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Physical and mechanical properties of unbleached and bleached bagasse sheets after exposure to Ultra Violet light

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ABSTRACT

The effect of the exposure of paper samples to UV rays at wave length 254 and 365nm at distances of 15, 30, 45 cm for time up to 100 hours treatment were studied. Two types of paper sheets unbleached and bleached bagasse paper were used in this study. The effect of these treatments on brightness, burst factor, breaking length, tear factor and carboxyl content was carried out. Aging of paper sheets using UV due to decrease in the brightness, burst factor and breaking length, but increase tear factor and carboxyl content.

Key Words: UV, unbleached, bleached bagasse paper, brightness, burst factor, breaking length, tear factor, carboxyl content.

INTRODUCTION

Papers loose its brightness (turn yellow) when exposed to light. Considering that brightness stability is an important optical property that paper manufacturers would like to measure, accurate test methods are needed to predict this characteristic of papers. Although accelerated light aging test methods have been used [1- 4], these methods have limitations due to high light intensity and the amount of UV component in the spectral out put of the light sources. Therefore, they do not reproduce the end-use conditions very well [5].

Both natural biopolymer materials and synthetic polymers undergo UV-induced discoloration, usually an increase in the yellowness on exposure. Lignocellulosic materials such as wood and paper readily undergo light-induced yellowing [6]. While both cellulose and lignin constituents of wood can photoyellow, it is the latter that is mostly responsible for the phenomenon. Lignin, which comprises 29–33 wt% of softwood, contains numerous chromophores that efficiently absorb UV radiation [7]. As much as 80–95% of the absorption coefficient of wood can be ascribed to the lignin fraction. The complex photochemistry of yellowing in lignin-containing materials is not completely understood; the present understanding of the process was succinctly summarized recently and at least four pathways of photodamage have been recently discussed.

The practical interest in discoloration relates specially to newsprint paper made of groundwood pulp that yellows rapidly on exposure to sunlight. Action spectra for photoyellowing of these pulps have been reported, and a recent study [8] confirms the solar UV wavelengths to cause yellowing, while the wavelengths in the region of 500–600 nm were shown to photobleach the pulp. The cellulose fraction in wood also undergoes free-radicalmediated degradation on exposure to wavelengths less than 340 nm.

For many years, it has been known that exposure of paper to very short-wavelength ultraviolet, such as 254 nm radiation, will induce post-irradiation effects, the specific results of which are influenced by both internal and external factors. [9- 12]. External factors during irradiation and subsequent storage include wavelength of irradiation, temperature, humidity, and atmospheric conditions. Internal factors relate to chemical composition of the paper: acidity, carbonyl groups, and the content of hemicellulose, extractives, and lignin. It is also known that exposure to visible and ultraviolet radiation results in complex discoloration effects both during and after exposure [13- 14]. Nevertheless, the fact remains that few studies have been carried out specifically to elucidate the behavior of papers subsequent to exposure to the wavelengths of visible and near-ultraviolet radiation normally involved in the display of works on paper, approximately 320 to 760 nm.

Launer and Wilson found that soda-sulfite paper irradiated under conditions that resulted in bleaching (330 – 440 nm radiation; sheet temperature 30°C) yellowed during a subsequent storage period of 15 months. [15] MacMillan reported the sensitivity to thermally induced aging following exposure of test papers in the Fade-ometer to be a function of the aldehyde-group content in the cellulose molecules. [16] This particular observation suggests that the observed post-irradiation darkening under visible and near-ultraviolet radiation may essentially be the result of thermal-aging processes even though the level of temperature of the paper when stored away from the light may not be far from normal room conditions.

Cellulose is in general considered to be quite stable when irradiated by daylight, and in a recent study lignin-free paper lost its optical properties slowly and was considered to be stable, although changes in fluorescence were observed in the initial phases of light ageing [17]. However, all papers involved in the study suffered a loss of mechanical strength to a considerably greater degree than expected during long-term natural ageing. This behavior was observed also for pure cellulose (Whatman filter paper) during 35 days of exposure to daylight [18].

