Is ultraviolet Radiation a Confounding Variable for COVID-19 in India?

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Abstract

The current global Coronavirus disease (COVID-19) became a pandemic due to its contagion nature and rapid spread throughout the world. The pandemic caused a lockdown resulting in a large decline in the level of anthropogenic emissions of tiny aerosol particles that altered the solar irradiance and decreased the quantity of aerosol, which opposes global warming. This study first demonstrates that surface ultraviolet radiation (UV) increased significantly during the lockdown period in four major Indian mega cities, whose magnitude varies based on city demography. Results shows that the correlation between the high rate of increase in Ultraviolet irradiance (UV-irradiance) on mortality and morbidity. Although there are numerous confounding factors for the pandemic, UV-irradiance could be one of the factors supporting the hypothesis that increased solar UV dose may increase rate of disinfection as radiation warps the structure of genetic material of the virus and deactivates it. Another factor which also have potential to add up increase of Vitamin D3 production per minute of exposure due to UV-irradiance resulting in an increased human immune system to fight COVID-19 more effectively. However, it is cautioned here that a high dose of direct UV exposure to humans may be fatal leading to skin damage and melanoma cancer. Hence, the harmful impact of UV-Irradiance on the human body and its application to possible disinfectant to virus deactivation should be understood in a proper perspective.

Keywords: COVID-19, Ultraviolet radiation, Lockdown, Pandemic, Anthropogenic Emissions

Introduction

The COVID-19 pandemic is perhaps the greatest challenge the world is facing since World War-II. It has infected millions of people and taken many lives. It is caused by SARS-CoV-2

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virus and has an extremely high transmission rate by droplet spray from coughing and sneezing and by a direct human to human contact[1]. The SARS-CoV-2 is not unique; but a new variant in the beta coronavirus family[2,3]. To fight the pandemic, many countries around the world implemented a lockdown. Although, India officially declared the first phase of countrywide lockdown from 24th March 2020 for about 3 weeks, the curfew-like situation started even a week before (18th March 2020) as the death count started to mount. The country-wide closure decreased almost all anthropogenic activities such as industrial emission and severely reduced car, bus, truck, and airplane traffic. The Satellite imagery of the Earth Observatory of NASA, reported that the aerosol levels have dropped significantly since the COVID-19 lockdown began in India[4]. It is known that anthropogenic aerosols negatively impact the environment and can cause everything from warming to cooling, to deadly air pollution. Recent studies report that the climate effects of aerosols have masked and countered some of the warming induced by greenhouse gases. The term called "solar dimming" happens when these aerosols absorb solar energy or reflect it into space. The result is a reduction in the amount of global direct irradiance at the Earth's surface[5]. These cooling temperature effects may appear beneficial but are almost certainly overwhelmed by aerosol's negative health impacts. UV radiation plays multiple roles. Excessive direct UV exposure is harmful for human beings, has the potential for damage to the skin and eye with an increase in UV radiation. It also suppresses the immune system[6]. According to the World Health Organization (WHO), annually around 1.5 million DALYs (Disability-adjusted life years) are lost through excessive UV exposure globally. Furthermore, environmental levels of UV radiation may suppress cell-mediated immunity and can enhance the risk of infectious diseases. However, on the other hand, UV radiation is needed for vitamin D production which plays an essential role in human immune system[7] and is particularly useful at destroying pathogen genetic material prevents viral particles from making multiple copies of themselves[8]. A recent study also stated that deficiency of vitamin D may increase the risk of severe COVID-19 due to reduced natural vitamin D synthesis[7]. Ultraviolet light has been demonstrated to be capable of destroying viruses, bacteria, and fungi in many studies[8].

