

Photo / UV sanitization and therapeutic techniques in the pandemic of COVID-19

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Abstract —Since, the onset of the COVID-19, leads the fear for the impulsive buying of several instruments / devices / accessories based on the ultraviolet radiation which can help in preventive and / or therapeutic measures in the current pandemic. This leads to the huge cash inflow in this sector but without enough return in term of effectiveness and curability. In this review, peer reviewed papers are reviewed regarding the disinfecting and therapeutic behavior of various techniques, devices and procedures in various spectral wavelength, i.e. infrared, visible and ultraviolet already in use against the microbial, viruses and fungi. This will help the general public and health care professional to optimize their vision for the photo / radiation based devices on the concrete scientific evidence / knowledge rather than on the market's trend of making ultraviolet radiation as the ultimate solution.

Keyword: COVID-19, virus, microbial, phototherapy, Solar, Ultraviolet, Radiation, Sterilization, infrared, Bio-aerosol

INTRODUCTION

Since, the onset of the pandemic COVID-19, which cause high level of fear in order to be protected and cured. The fear deprived the market hungry for the products which might be helpful for the treatment and prevention of the pandemic. Several new entrepreneurs and experience manufacturers from other fields, jumped into and flood the market with broad variety of products, such as ultraviolet sterilizers, face mask, herbal products along with several Meta-physical techniques and therapies. Most of them are with the exceptional claims and specifications regarding the prevention, propagation and treatment of the COVID-19 [2, 3, 8, 9].

The fear and hype triggered the animal instinct which leads to the impulse buying of several underrated items, machines and several precautionary measures were taken without evaluating their results and efficacies. Several machines, infrastructures and walk-through gates are mounted but useless and / or scraped / discarded. Even some ordinary products such as face Masks, which were already present in the market but they were sold for much higher prices with the additional tag of COVID-19 [10, 11].

Several investor / manufacturers made a lot of money out of the pandemic while general public even lose their breadwinning job and hook up to the social / welfare system due to lock down scenario. This leads to the drastic reduction in the demand of the energy sector especially oil and gas companies appeared as the most highly affected sector of the world's industries [2 - 7].

The sanitizer (chemical and UV), face mask, walk-through-gates for full body sanitizing were sold in large amount and the market is still depriving for these products. This results in fabrication of several manufacturing units / factories especially developed in the COVID-19 pandemic duration [8,9, 11].

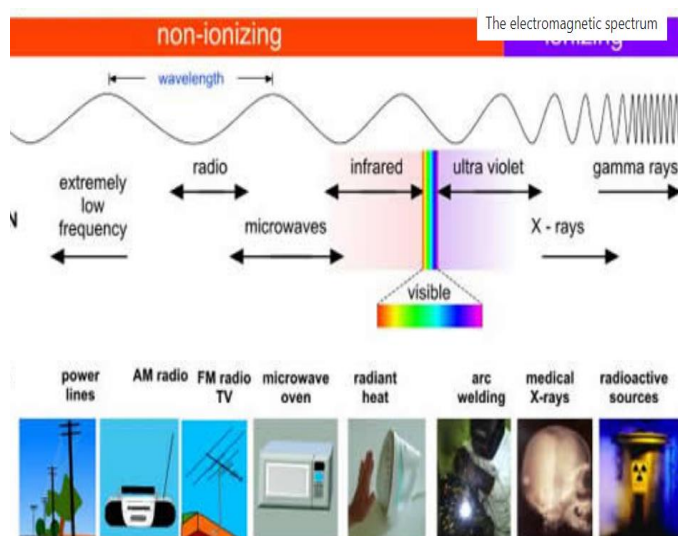


Figure 1 Spectral distribution of the radiation as function of the wavelength in meters. The wavelength above 1020 are the ionization radiation which produce dangerous side effect on the human body adapted from [62].

Furthermore, several techniques / instruments and methods are become famous and proven to be the ultimate

solution for COVID-19, such as UV radiations without considering the health hazards associated with it. This increases the sale of such machines / accessories with huge capital investment without proper return in terms of prevention and treatments. Indeed several scientific published data confirm the germicidal effects of the UV light but most of these experiments are done in control laboratory environment in certain controls set of conditions [1, 18, 20, 32, 33, 34, 35]. This will be further analyzed, interpret and reviewed in this reviewed article.

