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STUDIES ON GERMICIDAL BENEFIT OF ULTRA VIOLET RAY UPON OLD PAPER DOCUMENTS

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ABSTRACT

In the ever-changing world, cultural heritage, especially through documents, plays an important role in a civilized developing country. The documents specially made of paper are organic products and more prone to bacterial formation. From most of the heritage archives, it has been informed/observed that bacteria destroys the important documents. The conservations of these articles are essential. From the point of view for good lighting system design, one can utilize a photobiological effect of light, i.e., UV range of the light source is killing bacteria too. Experimentation has been carried out on different paper documents with different intensities of UV contents from light sources. The bacteria content in a sample at the initial stage as well as after UV treatments with different intensities have been noted, analyzed, and furnished in this paper. The process shows a successful result as per expectation. If this methodology can be implemented for the conservation of paper archives, it will give a fruitful result for the conservation of our cultural heritage, which is very much valuable for the development of a society.

Keywords: archives, bacteria, conservations, heritage, lighting, swap test

1. INTRODUCTION

Bio deterioration can be defined as "any undesirable change in the properties of a material caused by the vital activities of living organisms" [1, 2], as distinguished from changes produced by "chemical, mechanical, and physical influences". Biological agents that produce deterioration are referred to as bio deteriogens, and these range from microorganisms like fungi to higher plants. Since organic materials, which are most vulnerable to biological attack, are used in many traditional artefacts also, and since the high heat and humidity in weaken organic materials and favour the growth as well as the reproduction of bio deteriogens, that faces critical problems in protecting its cultural collections from bio deterioration.

Preservation [3, 4] of historic materials, particularly of organic materials like textile, papers, wood, palm leaf, birch leaf etc. is a matter of serious concern and thorough investigation to prolong the useful lifespan of physical items that hold outstanding records of the past wisdom. Light, both natural and artificial, is one of the environmental factors that need to be controlled in achieving this goal for the preventive care of such important historic repositories in national archives, heritage building as well as libraries and museums. Nowadays, it is well known that microorganisms are responsible for the deterioration of archival artefacts of cultural heritage etc. Two main factors responsible for the proliferation growth of microorganisms on archival objects, especially on paper, textiles, wood, palm leaf, birch leaf [5, 6] infestation are due to the chemical nature of the substratum and the environmental conditions, such as the availability of nutrients, favourable temperature, humid condition etc. Therefore, it is necessary for a lighting engineer to find out ways and means for destroying microbes like fungi, algae, bacteria etc., by the application of light. An ef-

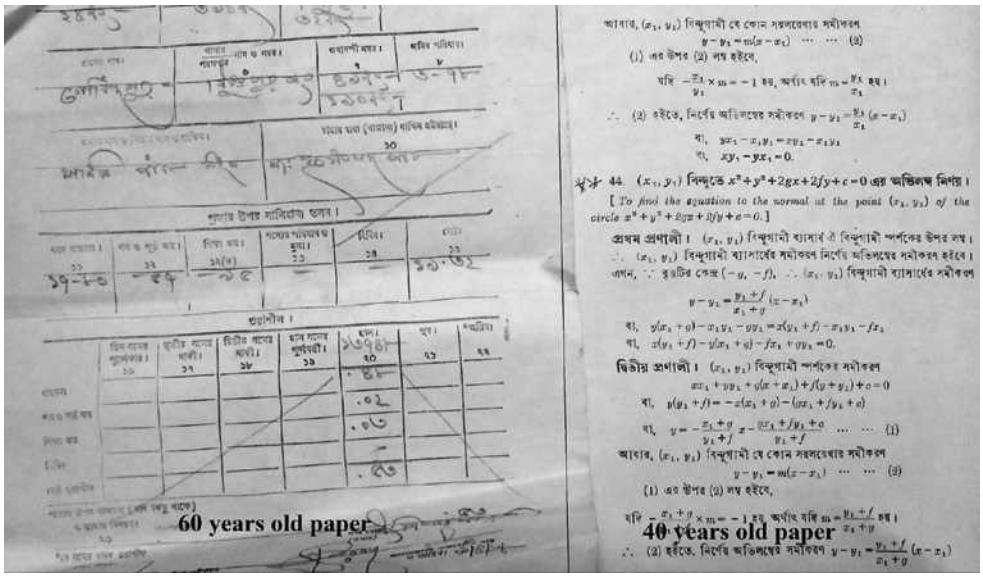


Fig. 1. Collected paper samples

fort has been made using UV radiation, which is available in artificial light sources especially mercury vapour type light sources. This paper attempts to give a brief idea about how UV radiation destroys or controls microbes like fungi, algae, and bacteria with specific kind, intensity, and exposure time.