UV radiation wavelengths ranges from 200 to 440 nm[9]. UV-A and UV-B ranges from 400 to 315 315 to 280 nm. According to the erythemal action the UVB radiation causes more sunburn than UVA radiation, Mie scattering is not strongly wavelength dependent however Rayleigh scattering is more effective at short wavelengths[10]. UVA spectrum portion does not damage SARS-CoV-1 was demonstrated by previous study[11]. It has been observed that

SARS-CoV-2 can be rapidly inactivated by exposure to UVC light (254-nm) from a low-pressure mercury vapor (germicidal) lamp[11,12] however inactivation amount depends on the dose for inactivation by sunlight. According to[13] UVC range can inactivate many viruses and bacteria in times less than minute depending upon the dose. Ultraviolet light can be an effective measure for decontaminating surfaces that may be contaminated by the SARS-CoV-2 virus[3]. The usage of concentrated forms of UV-C radiation was on the front line in the fight against Covid-19 in China. In China blue light had been used for disinfection of buses, UV-emitting robots for cleaning floors in hospitals, UV-radiations to disinfect money in banks[14]. Meteorological parameters are important factors influencing infectious diseases such as severe acute respiratory syndrome (SARS) and influenza outbreaks[15]. Past studies demonstrated that absolute humidity had significant correlations with influenza viral survival and transmission rates[14,16]. Recently, it has been reported that COVID-19 counts decreased with the increase in temperature[17], but their effects on mortality have been sparsely reported. Influenza viruses have shown that their survival period on certain surfaces may reduce when exposed to high temperatures or high UV radiation. Although earlier studies have shown that UV radiation can be used against other corona viruses, such as SARS[18], no results have been reported in so far providing evidence relating Covid-19 related mortality with UV radiation.

The objective of the present study is to investigate the impact of reduction in emissions during the COVID-19 lockdown of 2020 in the UV-irradiance. For the purpose we compute the variability between year 2020 and that of averaged value of year 2017-2019. We also hereby report the relationship of COVID-19 related mortality /morbidity with that of relative increase in UV irradiation during year 2020 with that of past years based on experimental data. The observational data used in the present study is taken from four major cities of India namely, Delhi, Mumbai, Ahmedabad and Pune (Fig. 1).

Methodology

This work uses data obtained under the project- "System of Air Quality and Weather Forecasting and Research (SAFAR)" of the Ministry of Earth Sciences, Government of India that is also adopted as a pilot project of the World Meteorological Organization (WMO)[19]. The SAFAR data is used for 4 Indian cities, namely, Delhi, Mumbai, Ahmedabad and Pune. The measurements of UV-radiation have been taken continuously by UVS-E-T radiometer deployed under the project (Fig.1). The UVS-E-Tare is designed for precise measurements of atmospheric ultraviolet radiation in three different spectral ranges. It measures global UV-irradiance, i.e. the sum of direct solar radiation and the radiation that has been scattered by particles or molecules in the air. The angular response follows the cosine of the zenith angle as with an ideal Lambertian surface. The UV index has been calculated quantitatively by multiplying the UVE radiation value by 40 m²/W[20]. The calculated value is presented in an integer. For example, 0.25 W/m² of UVE represents a UV Index of 10. This is the value used for public health information. The calibration of instrument has been done as per recommendation of WMO at the time of installation of instrument. For instruments designed to measure erythemally weighted UV, the radiation amplification factor (RAF) should match the RAF for erythema (e.g. RAF= 1.21 at 30 SZA and 300 DU)'[21]. According to the spectral mismatch details, a unique software program for post-processing and analysis of UV data 'the UVIATOR program' had been developed by Kipp & Zonen. It performs automatically a number of UV measurement corrections and thereby improves the measurement quality significantly. To achieve the most accurate measurement result with broadband UV radiometers the spectral mismatch error correction is based on the calibration and correction method described in the WMO Report 141 and 164[21,22]. First the raw signal of the instrument (in units of Volts) has to be transformed into an irradiance (in units of W/m2) then irradiances have correct for the spectral mismatch error with 'conversion factors', determined using modeled UV irradiances as a function of various total Ozone column densities and solar zenith angles[20]. The measurement conditions for which correction factors are calculated are obtained by varying the solar zenith angle, _0, and the total Ozone column density. The solar zenith angles, _0, are varied between 0° and 85°. Applying these corrections improves the accuracy by a factor of 2 or more. Yearly calibration of UVS-E-T Radiometer is performed with a Xe lamp system, a monochromator (ORIEL Cornerstone MS257), and a calibrated Si-photodiode detector. The measurement with Si-photodiode is used to determine the UVS radiometer-weighted irradiance and finally radiometric calibration factor is obtained according to $r=U_{UVS}/E_{UVS}$ and to account spectral mismatch error the min sensitivity (%) also determined.

