Proposed Safe Distance between Object & Artificial Light Sources in Historical Building or Museum in Terms of Conservation

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Abstract: ***It is well known fact that light is associated with its neighbouring spectrum of Ultraviolet ray (UV ray). UV has deleterious effects upon living and non-living objects. In order to avoid this bad effect of UV some simplified methods to need to try out. Experimentation has been carried out with Incandescent lamp, Conventional Fluorescent lamp, Compact Fluorescent Lamp (CFL) and Light Emitting Diode (LED) lamps and separately UV content as well as illuminance at various distances have been measured. UV-measurement has been made by UV meter made through world reputed make- Konica Minolta, Japan and illuminance is measured by Lux-Meter. The observations have been shown in the main body of the paper which shows successful results as per expectations. The system can be adopted for Museum lighting where important archives can be saved from bad effects of emitted UV from the ambient light sources. This simple methodology can thus be adapted for indoor application in Museum lighting/ Heritage building lighting where archives can be easily conserved.***

Keywords: Historical, Heritage, Ultraviolet Radiations, Illuminance, Light Emitting Diode (LED), Conservation.

I. INTRODUCTION

Light is an electromagnetic spectrum [1] that comprises of mainly visible, Ultraviolet (UV) and Infrared (IR) radiations. It's also called optical radiations. In this spectrum, the Ultra violet radiations broadly classified UV-A, UV-B, UV-C and their penetration capability depend upon its wavelength. This is a real news since shorter wavelength of UV-C has most deleterious effect than UV-A where the effect of UV-B is intermediate. Light, whether it is artificial or natural is utilised to arise visual sensation. Electric lamps which have taken up a great utility in artificial lighting are classified as-Filament lamp (although gradually diminishing), Gas Discharge lamps (widely in use)and Solid state LED based lamp assemblies. Thus uses of artificial lights, it is necessary need to be measured UV radiations in individuals. In laboratory, studies have been carried out on various lamps which are in common use in Historical Building or Museum. It has been observed that the UV content of the each lamps is different and its values are decreased with increase the distances. Before application of this artificial light source(s) proper assessment including quantification is needed for safe usage.

II. OBJECTIVE OF EXPERIMENT

1. Measurements of UV-A, UV-B & UV-C [2] for each artificial lamp with varying wattage,
2. Identify the value of illuminance level at several distances of each lamp and its corresponding value of UV.
3. Proposed a safe distance between archival [3] objects and artificial light sources according its wattage and percentage of colour degradation according previous experimental data.

III. EXPERIMENTAL INSTRUMENTS

I. **UV Meter:** It is an instrument for accurate measurement of UV radiation separately as per their wavelength. Separate heads of sensor for UV A (**400 µW/cm$^{2)}$**, B (**360 µW/cm^2**) and C (**250 µW/cm^2**) are connected to the meter head for measuring the value UV at several distances from the lamp. It is made by **Konica Minolta** model no **UM10**.

Fig 1. UV-Meter made by Konica Minolta

II. **Lux meter:** Lighting is provided to give uniform illumination over the work area to meet the lighting requirement for a particular type of work. To determine the adequacy of this lighting for the work area, an assessor may measure the illuminance with help of Lux meter. In this experiment, the values of illuminance are to be measured at different distances from lamps which are commonly used in Heritage site. It is made by Metravi model no. 1332.

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Fig 2. LUX-Meter made by Metravi

IV. AVAILABLE ARTIFICIAL LIGHT SOURCES WHICH ARE COMMONLY FOUND IN HISTORICAL BUILDING/MUSEUM[4]:

In this experiment measure the Ultraviolet radiation with several artificial lamps [5] (varying wattage) which are commonly used in Heritage building or Museum i.e. Incandescent Lamp, Conventional Fluorescent Lamp, CFL-Compact Fluorescent Lamp (both Warm & Cool [6] white) and LED-Light Emitting Diode (both Warm & Cool white).