From a mechanistic point of view, not much is known about the reactions leading to light-induced discolouration (brightness reversion) and degradation of bleached chemical pulps or cotton cellulose. However, the mechanism is considered to differ from that occurring during thermal ageing [19]. Studies of chemiluminescence may provide additional insight into the initial processes [20], and further mechanistic research is planned within the 'PAPYLUM' 5th Framework project. Although exposure to light is considered to be of minor importance for general archival and library collections, its effects on the most precious objects, which are often exhibited, should not be underestimated.
In natural aging daylight is more damaging than artificial light in the early stages of aging. Additionally in natural aging, all papers reach a limit beyond which loss of optical properties ceases. The papers remain optically stable thereafter. In a minor way color and brightness properties of the paper are affected by humidity change. The rates of change of optical properties differ considerably depending on the particular paper composition. For example, the cotton papers and those of pure chemical wood pulp lost optical properties only very slowly. Those containing lignin experienced rapid loss of optical properties. This was as expected because of the known photo reactivity of lignin.

Biodeterioration of library materials is a worldwide problem and it causes great damage especially to unique manuscripts and books stored in the libraries [21-25]. This study was intended to discuss one of the biological factors as a main external group of factors that influence library materials. Fungal spores are an important component of the bioaerosol. There are about 80,000 species most of which are cosmopolitan in origin. The biological features of the fungi i.e. their ease of dispersion makes fungi one of the chief agents of contamination of any type of substrate including cellulose materials in the books of library. Many are pathogenic to human beings causing allergic problems including asthma due to differential deposition in the respiratory system. It also causes the skin infection like Dermatophytosis or ring worm infection or tinea is by far the most common disease in human beings [26]. These fungi along with bacteria are responsible for the deterioration of the materials in the library. The activity of different environmental factors may cause some changes in physical and chemical properties of library collections and most of the time it has been seen these conditions are conducive for the growth of microbes hence, accelerating the deterioration process. In addition to internal causes for the deterioration of paper in books, due to its acidity, external agents are also a major threat to manuscripts [25, 27].

The aim of this work is to find the effect of UV light at wave length 254 and 365nm at distances of 15, 30, 45 cm for time up to 100 hours on the physical properties of bleached and unbleached bagasse paper sheets.

MATERIALS AND METHODS

Unbleached kraft bagasse pulp provided by Edfo Mill, Egypt was bleached by the conventional three stages method; the chemical and physical analysis of both pulps was as follow:

Table (1): Chemical and physical analysis of unbleached and bleached bagasse pulp.

property	Unbleached	Bleached
α-cellulose %	64.0	73.7
Hemicellulose %	27.5	24.4
Lignin %	4.80	1.18
Breaking length (m)	5610	3700
Burst factor	2.15	1.95
Tear factor	45.2	61.8
Brightness %	51.4	70.0
Carboxyl mg.eq./100g	161	142

Both pulps were beaten till 30 ºSR and paper sheets were made according to the Swedish Method (S.C.A.). Strength properties [28] and brightness [29] of the prepared sheets were determined. Paper sheets were aged in isolated place using UV as an accelerating aging at wave length 254 and 365 nm at distances of 15, 30, 45 cm for time up to 100 hours under temperature 25 °C and relative humidity of (70 % RH).

RESULTS AND DISCUSSION

Bleached and unbleached paper sheets subjected to UV light at 254nm and 365nm at different distances 15, 30, 45cm for time intervals up to 100 hours were tested to find the effect of these treatments on its mechanical and chemical properties. Brightness, burst factor, breaking length, tear factor and carboxyl content were found for all the treated sheets, the results found will be discussed in details in the following chapter.

Effect of UV treatment on sheets brightness

The brightness is one of the most important properties of paper because it affects its use as writing or printing papers. The effect of U.V. treatment (aging) on this property was found on Figs (1 and 2).