We have used the peak value of the day in this work as we feel that the highest signal would be a better marker to understand the day to day variability for comparison purpose and correlative study. It is stated here that we have performed the analysis based on 4 city data and derived the correlation because we were constrained with the data available only for 4 cities. The standard deviation also obtained during the study period for cities.

We hereby introduce another terminology which is known as Ultraviolet Index (UVI) in this paper. The WHO recommended the use of UVI in order to evaluate and increase the awareness of the risks connected to exposure of UV-irradiance. The UVI is a simple and informative indicator to alert the general public about health risk exposure. The UVI can be adopted for the evaluation of the UV dose, even as prediction tools [23] to reduce the threat of skin cancer like diseases[24]. UVI is a unit less measure of the level of solar UV irradiance at the earth's surface. The UVI values are grouped into exposure categories as shown in Fig. 1. The values of the index range from zero upward - the higher the UVI, the greater the potential for damage to the skin and eye. However, it may be noted here that UVI may not be a good indicator for the risk of UV-induced ocular disease[25] as ocular exposure was approximately 1/10 that to the crown and effects of exposure also varies with different meteorological condition[26]. It may shows the maximum impact on eye only when the sun is directly at the front at approximately 40° of solar altitude.

It has been also correlated with peaks of influenza virus activity during year 2010-2018 in northern Europe[27] and with transmission of COVID-19 during year 2020 in Chinese cities[28]. The clear-sky UVI is the erytherrmally weighted UV irradiance (1 unit equals 25 mWm^{-2}) reaching the Earth's surface modified by the McKinlay and Diffey (1987) action spectrum for the susceptibility of Caucasian skin to sunburn (erythemal) and it is valid for cloud-free conditions[30]. UVI data has been measured for the period from 20th February to 10thApril 2020 to cover the period before and after the lockdown. The data for the identical period of previous three years (2017-19) have been averaged for the comparison. We have used the peak UVI value of the day in this work as we feel that the highest signal would be a better marker to understand the variability for comparison purpose.

Result and Discussion

The peak index in tropical Indian cities is observed during the day between 12 noon to 4PM. Our analysis covers 2 regimes- (a) Normal (Before lockdown): Business as usual scenario during February 20th to 18th March; (b) Lockdown period (between 19 March to 10th April). Fig. 2 (a-d) shows the comparison of peak value of UVI in all 4 cities for the above 2 regimes of 2020 and that of averaged values of past 3 years (2017-2019) for the identical period. A vertical line separating the normal and lockdown period is shown in Fig. 2 on 19th March. Due to the much reduced emission activities and movement of people, levels of air pollutants declined significantly [31] in India leading to sudden cleansing of the atmosphere, which not only affected the ground pollution but also the major part of the troposphere. A comparison of 2020 with past years (Fig. 2) shows that the UVI was comparable before the lockdown but immediately after the imposition of lockdown, a significant upward jump is observed and the magnitude of UVI during 2020 continued to remain elevated as compared to previous years. The total irradiations are likely to increase due to less scattering /reflection in presence of less thick layers of aerosols in the troposphere under lockdown that otherwise remain thick[4]. The presence of aerosols during normal days acts as a solar radiation reflector by scattering mechanism[14,32]. The reduction in aerosols during lockdown must have resulted in increasing ultraviolet radiation as shown in Fig.2.

