Project Title: UV Clean: Sustainable Hand Hygiene through UV Sanitation Stations
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Selected Need: Individuals need a way to maintain hand hygiene in areas with water shortages in order to prevent transmission of the virus.

1. Problem Overview / Relevant Clinical Background

Hand hygiene is important in preventing the spread of the novel coronavirus. Infective respiratory droplets can live on surfaces for hours and our hands serve as the vehicle for the droplets to enter our body. Public health officials advise the public to frequently wash their hands with soap and water for at least 20 seconds to prevent virus spread.

Unfortunately, many regions of the world lack sufficient access to running water, which makes hand washing extremely difficult to routinely practice. Hand hygiene campaigns in developing countries try to make "tippy-tap" devices to store water and develop water-related infrastructure in order to address this problem; however, this approaches reliance on water availability constrains its impact. Three billion people still lack basic hand washing facilities today according to the WHO. This is especially concerning during the global coronavirus pandemic because many of the places lacking access to water are in low and middle income countries. These places often have extremely high population density, and people living here often do not have the luxury of staying home from work to protect themselves from COVID-19. This makes them already especially vulnerable to a major pandemic, and when the infectiousness of COVID-19 combines with the lack of hand-washing in these dense under resourced areas, the results could be disastrous. Lack of water is not only a source of concern during this pandemic, but it affects daily life in normal circumstances as well. Too often, people must choose between drinking, bathing, hand-washing, and cooking, because not enough water exists for all four. Handwashing alone can take 100 to 200 liters of water per day for a family of five, so it is often neglected. As a result, children die of preventable diseases, such as diarrhea, because of hygienic problems related to lack of handwashing, and women and girls cannot attend school or have a career because the burden of fetching water falls on them.

2. Proposed Solution

Our solution is a "UV sanitation station" that will safely and effectively clean hands. It will use far-UVC light at a wavelength of 222 nanometers to inactivate viruses and other microbes by destroying molecular bonds that hold DNA and RNA together. This specific wavelength does not harm mammalian skin or pose human health hazards. Studies show far-UVC to be effective at low dosages over efficient time scales: 2 mJ/cm^2 for 20 seconds should inactivate approximately 99% of viral material.

A prototype of the station was designed in AutoCAD (Figure 4). It incorporates a round wall-mounted design to prompt user comfort, as it is reminiscent of already-familiar hand dryers and paper towel machines. The casing of the station will be made from injection molding. The station is planned to be mounted with the top at a height of four feet, to allow ease of use for both children and adults. Openings on each side of the station allow ready hand access into a round oval-shaped chamber. A single far-UVC LED light is mounted in the top of the chamber, and a reflective material coats the chamber to allow for reflection and even distribution of light. We will be using a 20W 222nm Excimer Lamp, encased with an Ultran UV-Transmitting Acrylic Sheet which will allow light to pass through but ensure no hand burns are caused by preventing direct contact with the lamp. An arduino is proposed as the method to control circuitry. A motion sensor will activate the far-UVC light to turn on for 10 seconds. A small LED will also light up to signify the user the machine is on, and turn off to signify when sanitation is finished. The user should slowly rotate their hands until the light turns off. If the user happens to rest their hands on the interior, no contamination will take place because the interior is cleaned by the light. At that point. The user can withdraw their clean hands. A simple pictographic on the front of the station will illustrate these use steps (figure 6). A rough physical prototype was also constructed (Figure 5).

These stations should be placed around a city for public use, and will decrease each individual's water use, simultaneously alleviating stress on water-lacking cities and giving citizens the opportunity to implement hygienic hand washing practices in places they previously could not. An adjacent website will communicate the instructions for use and information about the stations as well as raise awareness about our solution (Figure 7).

3. Use Case

Chennai, India is chosen as the initial target city for these devices. Chennai is a dense city in extreme drought. People in the city currently wait hours to get their water from private tankers, and public water in facilities such as bathrooms is highly unreliable. Chennai has surplus electricity to power the far-UVC stations and has internet access that will allow users to visit the adjacent website. The station should be installed in public settings, such as restrooms, where the primary user, the general public, will have easy access. A simple hand insertion, wait of 20 seconds, and hand withdrawal will be the only effort needed to use it.