Fig (1) illustrates the effect of treatment at 254 nm for time intervals at different distances 15, 30, 45cm. From the Fig it is clear that a sharp decrease take place during the 1st 2hours especially for the unbleached papers. After that the decrease in brightness was moderate till 100 hrs treatments. The brightness of 71% of the original value was found at 15cm distance, while at 30 & 45cmthe value obtained was 78 and 86% of the original brightness. This shows that the distance between the source and the sample has an effect on the aging speed. For the unbleached samples the effect of the treatment was clearer than the bleached one, at 15cm distance and after 100hrs exposure we obtained only 38.5% of the original values which increased to 48 & 54% of the original values at 30 and 45 cm. The above results can be explained by that U.V. oxidize some chromophoric groups of the cellulose or residual lignin and resulted in more darkening or yellowing of the samples and this is clearer in the unbleached samples.

Fig (2) illustrates the effect of the treatment on paper sheets bleached and unbleached at 365nm, the same discussion can be applied here with keeping in mind that the effect of U.V. here is less effective than that at 254 because as the wave length of the ray increased its effect (energy) was decreased. For the above reason we obtained 77, 84.5 & 92.5% of the original brightness values at 15, 30 &45cm compared with 71, 78 and 86% respectively for the bleached samples exposed to 254 nm. For the unbleached samples we obtained 48, 54 & 57.5 of the original brightness value for treatment at 15, 30 & 45cm respectively compared with 38.5, 48 & 54% for samples treated at 254 nm.

We can concluded from the above results that the effect of UV treatment (aging) on the brightness is more clear at the 1st 2hrs of treatment also the effect is drastic at 254 than at 365nm and the effect is noticeable for the unbleached paper sheets.

Effect of UV treatment on burst factor

Figs (3 and 4) illustrate the effect of UV treatment at 254 & 365nm on bagasse sheets. Fig (3) shows the effect of UV treatment at 254nm on bleached and unbleached bagasse paper sheets for tomes up to 100 hrs and at distances 15, 30 & 45cm. From the Fig it is clear that the burst factor decrease with increasing treatment time also the value of burst decreased as the distance is small. The unbleached samples retain 79.5, 84 & 91% of its original burst values after 100hrs exposure at 15, 30 & 45 cm whereas the bleached samples retain only 78, 84 & 84% at 254nm.

This show that the effect of the treatment is more effective on the bleached samples where it lose 13% of its value where at the unbleached samples lose only 9% of its value at the same conditions (45cm and 100hrs).

Fig (4) shows the effect of treatment on paper sheets at 365nm. The same discussion as above can be applied except that the decrease in burst factor is not as big as in case of 254 nm due to the reasons explained before. We can see also from the Fig that the effect of treatment on both bleached and unbleached sheets is nearly the same where both retained about 90% of its value after 100hrs at 45cm.

Effect of UV treatment on breaking length of bagasse paper sheets

Breaking length is one of the most important mechanical properties of paper sheets since it affecting printability. Figs (5 and 6) illustrate the breaking length decrease as a result of UV treatment at 254 & 365nm. A sharp decrease occurred during the 1st 2hrs of treatment then a slight decrease was observed till 100hrs treatment, also it is clear that the decrease in breaking length become smaller as the distance increased from 15-45cm. Bleached samples after 100hrs treatment retain 54.1% of the original breaking length at 15cm and 60.8, 70.3% at 30 & 45 cm respectively. The unbleached samples retain 52.6, 57 & 64% at 15, 30 & 45cm respectively; this indicates that the unbleached samples are more sensitive to UV treatment than the bleached one.

Fig (6) was the same as Fig (5) except it gives the effect of UV treatment with wavelength 365nm. The bleached samples retain 68.9, 75.7 & 85.2% of the original breaking length values after 100hrs treatment at distances 15, 30 & 45cm, while the unbleached samples retain only 57.9, 61.4 & 65.8% of the original values. This shows that the unbleached samples are more affected by UV considering the breaking length factor.

Effect of UV treatment on tear factor

Tear factor differ from other mechanical paper properties since it depends on the lateral bonds between cellulose fibers in paper sheets mostly these bonds are hydrogen bonds between the lateral cellulose chains. As a result of UV treatment some of the OH groups are oxidized to COOH groups, which allow more lateral hydrogen bonding between the cellulose chains, this resulted in higher tear factor with increasing the UV treatments.