Fig. 2a shows the daily distribution of the peak value of UVI over Pune city. It was observed that UV index steadily increases after the lockdown from 5-6 to 7.5 during the lockdown which falls under the "High Risk" category. The UVI was in the range of 3.9 to 6.1 before lockdown. The city was exposed to a high risk level of exposure for 18 days (nearly 37% in 2020 during the lockdown period of 20 days as compared to last three years average UVI during the same period. The steady increasing trend was observed in Ahmedabad (Fig. 2b) where UVI increased from 6 to 8from normal to beginning of lockdown period. Although a slight declining trend in UVI is noticed in the later part of 2020 lockdown but magnitude of UVI in 2020 continued to remain higher than that of past years. It crossed from moderate risk category level to high-risk category immediately after lockdown. High-risk means continuous exposure to sun rays for more than an hour can cause sunburn to Indian skin type and eye irritation. In Mumbai, a sudden jump in UVI is observed immediately after the lockdown and this elevated level was maintained throughout the lockdown period. However, level of UVI in 2020 was found to be consistently higher than that of previous three years average as evident from Fig. 2c. Fig. 2c also shows that the city recorded the peak UVI level of 6.5 in 2020 as compared to an average level of 5.6 in the last three years. The overall magnitude of UVI in Mumbai is found to be lowest among all 4 cities. Mumbai is surrounded by sea from 3 sides and the reflectivity index is relatively high from the water surface as compared to land except for specular reflection. Fig. 2d shows the time series for the peak value of UVI for Delhi which shows a maximum jump in UVI after the lockdown. Further, it can be noted that UVI values prominently altered within the range of 6-7 during the lockdown period. The highest level of UVI was recorded during 6-7th April 2020 when the UVI touched ~7.3 which falls in the high-risk category. The UVI was in the moderate level (3-5) during normal period in Delhi. It is noticed that the magnitude of UVI in 2020 was significantly higher when compared with last three years. It is noteworthy to mention here that citizens of Ahmedabad were exposed to the highest UVI values but in spite of elevated level as compared to past 3 years during lockdown, a slight declining trend is noticed, probably due to the fact that it has already touched a maximum level. The UVI has indicated a minimal increase for Mumbai in 2020 as compared to the previous three years average. There are various meteorological confounding factors which affects the morbidity and mortality of COVID-19[33]. According to[34], relative humidity and absolute humidity showed a moderate positive correlation with the daily COVID-19 cases in few cities of India. Despite many studies, there is inconsistencies in findings[35] due to impacts of regional factors like geographical locations and population[36].

Percentage variability in day to day UVI during the lockdown period for 2020 with respect to averaged UVI of past 3 years in all 4 SAFAR cities are shown in Fig. 3a. In Pune, it is found to vary from 2% to a maximum of 50%. The % increasing trend in UVI of Ahmadabad varied from a minimum of 6% to a maximum of 43% on 3rd April 2020. At the same time, UVI at Mumbai showed a fluctuating pattern and reached to its peak at 37%. The % increase in UVI for Delhi was 5% immediately after the lockdown which shot to ~ 42% towards the end of lockdown period. Average percentage variability in UVI during 2020 as compared to past 3 years are also provided in Table 1. The standard deviation (SD) from the mean for all the 4 cities is also shown in Table-1. The SD is found to be highest in Pune (± 14) followed by Delhi (± 13), Mumbai (± 13) and Ahmadabad (± 9).

Fig. 3b and 3c show the cumulative growth in percentage variability of UVI during lockdown period of 2020 as compared to past 3 years along with mortality and mortality in all the 4 cities. The cumulative value of UVI is obtained by averaging the peak values of UVI over the lockdown period of 19th March to 10th April for 2020.

The percentage increase in cumulative UVI is calculated by comparing it with the cumulative value of the same period of the previous three years. The cumulative increase in UVI in 2020 w.r.t past 3 years are found to be 27%, 22%, 20% and 18% for Pune, Ahmedabad, Delhi and Mumbai respectively. The correlation coefficient is also derived to understand the association between UVI and COVID-19 related deaths and infection counts among 4 cities during the lockdown period which is found to be anti-correlated. The correlation coefficient of UVI with mortality and morbidity is found to be -56% and -86% respectively. In general it is found that higher rate of increase in UVI is associated with the lower death counts. Similar results are also observed by[33]. The anticorrelation established the fact that in a city like Ahmedabad, the number of mortality counts is found to be lowest because % growth in UVI is highest (22%). In the case of Mumbai, the growth in UVI w.r.t a normal level is found to be lowest (18%)

but the rate of mortality is highest. In Pune, UVI increase was highest (27%) and COVID infection counts were found to be lowest 182 as compared to other cities. In Mumbai city, a sharp increase of 1241 infection cases is found which relates well with lowest growth rate of 18% in UVI. However, it may also be argued that a strong correlation may be a combined effect of above factor and that of additional production of Vitamin-D3 because UV-irradiance is capable of producing Vitamin D and other compounds in the human body[37,38]. This may enable the human immune system to fight COVID-19 more effectively by preventing the rapid development of the SARS-CoV-2[39]. This has limitation for protection against worsened COVID-19 outcomes as a supplementation of vitamin D is due to lack of genetic evidence[40].