Table 1. Specification of Light sources under Test

Sl no	Type of lamp	Experimental wattage Value (watt)
1	Incandescent	30,40,60,100,150
2	FTL	28,36
3	CFL (Warm)	6,8,11,15,18
4	CFL (Cool)	6,8,11,15,18
5	LED (Warm)	3,5,8,10,15
6	LED (Cool)	3,5,8,10,15

V. EXPERIMENTAL PROCEDURE [7]:

a. At first the available artificial lamps are secured and positioned in a central portion of laboratory.
b. Then mark the grid according horizontal position (after 1foot distance).
c. Take the reading with help of a UV- meter for measurement of UV-A, UV-B, UV-C ($\mu W/cm^2$).
d. Take the value of illuminance for same point with help of Lux meter**.**

VI. EXPERIMENTAL RESULT [8,9] :

I. Incandescent Lamp: - Following measurements should be taken for 30, 40, 60,100,150 watt Incandescent lamp with help of Lux meter and UV- Meter.

Table 2. Value of Illuminance & UV according several distances

Sl No	Lamp Specification			Distance in Foot	Illiminance Value in Lux	Value of UV		
	Lamp Type	Wattage	Lumen			UV-A	UV-B	UV-C
I	Incandescent	30	300	2	45	2.5	0.4	1.7
				4	18	1.3	0.1	0.7
				6	8	0.8	0.1	0.4
				8	4	0.7	0	0.2
		40	500	2	67	2.8	0.5	2.1
				4	20	1.5	0.2	0.9
				6	9	1.1	0.1	0.7
				8	5	0.8	0	0.5
		60	750	2	85	3.1	0.6	2.5
				4	22	1.7	0.2	1
				6	11	1.4	0.2	0.6
				8	8	1.2	0.1	0.4
		100	1000	2	102	3.6	0.8	2.8
				4	32	1.9	0.4	1.6
				6	18	1.7	0.3	0.7
				8	14	1.5	0.2	0.5
		150	1500	2	185	4	1	3.1
				4	62	2.5	0.5	1.8
				6	38	1.9	0.3	1
				8	24	1.6	0.3	0.6

II. Fluorescent Tube: - Following measurements should be taken for 28 & 36 watt conventional fluorescent lamp with help of Lux meter and UV- Meter.

Table 3. Value of Illuminance & UV according several distances

Sl No.	Lamp Specification			Distance in Foot	Illiminance Value in Lux	Value of UV		
	Lamp Type	Wattage	Lumen			UV-A	UV-B	UV-C
II	FTL	36	2800	2	432	17.8	2.5	1.1
				4	165	3.1	0.5	0.2
				6	48	1.8	0.1	0.1
				8	32	1.5	0	0
		28	3200	2	458	15.5	1.9	0.9
				4	251	2.8	0.4	0.2
				6	195	1.5	0.1	0.1
				8	52	1.2	0	0

III. CFL Warm White Lamp: - Following measurements should be taken for 6, 8, 11, 15, 18 watt CFL warm white lamp with help of Lux meter and UV- Meter.

Table 4. Value of Illuminance & UV according several distances

Sl No.	Lamp Specification			Distance in Foot	Illiminance Value in Lux	Value of UV		
	Lamp Type	Wattage	Lumen			UV-A	UV-B	UV-C
III	CFL Warm	6	300	2	72	5.4	0.5	0.3
				4	22	1.1	0.2	0.2
				6	11	0.4	0.1	0.1
				8	6	0.2	0	0
		8	500	2	85	6.8	0.7	0.5
				4	29	1.6	0.2	0.3
				6	14	0.6	0.1	0.1
				8	8	0.3	0.1	0.1
		11	750	2	98	7.3	0.8	0.6
				4	33	2.5	0.3	0.3
				6	18	0.9	0.2	0.2
				8	10	0.7	0.1	0.2
		15	1000	2	112	8.7	1	0.7
				4	41	3.1	0.4	0.4
				6	25	1.1	0.2	0.3
				8	14	0.9	0.2	0.2
		18	1500	2	145	12.7	1.3	0.8
				4	52	3.6	0.5	0.4
				6	33	1.5	0.2	0.3
				8	19	1.1	0.2	0.2

IV. CFL Cool White Lamp: - Following measurements should be taken for 6, 8, 11, 15, 18 watt CFL cool white lamp with help of Lux meter and UV- Meter.