2. EXPERIMENTAL STEPS [7, 8]

- Collection of old artefacts like paper from Heritage Sites;
- Collection of market available UV lamps with different intensities;
- Preparation of Czapack-Dox media for growing bacteria and fungi;
- Collection of bacteria and fungi infested handmade and machine-made form paper and textiles materials using swap test method before UV exposure, i.e. initial stage, and identification and counting of the concentration of bacteria in the sample;
- Keeping the old subject in Laminar Flow Meter under UV exposure of various intensities for a certain time;
- Collection of bacteria and fungi from paper and textiles after treating with UV radiation in the same manner;

Table 1. Classification of UV Radiation with Ranges

Class of UV	Range of UV
UV-A	400 nm – 315 nm
UV-B	315 nm – 280 nm
UV-C	280 nm – 100 nm

- The final comparison of the bacteria and fungi concentration from heritage artefacts before and after UV treatment.

3. COLLECTION OF OLD ARTEFACTS FROM HERITAGE SITES

At first, two types of paper handmade/machine-made samples have been collected from heritage sites, which are above forty and sixty years old respectively (Fig. 1). These pieces of paper may contain signatures and official records of the circumstances surrounding particular moments and events, and it could be a heritage capsule of the period.

4. COLLECTION OF UV LAMPS WITH TWO DIFFERENT INTENSITIES

Sun is the natural source of light with a wide band of spectrum broadly classified into a Radio wave, Microwave, Infrared, Visible, Ultraviolet, X-rays, and Gamma rays. In these particular wave spectrums, Ultraviolet ray (UV) is electromagnetic radiation with the wavelength shorter than that of visible light, but longer than x-rays. It is in the range between 100 nm to 400 nm (Table 1).

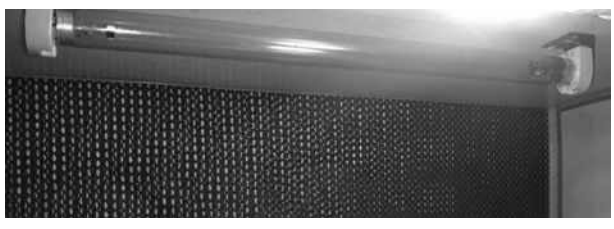


Fig. 2. Experimental UV lamp

Fig. 3. Laminor flow meter and autoclave

In this experiment, the measured values of UV irradiance of two different lamps (Fig. 2), which have been employed to minimize the concentration of bacteria from old artefacts, are **612 μW/m^2** and **306 μW/m^2** respectively.

5. NECESSARY MINOR/MAJOR INSTRUMENTS THAT ARE USED TO CARRY OUT EXPERIMENT

5.1. Laminar Flow Meter

It is incorporating a UV lamp in the laboratory-based equipment used for the germicidal operation (Fig. 3). Typically, in a laminar flow or biological safety cabinet, the UV lamp is activated, while the cabinet is not in use, to keep the interior of the work zone clean and decontaminated.

5.2. Autoclave

An autoclave (Fig. 3) is mainly used to sterilize surgical equipment, laboratory instruments, pharmaceutical items, and other materials. It can sterilize solids, liquids, hollows, and instruments of various shapes and sizes. Autoclaves vary in size, shape, and functionality. A very basic autoclave is similar to a pressure cooker: uses the power of steam to kill bacteria, spores, and germs resistant to boiling water and powerful detergents.

5.3. Incubators

An incubator is a device used to grow and maintain microbiological cultures or cell cultures. The incubator maintains optimal temperature, humidity, and other conditions such as the *CO* (CO_2) and oxygen content of the atmosphere inside. In this experiment, the incubator has been used for the growth of collected bacteria from the test sample at the specified condition.

5.4. Lamp Parameters

Two different lamps, which have been employed to minimize the concentration of bacteria from old artefacts, are used for this experiment purpose (Table 2).

