Automated System for Lavatory Disinfection

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Abstract- Instead of that conventional method of chemical (sanitizer spray) disinfection, this paper introduces a novel idea to fight the attack of microbes causing infections and diseases from the source like lavatory and specially its seat. Here we utilize the germicidal power of ultra violet light ray’s .i.e. Ultra Violet C range of the light spectrum against the viruses (SARS-CoV-2), bacteria (E. coli) and other microbes. This system of disinfection constitutes the UV LEDs placed on the arm above the toilet seat. The range of wavelength is from 200nm to 280nm. Implementation of this technique ensures safety, by human free room with the automatic motion control using Arduino, motor and door locking gadgets. UVC light is very advantageous over other methods as it is eco-friendly, chemical free, non-corrosive, and no hazardous waste is produced and also inactivates viruses by attacking the DNA strands in the microbes ensuring that the replication does not happen further stops spreading of contagious diseases leading to pandemic. Usage of toilet paper and other methods used conventionally could come to an end. Thus an effective idea is derived for the hygiene establishment.

Keywords: UVC, SARS-CoV-2, non-corrosive, DNA, germicidal, lavatory, automation.

1. Introduction

During this COVID-19 pandemic year, we must have a cover over us to protect from the spreading of the diseases. But by reducing the consumption of environment resources; such as cutting of trees for papers and production of hazardous waste residues. All these are replaced by UVC for germicidal purposes.

Since the past years, we all are facing many infective diseases; these infections come from many sources, including contaminated hands and unclean surfaces. However these could be decreased by doing serious sanitizing efforts, and by a continuous effort to reduce these infections, healthcare facilities have turned to several disinfection methods. Ultraviolet light spectrum is a form of light that a human eye cannot see or sense. That is present in electromagnetic spectrum in between X-rays and visible light. In the sun’s ultraviolet light emission; much of it is assimilated by ozone layer. The unique characteristic of this light is that a specific range of its wavelengths, those between 200 and 300nms and are categorized as germicidal which means they are able of inactivating microorganisms, such as bacteria, viruses and protozoa. This ability has allowed large adoption of the Ultra Violet rays
spectrum as an environmentally friendlier, chemical-free, and highly efficient way to disinfect and guard water against harmful microbes. In Ultraviolet spectrum in the Ultra Violet-C band is called to be UV-C germicidal spectrum, which is utilized in large scale for purification of the equipment for reuse. And thus creating sterile environments. They are also used in the food and water industries to deactivate microbes and germs.

Unlike the chemical approaches of disinfection, Ultra Violet provides spontaneous and efficient deactivation of microbes by using a physical procedure. The Ultra Violet radiation has depicted efficacy against the pathogens, including that are responsible for hepatitis, typhoid, polio, cholera and other parasitic, viral and bacterial diseases. In addition, UV light (maybe only UV or combined with hydrogen peroxide i.e. photo sensitizer) can decontaminate the chemicals pollutants such as insecticides, pest repellents, the industrial solvents and waste from pharmaceuticals through the process known as UV-oxidation. Microorganisms like bacteria and protozoan are destructed by utilizing Ultra Violet spectrum of light as a result of which there is damage in the nucleic acid. The enormous energy produced by the short wavelength Ultraviolet Violet energy, basically 254 nm, is captivated by cell’s DNA strands and RNA strands. This engulfing of Ultra Violet energy creates new bonds between the nearby nucleotides, creating multiple bonds or else dimers. Dimerization of nearby molecules, specifically thymine takes place. The most vulgar photochemical damage will occur. Formation of numerous dimers of thymine in the DNA’s of virus and bacteria prevents production of replicas and reduce the capability to infect.

2. Background

Contemporarily, many procedures are presently there for sterilization in pharmaceutical and medical field products like these chemical treatment, thermal treatment, ultraviolet radiative treatment and plasma radiation [1]. Such as in the COVID-19, pandemic period. Personal protective equipment used are as facemask respirators, protective isolation garments, goggles for eye protection and also face shields that an all are utilized to attain the promised safety of the health care workers. There are use and throw items and reusable wearable’s also available in the commercial market. Reusable garments can be worn for several times. The sterilization or disinfection procedure includes washing, parching or sterilization. Thus process, of using dry steam at 1210C for 30 minutes are usually used process of sterilization [2]. The United States Centers for Disease Control gives recommendation for cleaning of face protection and eye guards using a cloth to clean and also use it with saturated with hospital solution EPA for disinfection or disinfectant wipe prior to the reuse [3].

In the chemical sterilization process, the chemical ingredients such as formaldehyde, glutaraldehyde and hydrogen peroxide are being used as sterilizing agent to inactivate viruses like SARS-CoV-2 also [4]-[6].Effectiveness and efficacy of UV disinfection is influenced due to the intensity of the light and its exposure time [7], [8]. From the wide range of Ultra Violet spectrum of light; Here we use the Ultra Violet Range from 210 to 365 nm specified UV LEDs [9].

![Fig. 1 Major advantages of the Germicidal UV](image)

3. Proposed Method
In Here we the property of log reduction which means logarithmic reduction, where it will be defined as the predicted degree of the dosage needed for the specific disinfection or sterilization. The logarithmic range of reduction is the percent of physically sterilized, inactivated microorganisms by this radiation procedure. By example, in log one reduction we can get a reduction in the pathogen that is to be deactivated reduced to 10% as in per the infection level before Ultra Violet exposure and disinfection. Microorganism number is also reduced by a count 10 or 1 log. And, the log 2 reduction will have around 1% of microbe that is by the factor 100 and thus goes on.