Table 5. Value of Illuminance & UV according several distances

Sl No.	Lamp Specification			Distance in Foot	Illiminance Value in Lux	Value of UV		
	Lamp Type	Wattage	Lumen			UV-A	UV-B	UV-C
IV	CFL Cool	6	300	2	65	6.5	0.3	0.4
				4	20	1.6	0.2	0.2
				6	10	0.8	0.1	0.1
				8	5	0.3	0	0
		8	500	2	79	8.5	0.4	0.6
				4	24	2.3	0.2	0.3
				6	12	1.1	0.1	0.2
				8	7	0.8	0.1	0.1
		11	750	2	91	10.1	0.5	0.7
				4	29	3	0.2	0.4

				6	15	1.7	0.2	0.3
				8	8	1	0.1	0.2
		15	1000	2	109	12.1	0.6	0.9
				4	37	3.7	0.3	0.5
				6	23	2.1	0.2	0.4
				8	12	1.8	0.1	0.3
		18	1500	2	139	18	0.7	1.1
				4	49	4.9	0.3	0.6
				6	29	2.8	0.2	0.4
				8	17	2.2	0.1	0.3

V. LED Warm White Lamp: - Following measurements should be taken for 3, 5, 8, 10, 15 watt LED warm white lamp with help of Lux meter and UV- Meter.

Table 6. Value of Illuminance & UV according several distances

Sl No.	Lamp Specification			Distance in Foot	Illiminance Value in Lux	**Value of UV**		
	Lamp Type	Wattage	Lumen			**UV-A**	**UV-B**	**UV-C**
V	LED Warm	3	300	2	124	0.8	0	0.1
				4	65	0.3	0	0
				6	49	0	0	0
				8	28	0	0	0
		5	500	2	173	1.1	0	0.2
				4	75	0.5	0	0.1
				6	58	0.1	0	0
				8	34	0	0	0
		8	750	2	300	1.4	0	0.3
				4	101	0.8	0	0.1
				6	65	0.1	0	0
				8	48	0	0	0
		10	1000	2	345	1.9	0	0.4
				4	145	1.5	0	0.2
				6	82	0.2	0	0
				8	55	0.1	0	0
		15	1500	2	463	2.3	0.1	0.5
				4	198	2.1	0	0.2
				6	91	0.6	0	0
				8	59	0.2	0	0

VI. LED Cool White Lamp: - Following measurements should be taken for 3, 5, 8, 10, 15 watt LED cool white lamp with help of Lux meter and UV- Meter.

Table 7. Value of Illuminance &UV according several distances

Sl No.	Lamp Specification			Distance in Foot	Illiminance Value in Lux	**Value of UV**		
	Lamp Type	Wattage	Lumen			**UV-A**	**UV-B**	**UV-C**
II	LED Cool white	3	300	2	131	0.9	0	0.2
				4	59	0.4	0	0
				6	43	0	0	0
				8	25	0	0	0
		5	500	2	176	1.3	0	0.3
				4	67	0.7	0	0.1
				6	52	0.2	0	0
				8	33	0	0	0
		8	750	2	285	1.6	0	0.3
				4	89	0.9	0	0.2
				6	61	0.2	0	0

				8	41	0	0	0
		10	1000	2	339	2.2	0	0.4
				4	138	2	0	0.2
				6	79	0.3	0	0
				8	47	0.2	0	0
		15	1500	2	432	2.4	0.1	0.5
				4	165	3.1	0	0.2
				6	48	1.8	0	0
				8	32	1.5	0	0

VII. OBSERVATIONS [8, 9]:

Most of the Heritage sites are incorporated with Conventional Fluorescent Tube, CFL cool and warm white lamps. Generally Fluorescent Tube is used for ambient purpose and CFL lamp is used for accent and ambient lighting according its wattage. In any Historical buildings, uses of Incandescent lamps are obsolete now a day. But use of LED is increased day by day. This experiment has been carried out on those lamps which have most found in Historical buildings. So, According to experiment it can be concluded that:

i. LED gives higher light output with less wattage compare to other artificial Lamps. So, LED is most energy efficient compare to others lamp.

ii. It can also be observed that all lamp consist several Value of UV-A, B, C which are corrosive in nature. It is very harmful for archival materials in Historical building. But the value of UV is low in case of LED warm white and cool white lamp compare to others.

iii. Out of UV-A, B, C; UV-C is most harmful. It has short wavelengths and lead to photochemical destruction often manifested as fading. According to data the percentage of UV-C is more in CFL and Incandescent lamps.

iv. For human safety optimum distance of separation need to be maintained from several light sources in Historical site or environment.

v. At present application of LED is increased day by day, compare to other artificial lamps due to its several benefits as well as energy efficiency.