Ultraviolet (UV) radiation is part of the spectral radiation with narrow wavelength in the range of 1×10^{-8} meters, which slightly above the visible spectral wavelength as shown in Figure 1. All of these radiations are called electromagnetic radiations which has both Electric and Magnetic field vectors perpendicular to each other and the propagation direction is perpendicular to both of them represented as follows

$$\Delta E = E_2 - E_1 = h \nu = h \left(\frac{c}{\lambda} \right) \quad \text{----- (1)}$$

Where ΔE is the change in energy absorbed among the two energy levels, h is plank's constant, c is the speed of light and λ is the wavelength of the incident radiations. The shorter the wavelength leads to the higher penetration depth inside the materials or atomic structure. The absorption of Energy (ΔE) will only occurs for the energy levels which matches the resonant frequency of the incident radiations.

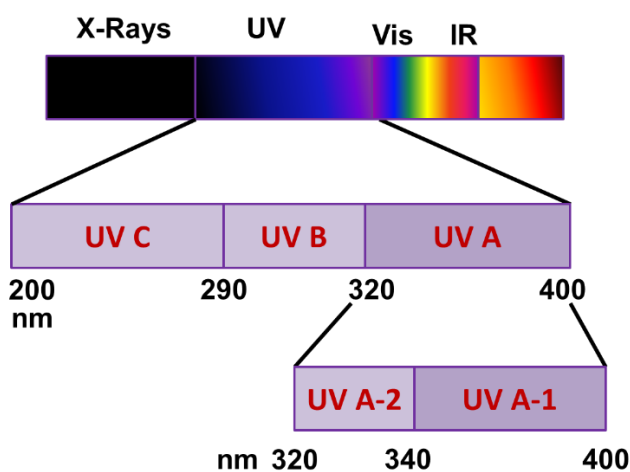


Figure 2. Spectral components of the Ultraviolet radiation in the range of 100 to 400 nm. UV A 320 – 400 nm; UV B 290 – 320 nm; UV C 200 – 290 nm.

The power and frequency are important factors for evaluating its effects for the Electro-magnetic waves. For higher frequencies from the visible and ultraviolet waves, the X-ray and Gamma Rays have adverse effects on the human body even with smaller power. As the frequency goes higher the penetration depth of the electro-magnetic waves increases which leads to higher damages.

Larger wavelengths are widely used in communications such as AM / FM radio and television transmission. They are non-ionizing radiations and present

around us which are invisible with more or less no side effects. Indeed they have dangerous side effects if their radiation power is higher which is normally observed near the transmission towers of the communication networks.

Microwaves are also widely used for heating the foods and related products. They match the resonant frequency of the molecules present in our food products. Once higher Energy (ΔE) of microwave interacts with food products, it results in faster resonating of the molecules which results in excessive heating of the food.

Microwave ovens are extensively used in our daily life due to its "contact less" and fast heating advantages but they are observed with serious side effects. When the molecules are vibrating at very high speed their bonds may sometimes break out which leads to the change in the chemistry of the food items, such as formation of micro-halides which are harmful for the human body.

Only the visible spectrum is visible to our naked eye and the rest of all spectrums such as Radio, Microwave and infrared are not visible to our naked eye. Similarly, the smaller wavelength i.e. X-rays and Gamma Rays are not visible to our naked eye and have an adverse effect on the human body.

Ultraviolet light is divided into three components of spectral wavelength as shown in Figure 2, i.e. UV A, UV B and UV C. The atmospheric layer filter / block the smaller wavelength below 320 nm and allow only UV A which is further sub-divided into two spectral components, i.e. UV A-1 and UV A-2. The allowable UV spectrum contributes to around 5 % of the total solar radiation on earth (see Figure 5). UV has higher penetration depth on the human skin and its exposure may cause skin burn or damages.

I. MATERIALS AND METHODS

Several types of phototherapy are used in various bands of frequencies depending on the type of applications.