Figs (7 and 8) illustrate this effect at 254 & 365 nm respectively. At 254nm with both bleached and unbleached samples a sharp increase take place during the 1st 2hrs of treatment, then a slight increase take place till 100 hrs treatments. After 100hrs and at 15cm distance a value of 133% of the original values was obtained for bleached sheets, 127 & 117% for 30 & 45cm distances for unbleached samples the values obtained was 120, 113 & 109% for distances of 15, 30 & 45cm. From the above results it is clear that the bleached samples affected more than the unbleached samples, this can be due to that the bleached samples contain a higher percentage of cellulose, which oxidize and affect the tear factor.

Fig (8) gives the results obtained when the samples treated with UV of 365nm. The same trend as before was obtained except that the values obtained for tear factor was some what lower than that obtained at 254nm.

Effect of UV treatment on carboxyl content

Carboxyl content was estimated as mg.eq./100g by a method described in the experimental part. The values obtained for the COOH content was gradually increased till 100 hrs treatment. The values obtained after 100 hrs at 15 cm was 133 of the original values where as it reach 127 & 117% at 30 & 45cm for the bleached samples. Unbleached samples give an increase of 120, 113 & 109% for 15, 30 & 45 cm distance between source and samples. It is clear that bleached samples affected by the treatment more than the unbleached samples for the reason mentioned before.

Fig (10) illustrates the effect of UV treatment at 365nm wavelength on the paper sheets on its carboxyl content the same discussions made for Fig (9) can be applied here also except that the effect of UV here is less than that for 254 nm. Also the bleached samples were affected more than the unbleached samples.

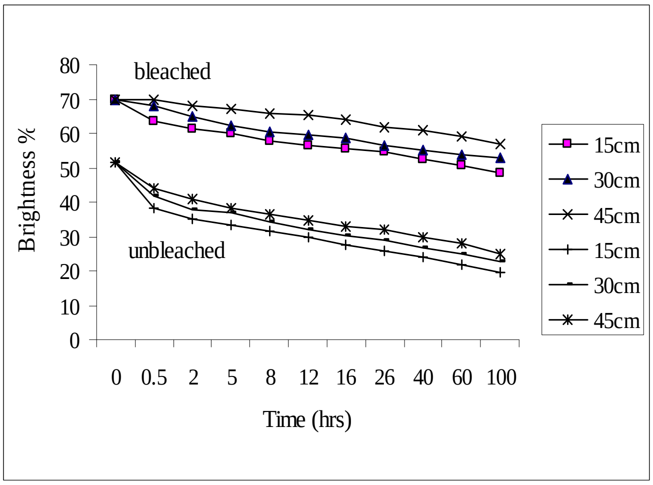

Fig (1): Brightness of unbleached and bleached bagasse pulp at 254 nm at different distances.

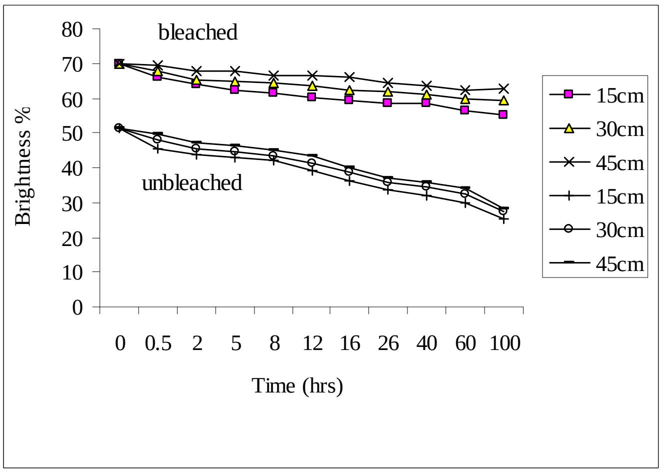

Fig (2): Brightness of unbleached and bleached bagasse pulp at 365 nm at different distances