Table 2. Lamp Parameters

Parameter	Low Intensity Lamp	High Intensity Lamp
Type	T5 Slim Line	T5 Slim Linkable
Power consumption, W	4	8
Distance, ft.	2	2
Colour temperature, K	2700	6400
UV irradiance at distance, μW/m^2	306	612
Voltage, V (AC)	220–240	220–240
Lifetime, hours	7500	8000

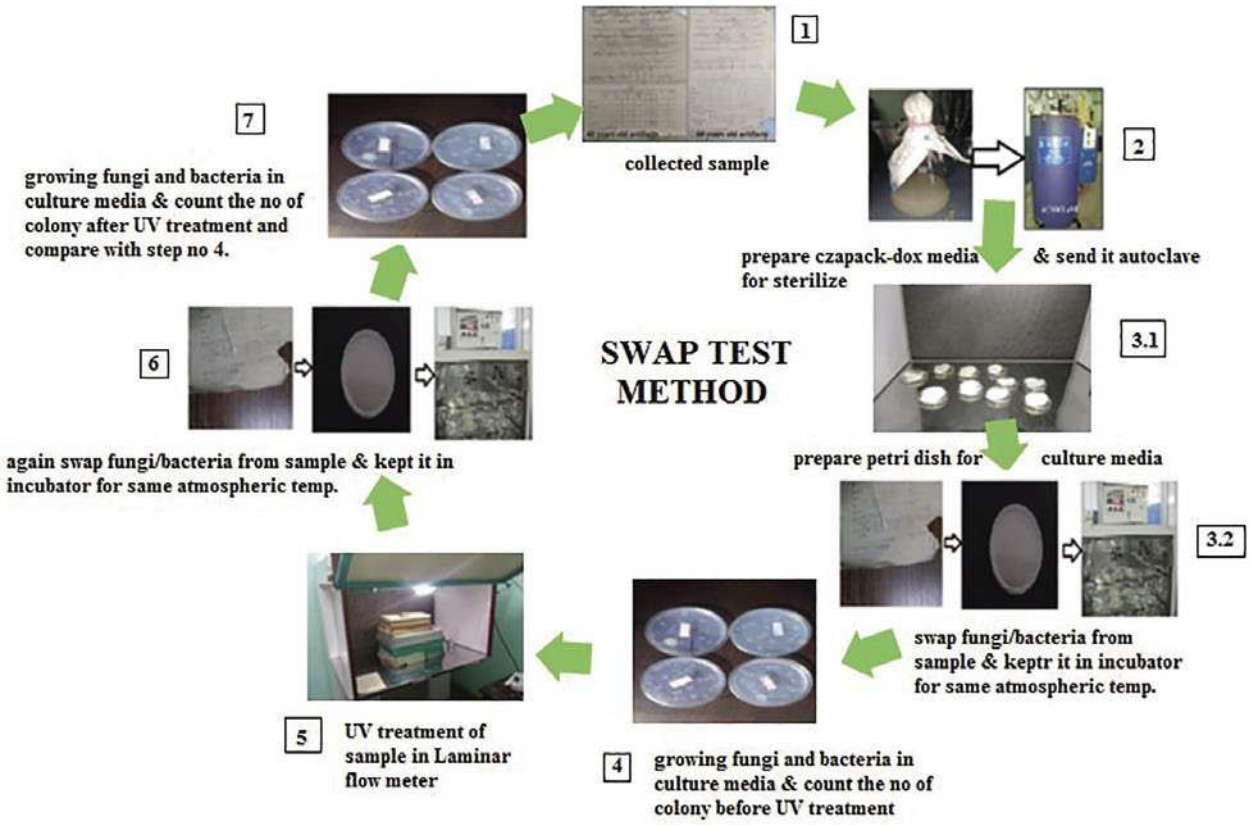


Fig. 4. Swap Test procedure according to order

6. ADOPTED METHODOLOGY FOR REDUCING BACTERIA AND FUNGI FROM OLD ARTEFACTS [9, 10]

The stages of the so-called Swap Test were the following (Fig. 4):

1) At first, samples were collected to carry out the experiments;

2) After collecting samples, czapack-dox/Agar media was prepared and sterilized by the autoclave machine at 121°C for 15 minutes to remove existing bacteria and fungi within the plate before usage and now pour this agar media in a Petri dish, where bacteria and fungi were grown in favourable circumstances;