Far-UVC hand sanitizing stations could eventually be adapted to remote villages with limited access to water or power via use of an alternative energy source, such as solar.

4. Evidence for Functionality/Efficacy.

Multiple studies show that far-UVC is consistently efficient in the inactivation of both aerosolized and droplet viral material, the exact category that Influenza and SARS-CoV-2 both are RNA viruses fit into. Research to absolutely confirm that far-UVC is effective specifically on SARS-CoV-2 is already underway. One specific existing study has shown that 222 nm light sources to inactivate H1N1 virus (>95% of aerosolized influenza virus) at low dosage (2 mJ/cm^2) without harm to exposed mammalian skin. Another study shows virucidal efficacy, with 20 seconds and average 1.5 mJ/cm^2 having a 97.48% reduction rate and 40 seconds with 3.0 mJ/cm^2 having 99.84% reduction rate of influenza virus from 50 cm away. Another study even suggests that far-UVC is more efficient than conventional antimicrobials in terms of cost and effective disinfection of surfaces. Microbes and pathogens cannot typically develop resistance to this type of disinfection, and light therapy affects a very wide range of microbes. In fact, far-UVC is already used for disinfecting materials in some hospital settings because it is so effective.

In terms of safety, multiple studies from various credible sources show that far-UVC is harmless to humans. It does not penetrate the skin, but still destroys genetic material of viruses and bacteria.

Calculations using costs of all raw materials and manufacturing costs have given a price point estimate of 85.00 USD per unit, plus the costs of putting together the casing and electronics, for production of 10,000 units (figure 8). Each far-UVC bulb can sustain slightly less than two million hand sanitizations, based on it's lifespan. Once the initial bulb's lifespan has elapsed, only the bulb needs to be replaced, and not the station. In comparison, if the same amount of hand sanitizations were done by using sanitizer, the cost of the raw material of sanitizer (since water is not available) needed would be about 18,000 USD. This is much larger than the 85.00 the UV sanitation station costs. In addition to saving money, each use of each unit saves 1.33 liters of water. If stations were eventually distributed to the whole city of Chennai, the water savings if each person used the station four times a day would be 37,708,160 liters a day.

5. Further Design / Testing Work Required

To bring this solution to fruition, specific further steps must be taken. First, a real physical prototype must be made. A manufacturing process must be designed, for the model we have designed using the materials we have chosen. We must then find a manufacturing plant for production. More design would need to be done to consider the heat transfer of the UV light and a determination made for whether a fan or cooling system would need to be installed.

In the future we can see these UV stations being implemented in more remote areas without reliable electricity by integrating solar panels with the stations. This can have a significant impact in the fight against diarrhea which kills over 2,000 kids every day.

6. Implementation Plan

After the manufacturing process is cemented, a means of distribution and motivation is needed to get these stations to Chennai. The route we have decided to pursue is to contact the Health Officers or Prime Minister of Tamil Nadu, the state in which Chennai rests. These officials could offer help in the mandating of installation of stations and contacting local officials for distribution via the various represented areas of Chennai. We have a planned route to contact these officials. Existing infrastructure in Chennai, such as public restrooms and existing power lines, could be used to mount and power the stations. An avenue that could be explored to help with distribution and installation are local philanthropic organizations that strive to help with the water shortage such as Water For People. If the devices need repair or bulb replacement, which should happen less than once annually, the citizens can contact their district representatives and health officers.

For motivation and education of users, the website and an informational pictographic on each station will be used.

In terms of timeline, as soon as manufacturing is cemented, the product could be produced and distributed as fast as physically possible.

7. Resources Needed for Completion

Expertise from an electrical engineer concerning the electronics (although relatively simple) is desired. Help from an engineer or someone with manufacturing expertise and contacts would be extremely helpful.

Funding is needed for initial production. Multiple avenues could be pursued to secure this. The local government may be interested in funding the installation of these stations if it could be shown that this would result in long-term savings for them and increased health for their citizens. Another option for funding would be reaching out to organizations that offer philanthropic funding, such at the Bill and Melinda Gates foundation, or the Moore foundation.