Although the present study is reported for summer season when temperature remain high but such factor may play a significant role in higher latitudes, especially considering the relatively cold spring time when people are still indoors, where the ambient UV cannot disinfect the Corona virus. Hence, it is pertinent to mention here that future study may also focus on the possibility of mitigating COVID-19 deaths via sensible sunlight exposure or vitamin D intervention[41].

Conclusion

Covid-19 pandemic caused a lockdown forcing major emission activities to be seized leading to thinning the aerosol layer in the entire troposphere[42–44] thereby, increasing the level of UV irradiation. The highest increase of UVI in 2020 with respect to past years is found in Pune, as it is located in the relatively higher altitude. Mumbai is surrounded by sea from 3 sides and radiations tend to get attenuated leading to least variability in UVI. This may also be due to combine impact of meteorological factors and high specific heat of water. Due to which sea surface absorb heat slowly and also loses heat slowly which influences the adjacent land temperature and ultimately affects the changes in daily UVI of coastal city. The critical finding of the present study is twofold- (1) to demonstrate that COVID-19 lockdown resulted in a rapid increase in UVI over Indian mega cities, whose magnitude depends on the geographical location and climatology of the city; (2) although there are numerous confounding factors for the pandemic, increase in UV-irradiation is found to have positive and favorable impact on COVID-19 cases. A strong anti-correlation with COVID-19 infection rate (-86%) tends to suggest that the rate of increase in UVI was found to be beneficial in spreading COVID-19.

A decrease mortality count due to Covid-19, may also be attributed to an additional production of Vitamin D and other compounds in the human body which leads to enhanced human immune system to fight Covid-19 more effectively. However, more evidence and research need to be done to fully understand the relationship. The difference between negative effect of UV-irradiance exposure and its positive impact towards disinfecting and reducing severity of Coronavirus needs to be properly understood and cautious approaches need to be adopted for achieving the maximum benefit. Any misconception needs to be explained and rectified concerning its useful application to disinfect regions of high risk without exposing the Human body which could be counterproductive.

The result from this analysis suggest that further studies are needed for confounding influence of UV radiation on COVID-19 mortality and morbidity by considering other weather parameters like rainfall, wind speed, and so forth. It shall provide additional information to mitigate the epidemic by carefully considering robust modeling.

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Figures:

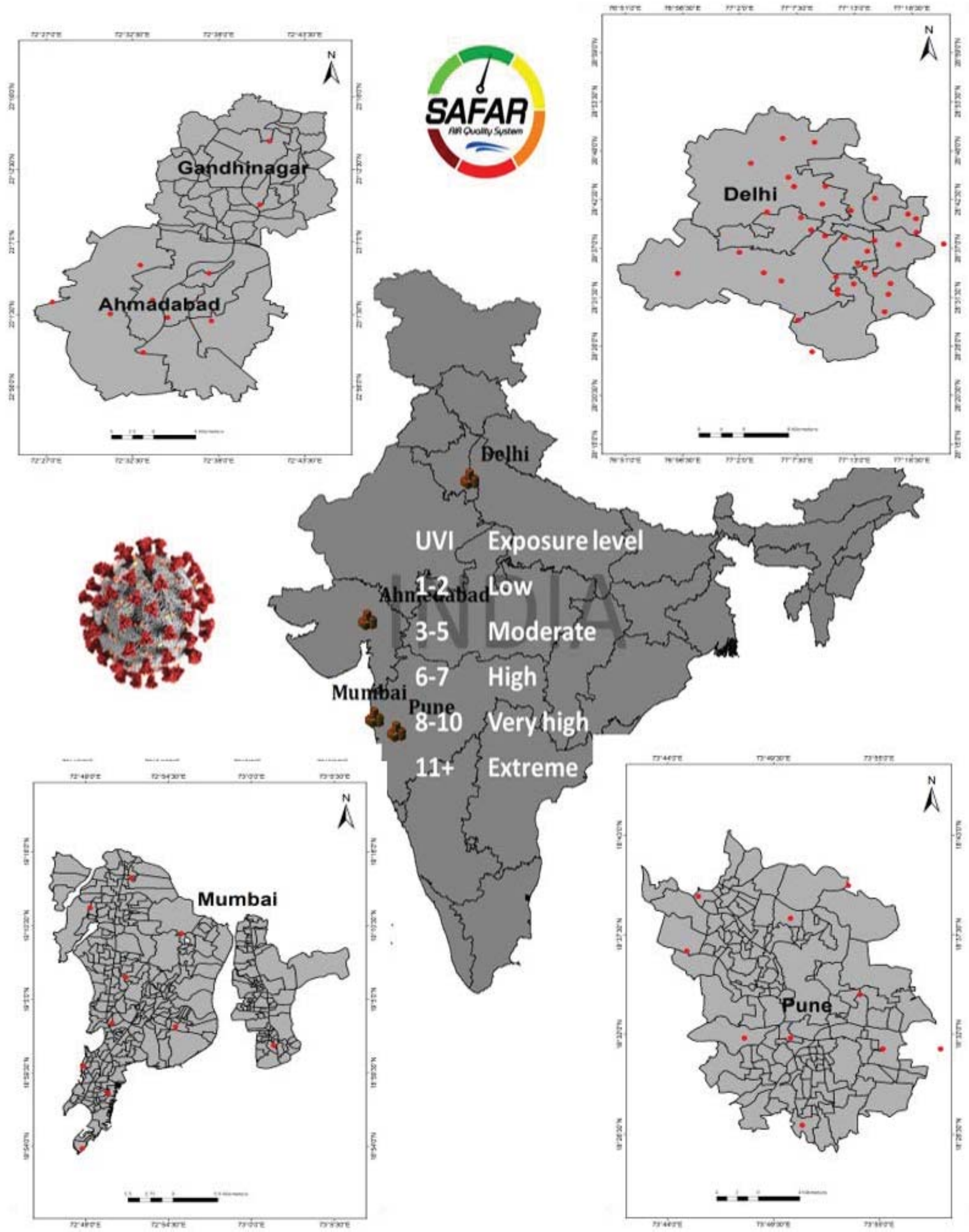

Fig. 1: The location of 4 Indian mega cities and the table indicating the UVI (Ultra-Violated Index) and associated health risk.