3) Bacteria and fungi were swapped from the samples and these swapping fungi and bacteria were kept into the agar plate in the incubator to maintain continuous controlled atmospheric temperature (28°C) for the duration of 5–6 days;

4) After 5–6 days bacteria and fungi grew up in the Petri dishes or agar plates, and the number of colonies grown in the agar media was counted;

5) Then these samples were treated under UV radiation in the laminar flow meter for three hours and four hours respectively, and the samples were kept at 2 ft. distance from the UV source;

6) After UV treatment it is swapped and kept into another new agar plate again in the incubator to maintain continuously at the same atmospheric temperature (28°C) for 5–6 days;

7) At last, after 5–6 days bacteria and fungi grew up in a new Petri dish, and the number of colonies was counted again. Thus, the number of colonies after the UV treatment was compared with the number of colonies before the UV treatment. It was counted whether the colonies had been reduced or not after the UV treatment.

7. ANALYSIS OF THE EXPERIMENTAL RESULTS (SWAP TEST) [11, 12]

The experimental results of the sample A (60 years old papers) are shown in Table 3, Table 4. The experimental results of the sample B (40 years old papers) are shown in Table 5, Table 6.

Several attempts have been made to destroy the bacteria in the affected sample through the non-destructive method, i.e. without destroying the subject artefacts. Lighting engineers' effort has been made

Table 3. Original and Microscopic View of Bacteria with the Number of Colony before UV Treatment for the Sample A

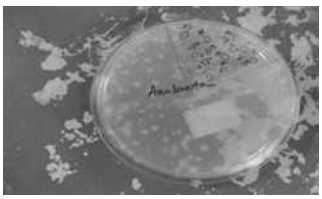
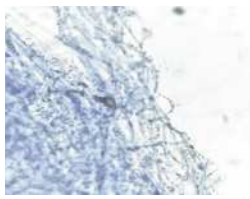
Number of colony (bacteria) before UV treatment	Original view of bacteria	Microscopic view of bacteria
Petri dish 1: 10		
Petri dish 2: 60		

Table 4. Original and Microscopic View of Bacteria with the Number of Colony after UV Treatment for the Sample A

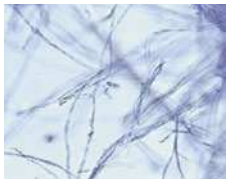
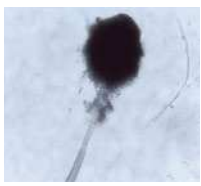
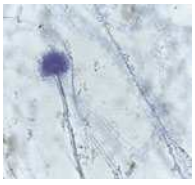
Petri dish 1					
Observation time, hours	**Irradiance of lamps $\mu W/m^2$**	**Dose, mJ/cm^2 [1, 2]**	**Number of colony (bacteria) sample A after UV treatment**	**Visual observation of bacteria**	**Microscopic view of bacteria**
3	612	1.836	4		
	306	0.918	5		
Petri dish 2					
6	612	3.672	17		
	306	1.836	29		

Table 5. Original and Microscopic View of Bacteria with Number of Colony before UV Treatment for the Sample B

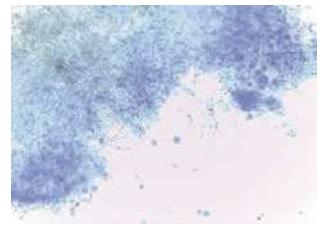
Number of colony (bacteria) before UV treatment	Visual observation of bacteria	Microscopic view of bacteria
Petri dish 3: 5		
Petri dish 4: 15		

Table 6. Original and Microscopic View of Bacteria with Number of Colony after UV Treatment for the Sample B

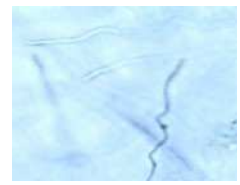
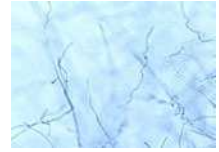
Petri dish 3					
Observation time, hours	**Irradiance of lamps, $\mu W/m^2$**	**Dose, mJ/ cm^2 [1, 2]**	**Number of colony (bacteria) sample B after UV treatment**	**Visual observation of bacteria**	**Microscopic view of bacteria**
3	612	1.836	2		
	306	0.918	3		
Petri dish 4					
6	612	3.672	4		
	306	1.836	7		