Appendix (Figures/Data/Tables):

Figure 1: Chennai's extreme drought forces people to wait in long lines to purchase water which is then rationed by each individual between drinking, cooking, bathing, and hand-washing.

Figure 2: Current state of bathrooms in Chennai. No clean sink or water to wash hands with is seen.

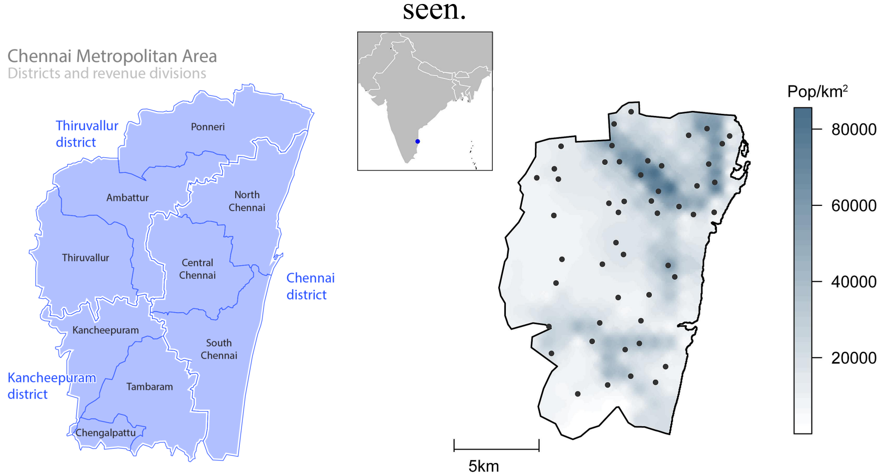

Figure 3: A map of the districts of Chennai is shown on the left, while a depiction of population density in 2015 is shown on the right.

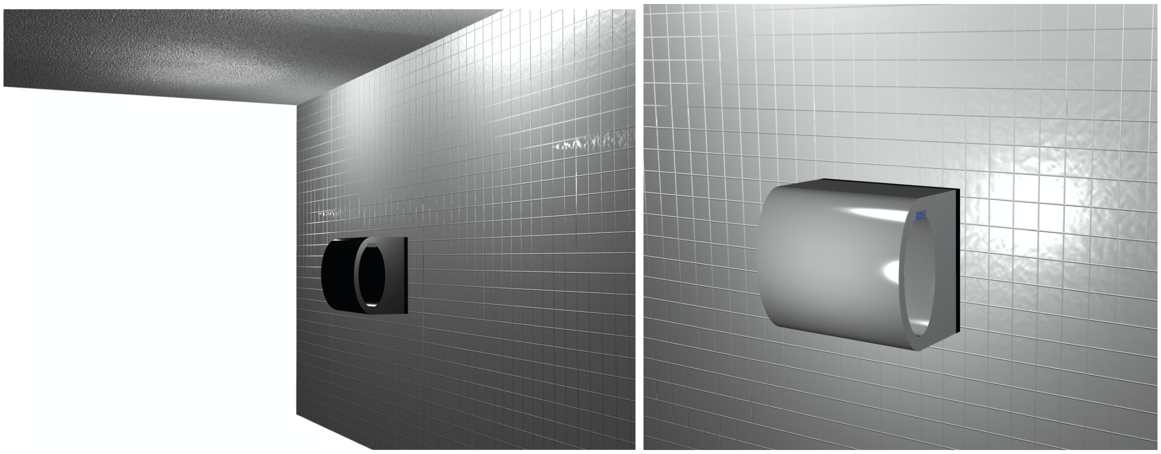

Figure 4: Prototype of UV Sanitation Station modeled in AutoCAD

Figure 5: A simple physical prototype of a sanitation station, built of aluminum foil. The link attached provides a simple experiential video of what it would be like to use the station.
https://www.youtube.com/watch?v=A1FWqi95c60&feature=youtu.be

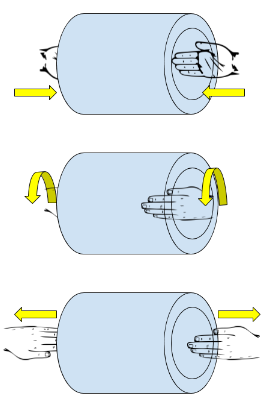

Figure 6: A simple pictographic shows how to use the station.

