease (both have yet to be tested in covid at time of paper though)
    - heat treatment: 70C = inactivation of covid within 5 minutes, or autoclave (high temps definitely not good in a car setting though, so not this method)
    - self-disinfecting materials/surfaces: copper/silver alloys (not feasible either)

- https://www.frontiersin.org/articles/10.3389/fphy.2021.683118/full (2021 non-thermal plasma (NTP) paper)
    - NTP is similar to ozonation approaches, although plasma just involves air+electricity producing reactive oxygen and nitrogen species, while ozone is a separate gas, and NTP interacts with the treated substrate more intensely, resulting in a broader range of species in NTP that in turn enhances its virucidal efficacy
    - pros: energy cost is similar to uv-c, can flow around surfaces (no shadowing, which is an issue with uv-c); cons: more effective on humid, rather than dry surfaces; doesn't work in solutions well since they exist at liquid surface and dissolve in liquid
    - airborne NTP: in a test tunnel with aerosolized viruses, cold oxygen plasma inactivated airborne viruses
    - NTP on surfaces: can deactivate covid on various surfaces (plastic, cardboard, metal) in <180s; non-smooth surfaces may reduce inactivation efficacies, also in part likely due to protein concentration present on surface (tested mainly on food and stainless steel surfaces)
    - NTP in solution: depends on the reactive species being produced, can't be sustained in liquid essentially
- https://www.sciencedirect.com/science/article/pii/S0167779920301086 (more non-thermal plasma (called cold plasma [CP] in this one))
    - CP can be applied at either low or atmospheric pressure; the former spreads in a large volume, while the latter requires the presence of large electric fields to spread

overall with plasma, it seems to work well for airborne/vent scenarios, for surfaces I found mostly very close distance testing so adapting to a bigger area/space like a car requires further research?

[60G Ozone Generator 220V Ozonio Gerador Long Life Ceramic Plate ozontor ozonizador air Water Cleaner Air Purifier|Air Purifiers| - AliExpress]



quick mentor meeting notes:

what do they currently do? (e.g. ambulance just drove a covid patient to the hospital, what process do they do right now, so we can see what problems they currently have; we could recommend differences in their current protocol)
crevices: does covid and stuff accumulate in crevices, is it a vital problem?

maybe need to clarify with somebody: is developing a solution necessary

should understand problem better: is sterilization required in all of these cases