Table 7. Analysis of Bacterial Colonies

Sample	Petri dish No.	Initial number of bacterial colonies	Intensity of UV lamp	Duration, hours	Dose (mJ/cm^2) [1, 2]	Final number of bacterial colonies	Reduction (%)	Observations
A	1	10	612	3	1.836	4	60.00	Colonies reduction is only 10 % while duration remains the same and intensity is doubled
A	1	10	306	3	0.918	5	50.00	
A	2	60	612	6	3.672	17	71.66	By increasing the duration of time with higher dose, further 11.66 % improvement
A	2	60	306	6	1.836	29	51.66	Not much effective with lower intensity
B	3	5	612	3	1.836	2	60.00	Colonies reduction is only 20 % while duration remains the same and intensity is doubled in case of lower initial concentration
B	3	5	306	3	0.918	3	40.00	
B	4	15	612	6	3.672	4	73.33	By increasing the duration of time with higher intensity, further 10 % improvement
B	4	15	306	6	1.836	7	53.33	Not much effective with lower intensity

to apply proper light sources. The UV content of the lamp has successfully reduced the number of bacterial colonies in the affected subject, without affecting the subject.

The comparison of the number of bacterial colonies before and after UV treatment is shown in Table 7. It has been observed for these studies that as the intensity and duration increases, the effectiveness of reduction for bacteria's colony increases.

8. CONCLUSION

The experimental work dealt with a photobiological effect of light, i.e., killing of bacteria through the application of UV ray. In this experimentation, a UV-B lamp has been used with varied intensity and duration. As per earlier studies/report, UV–C is very much dangerous to use, UV-A is less effective, and UV-B is mostly used for germicidal applications in microbiological laboratories. The results show that the destruction of bacteria response properly as per the stated dosing. Lighting engineers' effort has been made to offer an overall good solution for conservation as well as suitable lighting [12] for proper documental archives with a lighting solution i.e. through UV, not using any sort of chemical, which usually damages the archives. However, experimentation has been carried out at the reasonably low intensity of light considering ambient lighting and UV level in museum hall. Occasionally at the certain interval, the archives may be taken for treatment with high intensities, that is through the laminar flow meter or equivalent devices, which is not easily possible to keep in a museum.

9. ACKNOWLEDGEMENT

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REFERENCES

1. Kowalski W. Ultraviolet Germicidal Irradiation Handbook UVGI for Air and Surface Disinfection // Springer Heidelberg Dordrecht London New York, 2009,501 p.

2. Bolton J.R. Ultraviolet Applications Handbook Third Edition (Updated) // Bolton Photosciences Inc., 2010.

3. Elottol M.A., Bahauddin A. A Competitive Study on the Interior Environment and the Interior Circulation Design of Malaysian Museums and Elderly Satisfaction // Journal of Sustainable Development, Vol. 4, No. 3, 2011, pp. 223–234.

4. Maev R. Gr., Green Jr. R.R., Siddiolo A.M. Review of advanced acoustical imaging acoustical imaging techniques for nondestructive evaluation of art objects // RNDE, No. 17, 2006, pp. 191–204.

5. Berger G.A., Russell W.H. Interaction between Canvas and Paint Film in Response to Environmental Changes // Studies in Conservation, Vol. 39, No. 2, 1994, pp. 73–86.

6. Sayre E.V., Majewski L.J. Technical Investigation of the Deterioration of the Paintings // Studies in Conservation, Vol. 8, No. 2, 1963, pp. 42–54.

7. Guidelines for Control and Prevention of Termite Infestation in Archives and Libraries // New Delhi: National Archives of India, 1991.

8. Jeyraj V. Care of Archival Materials // Thanjavur Saraswati Mahal, No. 395, 1995.

9. Repair and Preservation of Records // National Archives of India, New Delhi, 1988.

10. Kizlasov L.R. Arheologicheskie issledovaniya na gorodishe Ak-Beshim v 1953–1954 gg [Archaeological research on the site Ak-Beshim in 1953–1954] // Trudi Kirgizskoy arheologo-etbographicheskoy ekspedicii, Vol. 2, Moscow, 1959.

11. McCrone W.C. Microscopical examination of art and archeological objects // SPIE Conference on Scientific Detection of Fakery in Art, Vol. 3315, 1998, pp.1–9.

12. Frank F. Museums and the Green World // LD+A Museum on Display, Vol. 39, No.02, 2009, p. 47–49.

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