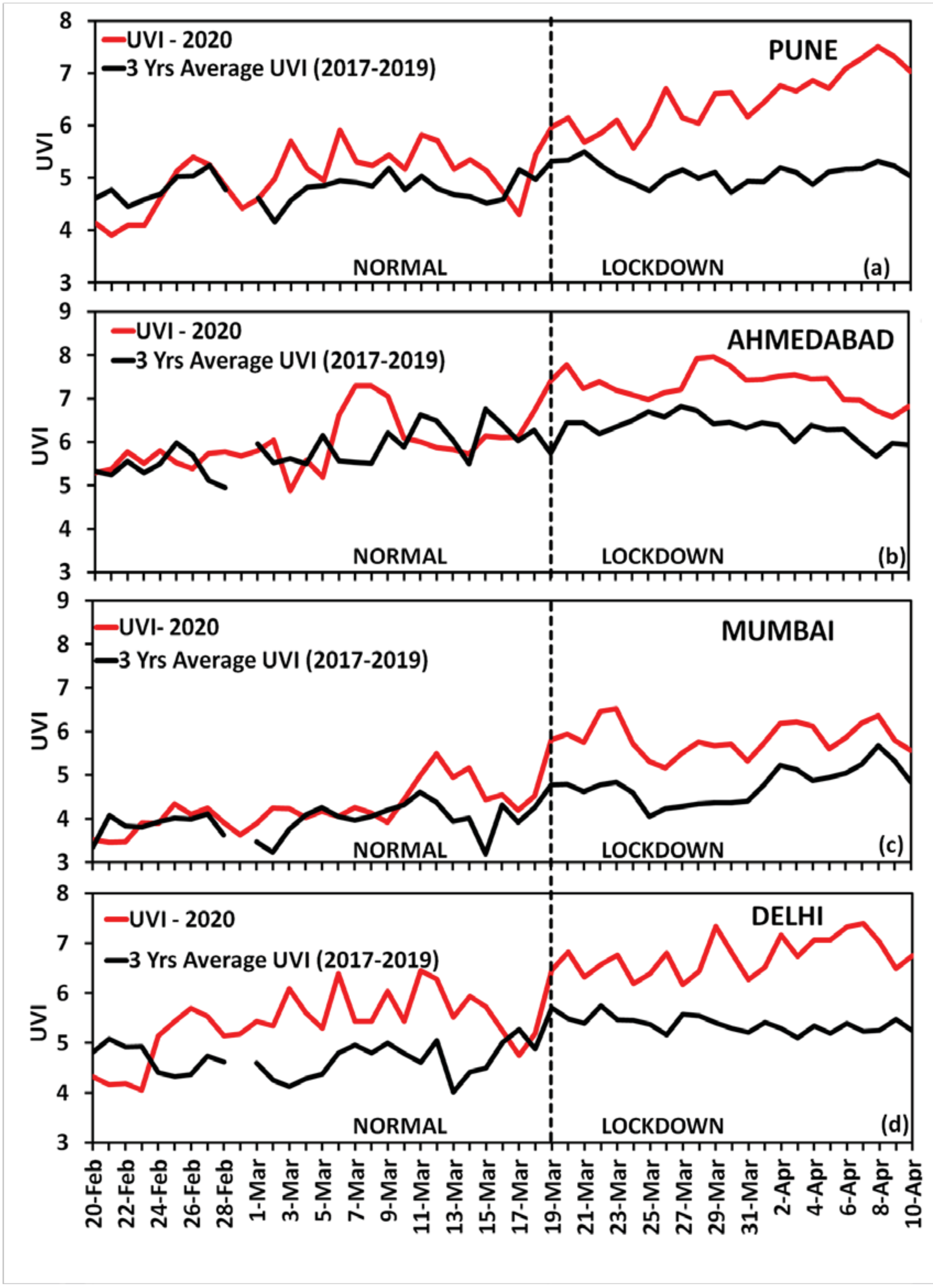

Fig. 2: A comparison of the peak value of UVI during the lockdown period of 20th February to 10th April 2020 with averaged values of past 3 years (2017-19) for the identical period in all four cities of Pune, Ahmedabad Mumbai and Delhi.