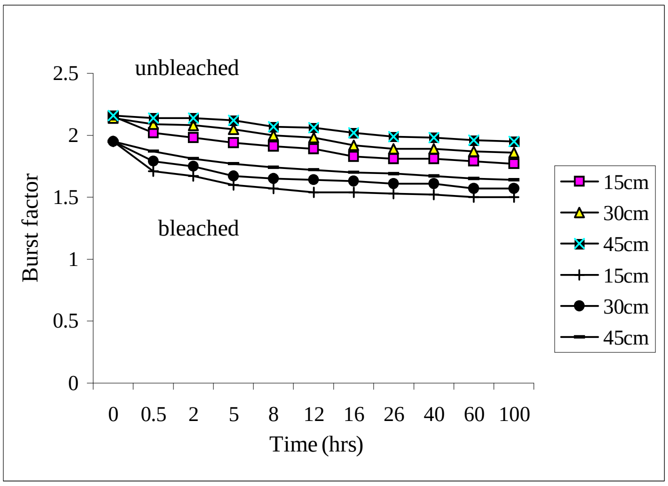

Fig (3): Burst factor of unbleached and bleached bagasse pulp at 254nm at different distances.

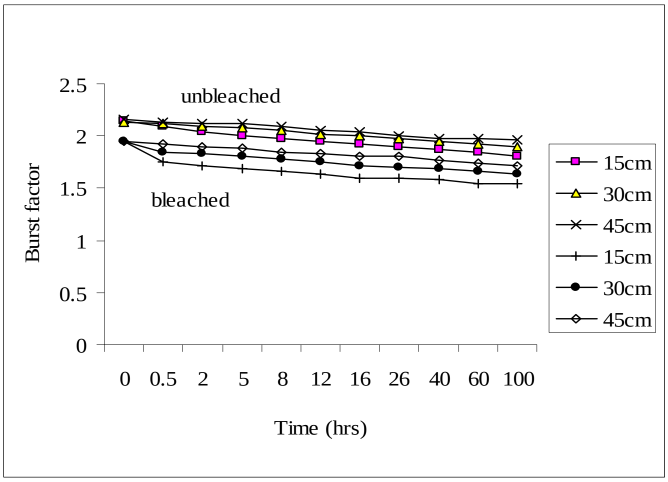

Fig (4): Burst factor of unbleached and bleached bagasse pulp at 365nm at different distances.

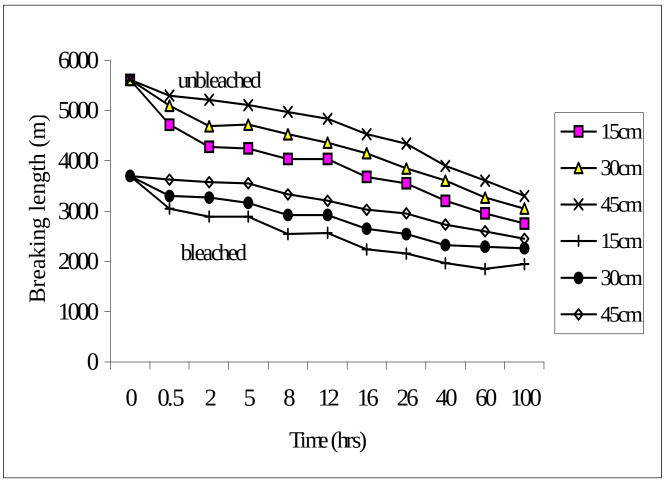

Fig (5): Breaking length of unbleached and bleached bagasse pulp at 254nm at different distances.