UV C dosage and response comparison defines at which rate particular microbes is inactivated by applying specific dosage of UV exposure. This computation is given as either by the amount by which microbes disinfected or the remaining proportion as a UV dose function. Response of UV radiation is computed by the following mathematical representation:

\[
\text{Log inactivation} = \log_{10} \left( \frac{N_0}{N} \right)
\]

And:
\[
N_0 = \text{infectious microorganisms concentration before the exposure to Ultra Violet radiation.}
\]
\[
N = \text{infectious microorganisms concentration after the radiation exposure of UV radiation.}
\]

Each microbe category has a unique curve for dose-response. This curve describes how every microorganism responds to different dosage of UV radiation of light.

![Fig. 2  DNA strand deactivation process](image)

Log 3 reduction is chosen here with respect to the following parameters:
1. Bulb Power
   The bulb we use in the system is UV-C LEDs of wattage 5W.
2. Distance
   The distance between the light source and the surface is 5cm.
3. Duration
   The duration for the UV exposure is less than 5mins of time.
4. Shadowing
   Here the shadowing is negligible for log 3 reduction since the distance is 5cm. We use multiple LEDS from different direction in order to avoid the effect of shadowing.

Log 3 reduction ensures 99.9% reduction in germs and microbes. Requires an exposure of \(6020\text{J/m}^2\) to attain Log 3 reduction. The table below gives the exposure time for a distance of 5cm for different UVC LEDs power ratings.
This disinfection technique cleanses both bowl and the seat of the lavatory overall. The proposed system consists of UV LEDs embedded on the arm lid over the toilet seat; along this the motor is connected with the arm and to the controller box. Different parts of the system are briefed below:

3.1. UVC LEDs

These LEDs emits UVC light which is invisible to human eyes, but inactivates the microbes (e.g., COVID-19). UVC light has much stronger germicidal properties than both UVA and UVB. UV C band is strongly sucked by RNA and DNA strand bases in the nucleus leading to structural molecular damage through a photo dimerization process. Thus results in virus deactivation, so that they are no longer will be able to multiply or replicate. The emission wavelength of them is 260-285 nm and beam angle of 130 Deg. Forward Bias of max 9V.
3.2. Closet lid actuation

PVC lid of the closet will open sideways actuated by stepper motor powered gear system. The Ultra Violet C band LEDs will be spread throughout the lid partition to have any even light distribution.

3.3. Control box

This consists of Arduino module that controls the motor actuation and auto door lock mechanism taking the relevant feedbacks from the sensors.

3.4. Electrical door lock

Solenoid operated door locking mechanism to avoid UVC subjection during disinfection process ensuring fool proving and safety.

3.5. Sensors and indicators

1. Inner door knob with occupancy indication.
2. Limit switch to detect door knob actuation.
3. Limit switch to determine solenoid lock position.
4. Limit switch to ensure door close.
5. Limit switch to ensure toilet lid position
3.6. *Auto door close*

Self-closing spring door hinge for auto door close is fixed.

4. **Experiments**

Different microorganisms have different sustainability to Ultra Violet light radiation; few microbes in this world are much affected, whereas other microbe requires more time and dosage UV C exposure for exact inactivation. An appropriate UV dosage is for the optimum deactivation of the targeted organisms. The UV dosage is to be calculated using the following mathematical representation equation:

\[
\text{Dosage} = \text{Ultra Violet light Intensity (E)} \times \text{Exposure time (t)}
\]

Or otherwise,

\[
\text{UV Dosage} = E \times T,
\]

Where;

1. Dosage is got in joules per meter square (J/m²) and also in milli joules/centimeter square (mJ/cm²).
2. Ultra Violet Intensity is to be measured in terms of milli watts/centimeter square (mW/cm²).
3. Time of Subjection is measured in terms of seconds(s).

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**Fig. 8** Block Diagram of automated lavatory.

5. **Results**

This novel system for automated lavatory was simulated and modeled using Tinkercad simulation software. The following figures are the output of the proposal.
6. Discussions

Ultra Violet LEDs enables new application such as water, surface and air decontamination and inactivation. And also in the bio agent detection, identification process, UV curing and biomedical analytical instrumentation UV is used. UV radiation inactivates viruses present on the upper surface which will be directly prone to radiation of Ultra Violet spectrum. Conventionally mercury lamps which are used as source of Ultra Violet radiation; but compared to UV C LEDs, lamps made of mercury does not have a rapid switching ON or OFF features. And they usually require a warming up and cooling down process that consumes energy and time both. Overall the lifetime hours of these mercury lamps reduces if they are more often switched on or off. These LED devices have low noise but high modulation in frequency, flexible type of form factor, space and the power spectral distribution, high internal, quantum’s efficiency and there is an ability to achieve high efficacy. This is compared favourably with conventional resources, e.g lamps of mercury.

Yes the components such as the lid and arm is only exposed to water which is water resistant and other parts are placed in the casing to protect from water. After the installation process is over, the system is user friendly and similar to the conventional system. On emergency there is E-stop switch which can
be used. Of course there is water saving as we use the germicidal power of UV-C light spectrum for disinfection instead of the conventional method using fluids and water for cleaning purpose. Thus water and toilet paper saving is ensured here.

7. Conclusions

In this scenario of the pandemic caused due to a small virus, it is important and essential to break the chain spread by strict sanitization measure especially in public places and the lavatories in public places which have the highest risk of exposure to the pandemic causing virus. The practical and cost effective method can be to utilize the sterilizing property of UV rays in the light spectrum. This can easily and safely implement in sanitizing lavatories in public places by the above discussed method. The total process of disinfection will take 3 minutes only. Therefore this is quick and efficient method.

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