Bright Light therapy: The visible bright light contains the spectrum of Red, Green and Blue with the wavelength of 400-700 nm is available in the form of light therapy bulbs / devices for treating several ailments relating to the cold winters especially in the countries in northern hemispheres where sun shine hours are very low. These devices come with variable intensity outputs up to 10,000 lux placed at the specific distance from the human body. Typical solar sun light is less than 15,000 lux in a bright sunny day. Several studies reported [41, 44] show excretion of serotonin hormone which plays a vital role for the regulation of the good mood and for SAD ailment [43 - 46].

The visible bandwidth in the range of 400-700 nm is considered safe even in higher intensities, i.e. above 10,000 lux. It is also used in **Photo dynamic Therapy (PDT)** where the **Photosensitive (PS)** dyes are used on the target cells in order to bind and kill /inactivate the harmful microbial and virus. The technique is complicated and it is difficult to avoid the harmful effects of photosensitive dyes to the host cells [43, 47 - 49].

Blue light Therapy: The blue light particularly in the range of 400-470nm is used topically for various skin diseases

particularly microbial / fungal infections, wound healing with almost no side effects because of their radiation lies above 400 nm (see Figure 2). It is also used for air and surface disinfections of the materials [51 - 53].

Several devices are patented in USA using blue light, with control unit, actuators, propagation and projecting assemblies for focusing on the area on the human skin for cosmetics and antimicrobial treatments. Neonatal jaundice incubators uses blue light in the range of 460-490 nm which is the absorption band of Bilirubin (yellow pigment) which sometime cannot filter out by the liver and efficiently used for jaundice treatment [54 - 56].

The drug resistance [37, 38, 40] of microbial is showing adverse effect of using antibiotic medicines for killing the microbial which appears as a biggest tread for treating diseases and disinfecting the devices and accessories as reported in the document published by USA department of Health and Human Services [37]. The report also link it with illness of the millions of people with severity in complication leading to the death of around 23,000 per year. The accurate financial statistics are hard to collect and interpret but it is observed [39] around \$ 55 billion are spend in excess per year for treating related complications and productivity.

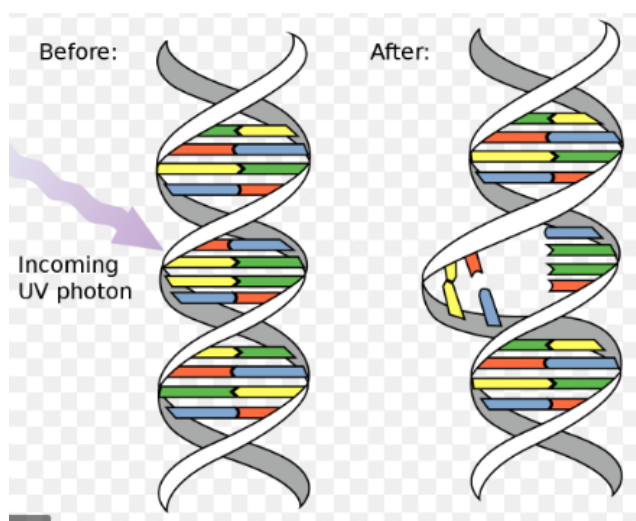


Figure 3. Effect of the ultraviolet light on the DNA before (left panel) and after (right panel) the exposure for certain period of time, intensity and wavelength.

Ultraviolet therapy: It widely used as germicidal radiations on clinical basis for dental, skin and sterilization procedures / cases. The penetration depth of UV-C is used to kill bacteria and germs colonies for the cost effective sterilization techniques. The UV light penetrates through their cell walls (see Figure 3) and absorbed by the DNA where it's disrupted their structure and deactivation of the viruses.

The typical absorption spectrum for the DNA is shown Figure 4 where the maximum absorption occurred in the range of 250 – 280 nm. The absorption of UV causes defects in the DNA such as pyrimidine dimer which further stop their replication and make them inactive.