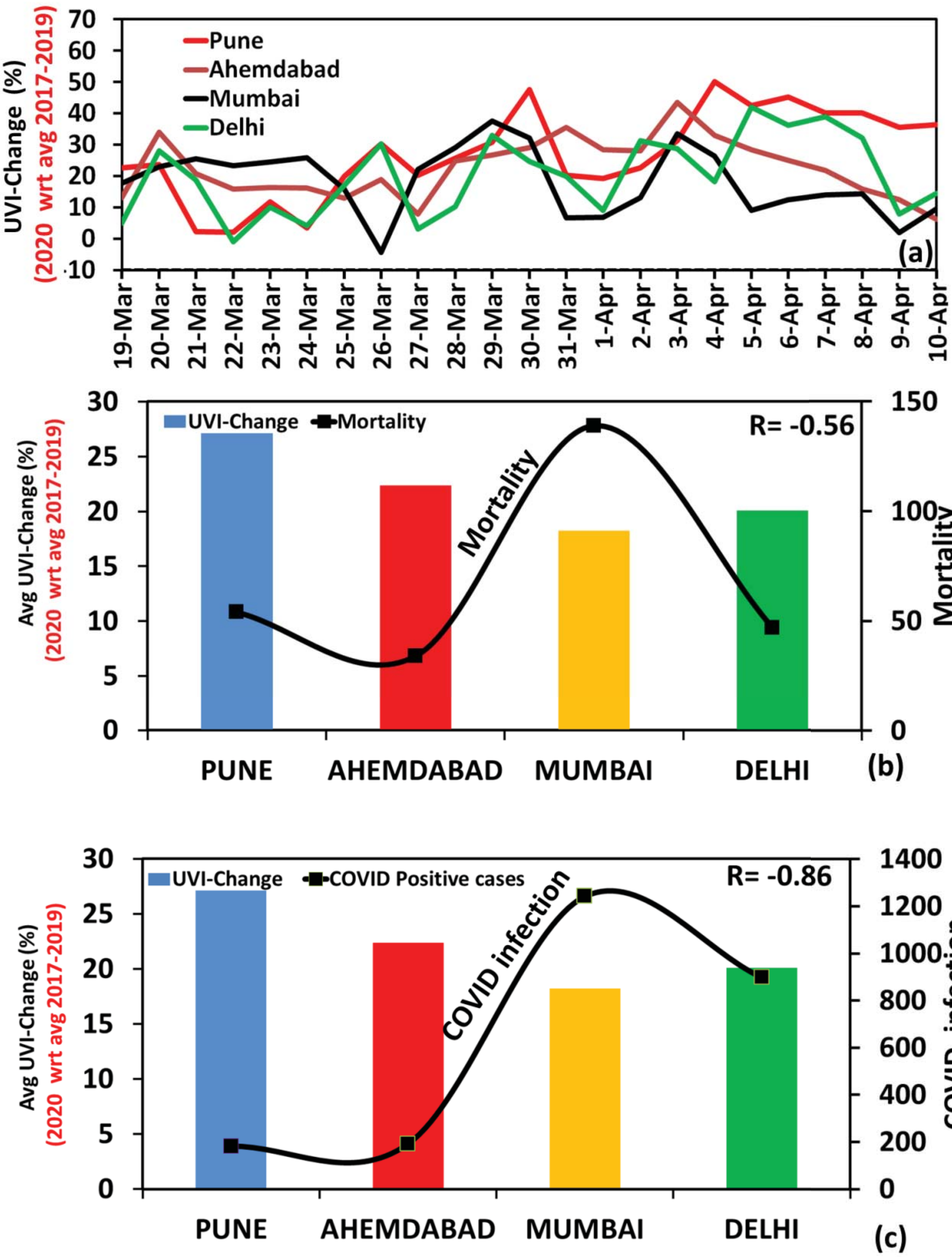

Fig. 3: (a) Percentage change in cumulative value of UVI averaged over the lockdown period (19th March to 10th April) of 2020 as compared to the averaged value of UVI of the past 3 years (2017-19) for the identical period in all 4 SAFAR cities. The correlation of % change in cumulative UVI in 2020 wrt average 2017-2019 with (b) mortality and (c) infection rate per lakh.

Tables:

Table 1: The percentage variability in peak daily value of UVI during lockdown period of 2020 as compared to averaged values of past 3 years (2017-19) for the identical period in all four cities as per Figure 3a.

Date	Pune (%)	Delhi (%)	Mumbai (%)	Ahmedabad (%)
19-03-2020	23	5	18	13
20-03-2020	24	28	23	34
21-03-2020	2	19	26	21
22-03-2020	2	-1	23	16
23-03-2020	12	10	25	16
24-03-2020	3	4	26	16
25-03-2020	20	17	16	13
26-03-2020	30	30	-4	19
27-03-2020	20	3	22	8
28-03-2020	26	10	29	25
29-03-2020	31	33	37	27
30-03-2020	48	25	32	29
31-03-2020	20	20	7	36
01-04-2020	19	9	7	28
02-04-2020	23	31	13	28
03-04-2020	31	29	34	43
04-04-2020	50	18	26	33
05-04-2020	42	42	9	28
06-04-2020	45	36	12	25
07-04-2020	40	39	14	22
08-04-2020	40	32	14	16
09-04-2020	36	8	2	12
10-04-2020	36	15	9	6
Standard Deviation	(± 14)	(± 13)	(± 11)	(± 9)

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