VIII. VIII. EXPERIMENTAL RESULT ANALYSIS & PROPOSED SAFE DISTANCE BETWEEN OBJECTS & LIGHT SOURCE [10,11] :

According to the experimental result it can be observed that the value of UV for each artificial lamps varying with several wattages and distances also. The illuminance level is also change according to the distances. So from above recorded data it can be proposed that which distance is safe to keep the object under artificial light sources. From above experiment it is already known that the effect of various artificial light sources is responsible for degradation of colour rate. So maintained proper distance and Lux level on archival materials is one of the methods to be reduced or altered to slow the rate of photochemical deterioration or colour degradation

** As per Indian Standard Guidelines IS-3646, where given the appropriate and standard Lux Value for specific area in a Historical or Heritage site. As per Project requirement compare the lux value form following table:

Table 8 Recommended illumination level of Art Gallery & Museum , as per IS:3646[12]

Type of Interior or Activity	Illuminance (Lux)
Exhibits insensitive to light	200-300-500
Light sensitive exhibits, for example, oil and temper paints, undyed leather, bone, ivory, wood, etc	150
Extremely light sensitive exhibits, for example, textiles, water colours, prints and drawings, skins, botanical specimens, etc	50
Conservation studies and workshops	300-500-750

So as per Indian standard guideline (IS:3646), following table is prepared where safe distance between object and light sources are to be maintained and check the application of artificial light sources (according to range of wattage) before the installation of a Historic building.

Table 9. Proposed safe distance between Object & several wattage light sources

Type of Interior or Activity	Range of Service Illuminance in Lux	Types of Artificial Light sources	Range (Watt)	Min. Safe distance (foot)	Application
Exhibits insensitive to light	300	Conventional Fluorescent Lamp	36,28	6	Used as ambient Light
		LED Tube	12 to 16	4	-do-
		LED Warm & Cool	5 to 8	2	Used as Pendent
		LED Warm & Cool	10 to12	4	-do-
		LED Warm & Cool	10 to12	4	Used as Down light

		LED Warm & Cool	12 to16	6	Used as Down light
		CFL Warm & Cool	18 to 26	6	Used as ambient Light
Light sensitive exhibits, for example, oil and temper paints, undyed leather, bone, ivory, wood, etc	150	LED Warm & Cool	1 to 5	2	Used as spot Light
		LED Warm & Cool	6 to 8	4	Used for highlight specific area or object
		LED Warm & Cool	12 to 20	6	Used as Track Light
		CFL warm & Cool	18 to 22	8	Used for highlight specific area or object
Extremely light sensitive exhibits, for example, textiles, water colours, prints and drawings, skins, botanical specimens, etc	50	LED Warm & Cool	1 to 5	4	Used as spot Light
		LED Warm & Cool	5 to 8	6	Used for highlight specific area or object
		LED Warm & Cool	12	6	Used as COB light
		CFL warm & Cool	12 to 15	8	Used for highlight specific area or object
		CFL warm & Cool	6 to 11	6	-do-
Conservation studies and workshops	500	Conventional Fluorescent Lamp	28	6	Used as ambient Light
		LED Tube	20	4	Used as ambient Light

[Note: Here, distance between objects and artificial light sources is to be arranged not only illuminance basis. The UV is one of the important factors for degradation of colour in an archival object. So, percentage of UV is varying lamp to lamp according their wattages too which is experimented already. For this, above table is prepared for considering both the parameters i.e. illuminance as well percentage of UV that is present in each light sources. Incandescent lamp is almost obsolete now days, for this it has not been included this table]

IX. CONCLUSION:

Throughout the analysis of the experiment, it can be observed that all artificial lamps comprise with ultraviolet ray. The percentage of UV is varying with several artificial light sources according various distances. It is already proof that UV is one of the culprits which have severe fading effects on archival materials. So a safe distance is evaluated between objects and light sources. It is one of the best ways to control fading effects on archival materials from UV rays.

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