The radiation band of UV-B and UV-C more effective widely used for the sterilization of the germs, bacteria and / or viruses. However, they are more harmful for the human's health especially skin. Therefore, care must be taken in using the instruments, accessories and operation relating to these radiations. Concrete guidelines and quality controls procedures and mechanism are required to regulate the Marketing, sales and operations of the related instruments and accessories [1, 15, 19].

The far ultraviolet [35, 36] in the range of 200 – 222 nm wavelength shows similar efficacy as that of 254 nm UV light but without damaging the human skin [36]. The results are tested on mice and simulated in human models and further extended to the fact that the shorter wavelength of far UV will penetrate and damage the microbial smaller than one micrometer while typical human cell is in the range of 10 to 25 micrometers.

Furthermore, M. Buonanno [36] et al also concluded that far-UV may be used as preventive measure to avoid the infections during surgical operations where blood / cuts on the skin may leads to sensitivity for getting the infections from the environmental and skin's microbial and viruses. However, the risk to human health is still need further experimentation in order to confirm their claims.

Several patents (from US Patent database) such as cited in the references [57] to [61] are marketed for various applications. R. M. Dayton [57] et al patented a device relating to the technique and experimental setup for disinfecting and sterilizing of the air, protecting zone and surfaces from the microbial contaminations. They used N-UV (New Ultraviolet) source instead of mercury based 254 nm light source. They claim that NUV source is more effective than mercury base UV light in destroying viruses' DNA, bacteria, spores and cysts. It is also couple with the setup for maintaining positive pressure inside the chamber during the NUV operational procedure.

Dental devices: R. G. Johnson [58] et al device uses ultraviolet – C wavelength fitted in the handheld device with sufficient intensity to apply for the mouth of dental patients with specific time and distance for killing bacteria during the dental operation. They claim that the device is effective for patient and doctor in protecting the infections.

Eye and Skin: A. Sharma [59] et al patented a device which uses LED of emitting UV-C radiation with a power of 5 mW projected at diameter of around 4 mm on the infected tissue of eye or skin. Since the radiation has dangerous effects therefore it was shine on the infected area in small duration of time pulses which should not increase from the continuous duration of one second. The treatment has considerable success but some serious eye problem was also observed such as retinal damage and vision ailments.

In case of close rooms / chamber sterilization by using the UV light can interact with indoor oxygen and makes Ozone (O₃) which can have adverse effects on the health of the indoor resident. Moreover, the change in control parameters of the radiation may leads to the reactivation of the viruses and microbial by their innate DNA repair mechanism. Especially in health care centers (hospitals, clinics etc.) mutations make them

more resistive against the repeated scheme and sequence of sterilization by using phototherapy.

Mostly in health care centers, the patients are signed by a “Disclaimer Agreement” prior to the procedures in order to put all blame on the patient if something bad happened during and or / after the procedure, to avoid legal complications. Therefore, in such cases patient’s complications after procedures are not well reported and documented which is one of the biggest hurdle in order to optimize the instrumental setup and procedures guidelines.

In such cases, the decision for selecting and performing the treatment should not be explicitly enforce on the patient because the patient is in the time crises / depression may take the risk and sign the “disclaimer agreement” but it might not be the right time to put the burden of decision on the Patient and or / their spouses. The decision should be explicitly taken by the boards of experts / doctors in the “time of crises” and the patient should be well informed before the procedures for the possible sides effects and negative outcomes even if their probability of occurrence is very low. This will help to report the clinical results / complication more effectively which can be rectify and update the instrumental setup and operational procedures.

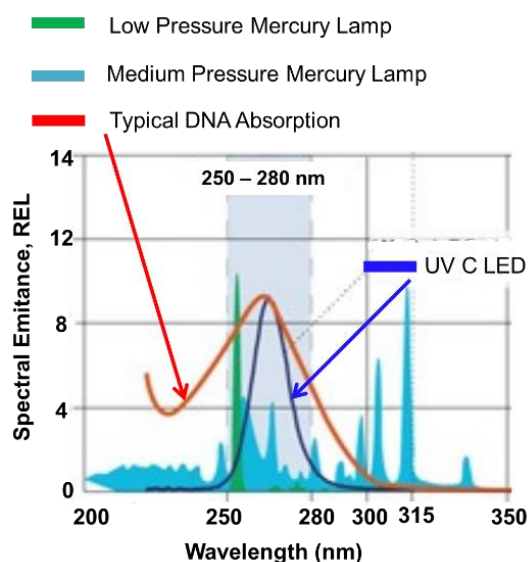


Figure 4. Typical Absorption Spectra of the DNA (red color) as function of wavelength in combination with the spectra of the UV C LED, Low Pressure Mercury Lamp, and High Pressure Mercury Lamp.