Figure 7: A snapshot of the website. The attached link provides direct access. https://randomuse00.wixsite.com/uvforyouandme

Plastic		Notes
units	10000	
size x y z in	18x12x9	
wall thickness in	0.25	thick enough for sturdiness
projected area %	85	leaving room for oval cut outs
volume %	15	Hallow not much inside to fill
Total	254,670	
per unit	25.47	
Total:	824,570	
cost per unit:	82.457	
Realistic Cost	$85.00	

UVC Bulb	
Estimated Bulb	27
# of units	10000
Total Cost	270000
Mirror finish	
Size: 540 in2	0.4
total:	4000
Bulb Plastic Cover	
Unit	6.24
Total Cost:	62400
motion detector	
Cost	4.95
Total Cost:	49500
Electronics	
Arduino Nano 33	18.4
Total	184000

Figure 8: Cost analysis for production of one unit.

References

1. Baes, Fred. "Hps.org." *Health Physics Society*, 3 Feb. 2011, hps.org/publicinformation/ate/q9450.html.
2. "Care222® Far UV-C Excimer." *Mercury-Free Far UV-C Excimer Lamps*, USHIO, 2020, www.ushio.com/files/specifications/care222-mercury-free-far-uv-c-excimer.pdf.
3. "Clean Water Charity Ending the Global Water Crisis." *Water For People*, 24 Oct. 2019, www.waterforpeople.org/.
4. Europa, Health and Consumer Protection Directorate-General. "SCCP Opinion on Biological Effects of Ultraviolet Radiation Relevant to Health with Particular Reference to Sunbeds for Cosmetic Purposes." *SCCP Opinion on Biological Effects of Ultraviolet Radiation Relevant to Health with Particular Reference to Sunbeds for Cosmetic Purposes.*, SCCP, 2006.
5. "Injection Molding at Protolabs." *Injection Molding at Protolabs*, www.protolabs.com/parts/injection-molding-production/?utm_source=google&utm_medium=cpc&utm_campaign=us-im&utm_term=injection%2Bmolding&gclid=EAIaIQobChMIr4me38PA6AIVBcZkCh2CAA7HEAAYASAAEgLaYfD_BwE.
6. "How to Protect Yourself." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 18 Mar. 2020, www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html.
7. Japan, Yamada, Haruki. "Performance Test for Virus Inactivation Efficacy by UV Radiation." *Performance Test for Virus Inactivation Efficacy by UV Radiation*, 2019.
8. Khan, Kevin. "Is UVC Safe? UV Light and Health Effects." *Klaran*, Klaran University, 2020, www.klaran.com/is-uvc-safe.
9. "Limiting the Spread of Coronavirus Using the Power of Light." *Crowdfund.columbia.edu*, Columbia University Center for Radiological Research, 2020, crowdfund.columbia.edu/pages/cuimc-research.
10. "Map of Chennai Showing Population Density Estimates and the 50 Locations Sampled in the Study." *Figshare*, PLOS Neglected Tropical Diseases, 3 Dec. 2015, figshare.com/articles/_Map_of_Chennai_showing_population_density_estimates_and_the_50_locations_sampled_in_the_study_/1486182.
11. "Modes of Transmission of Virus Causing COVID-19: Implications for IPC Precaution Recommendations." *World Health Organization*, World Health Organization, 27 Mar. 2020, www.who.int/news-room/commentaries/detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations.
12. Narain, Sunita. "Water in the Age of Coronavirus." *Down To Earth*, 21 Mar. 2020, www.downtoearth.org.in/blog/water/water-in-the-age-of-coronavirus-69905.
13. United States, Congress, Centers for Disease Control and Prevention, and David Snyder. "Diarrhea: Common Illness, Global Killer." *Diarrhea: Common Illness, Global Killer*, pp. 1–4.
14. Welch, D., Buonanno, M., Grilj, V. *et al.* Far-UVC light: A new tool to control the spread of airborne-mediated microbial diseases. *Sci Rep* 8, 2752 (2018). https://doi.org/10.1038/s41598-018-21058-w