Furthermore, several instruments are made on the basis of the patents of the recent applied research in the developed countries equipped with phototherapy LED / bulb and tube lights where their quality and authenticity are well regulated. However, poor countries are not able to pay higher cost of such instruments and try to find cheaper solutions and launched in their respective local market. For instant, Neonatal baby incubator (for Jaundice / bilirubin removal) are available in the local market without manufacturer’s identity along with NO information regarding the wavelength of the emitted radiation. Such kind of simple instruments are normally bought by the general public in the time of emergency to treat their patient at

home in order to cut-down the expenses of the hospitals. In fact, it more important for such kind of instruments to be highly checked and quality control, prior to be sold to the general public.

In case of general public, the seller convince them, the problem was happened due to their mishandling, operation procedure, electricity fluctuation, and or any other reason which can get him to be get-out of the blame. In addition, general public are not technically sound to trouble shoot exactly where the actual problem was that causes damages to human health. Even though it was difficult for us to differentiate and check / evaluate the quality of the product. Similarly, it was not easy to convince the seller / manufacturer for malfunctioning of their instrument which make it more difficult to report and documents the clinical and /or real time user’s trails. This make it more difficult to amend and upgrade to the better version of the instruments.

In the modern world human are spending more than 90 % of their time indoors [24]. In most cases, their temperature, light and humidity are controlled automatically in order to increase the building efficiency in terms of power consumptions. The natural sunlight also increase the indoor temperature and avoided by using curtain and /or windows blind [25 - 27].

Sun light emits broad range of electro-magnetic radiation (see Figure 1) which are stop from the several atmospheric layers surrounded by the earth surface and only the radiation shown in Figure 5 can reach the earth surface in the range of 200 – 2500 nm where 5 % are ultraviolet, 43 % are visible and 52 % are infrared radiations [63].

Infrared radiation is the major constituent of the natural sunlight which typically causes heating effects. Warmer countries normally avoid sunlight via Curtin due to the infrared heating in order to increase the cooling efficiency of air conditioners. The ultraviolet in sunlight is lies in the range of 300 to 400 nm which is normally higher with the minimum inclination of sun with respect to the earth. Natural UV spectrum emitted from sun leads to several vital functions / operation on the earth surface such as vitamin D production by converting cholesterol in human skin, degradation / disposition of the waste materials and germicidal affects [43 - 46].

The resident of the countries lies in the northern hemisphere of the earth has little sun shine hours in comparison to the countries lies at or near the equator. Such resident use artificial lights and food supplements and / or UV radiation’s bath for regulating their vital health functions. However, artificial UV lights and baths are found dangerous for health such as skin illness and cancers [40 - 43].

Surprisingly, more than 50 % of the illness related to the respiratory and gastrointestinal tracks are causes due to the indoor environments. Several illness and health risk may associate with the sick building syndrome. These buildings may contains wide variety of microbial and Bio-aerosol (virus, bacteria or fungi etc.) which may be travelled to larger distances [21, 28, 30, 71].

The SARS (Severe Acute Respiratory Syndrome), Influenza and norovirus were supposed to spread via the contact and / or drops while it aerosol transmission is also observed in

the smaller distances. Furthermore, their sizes are so small to capture or deactivate after passing through the filters installed at the air-conditioning and ventilation systems. In addition the indoor population, human activities and occupancy has strong impact on the modulation of these microbial and aerosol communities. This leads to the inefficiency at work places and increase infectious diseases [28 - 31].

The exposure of natural sun light inside rooms and building has the proven health benefits as reported in several studies [20]. In fact it not easy to check the efficacy of sunlight for the viral deactivation but S. Ratnesar-Shumate [12] et al observed it for the simulated sunlight. The deactivation of **SARS-CoV-2** dried out on the stainless steel surfaces by using the simulated sunlight with the conventional mimic of natural UV-B band for the deactivation of samples on the stainless steel dried viruses/. The parameters for the simulated sunlight were mid-day summer, 40° North, Latitude, which causes around 90 % of viruses deactivation in 6.8 minutes. The time of deactivation increase to 14.3 minutes for the simulated sunlight with the winter season parameters i.e. 40° North, Latitude [21].

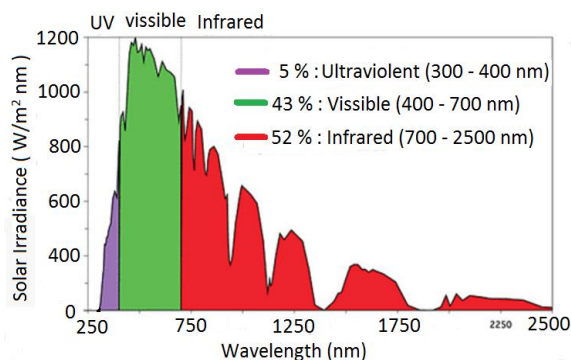


Figure 5. Typical solar irradiance spectrum as a function of wavelength. The Ultraviolet radiation is around 5% of total radiation in the range of 300 to 400 nm [63].

Furthermore, the effect of darkness was also studied by S. Ratnesar-Shumate [12] et al for the similar set of conditions used for the simulated sun light exposure and observed the viral activity for more than 60 minutes which is in close agreement with the reported results in references [13 - 17].

The well ventilated and natural sun light exposure to the inside of the health care centers can be more beneficial [25, 26] than to install the UV devices which can interact with the indoor oxygen and convert them into ozone (O₃) in order to get faster recovery from the illness / infections [27 - 30].

The excess cleaning and sanitization also leads to the disruption of the natural healthy flora of microbial which are helpful for human's health. The bacteria has CRISPR (Clustered Regularly Interspace Short Palindromic Repeats) mechanism [66 - 68] which helps them to develop resistances and fight against new viruses and pathogens by remembering their genetic code sequences. This enables them to upgrade their fighting ability against the viruses and pathogens and pass them to their offspring which are born with the modified innate resistance. Therefore, the trend of excessive cleaning and sanitization might

leads to be more risk to fight against viruses due to the washout of the human's friendly microbial [69 - 71].

CONCLUSION AND OUTLOOK

The sterilization of viruses might not be as simple as it is shown in the market for their sterilization techniques. Even though several research journals published results which indicate the deactivation of the several viruses but in special set of laboratories conditions and some of them also report innate repair mechanism under several circumstances [28, 29, 31].

The detection, identification and discrimination of wide variety of viruses, microbial and bio aerosol is a complex task which need cutting-edge technology and high end preventive measures for these laboratories with trained human resource. These facilities needs huge initial capital along with a high recurring cost for their smooth and save operation. In fact the investigation / details are not yet well understood in case of COVID-19 but mirror slips / mistakes can have dangerous outcomes as observed in fast spreading of virus with several thousands of mutations. Such kind of facility is still out of reach of several health care centers, manufactures and quality control authorities. Therefore, it complicated to identify the impact and efficacy of the instruments / accessories / related to the ultraviolet sterilization and health care treatments.

Several vendors, hospitals, manufactures and companies are in the race of buying and installing the UV disinfectants instruments / accessories, sanitizers etc. in their indoor environment which might not be as efficient as the open windows with natural sunlight, well ventilated and no artificial air conditioning. Indeed this will increase their cost of cleaning due to excessive dust and microbial but it might has better impact than control close indoor environments with reduced electricity cost for the air conditioning system. Several human's friendly microbial are also washed out due to excessive sanitization and cleaning operations [69, 71].

The importance of the healing environment was well identified by the Florence Nightingale [26] as pointed out in her remarkable note that, "Open windows and big wards has the vital role for the healing of the patients in the hospitals and health care systems [25, 26].

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