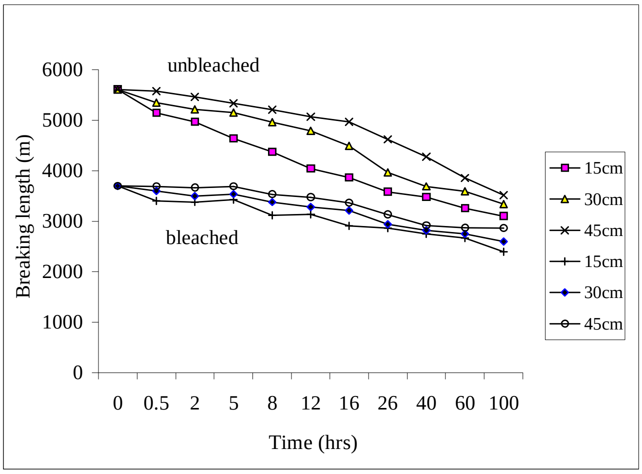

Fig (6): Breaking length of unbleached and bleached bagasse pulp at 365nm at different distances.

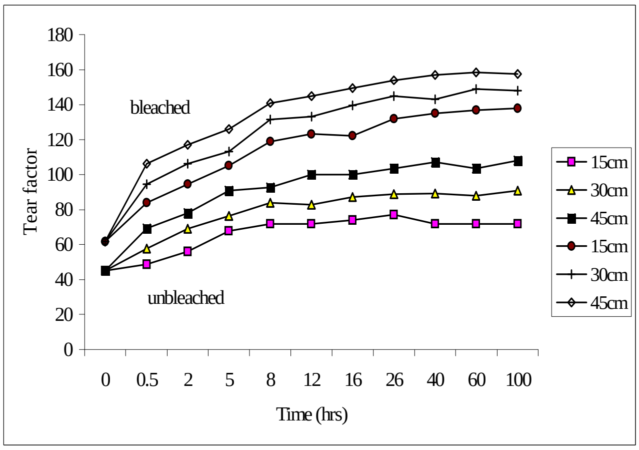

Fig (7): Tear factor of unbleached and bleached bagasse pulp at 254 nm at different distances.

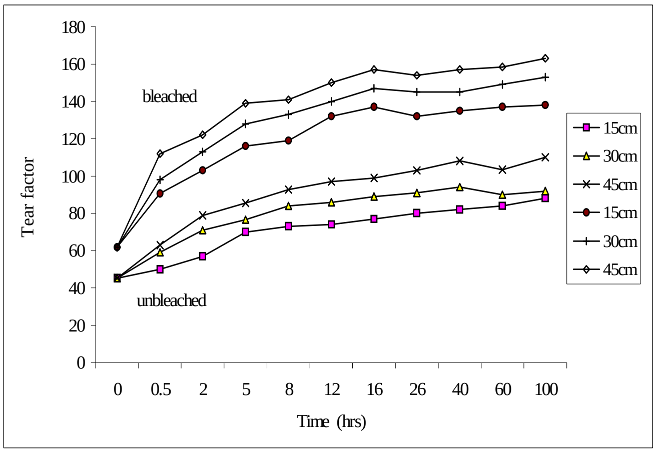

Fig (8): Tear factor of unbleached and bleached bagasse pulp at 365 nm at different distances.

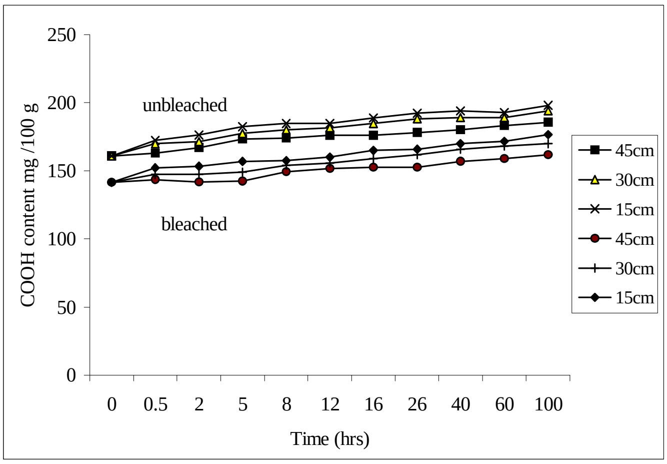

Fig (9): Carboxyl content of unbleached and bleached bagasse pulp at 254 nm at different distances.

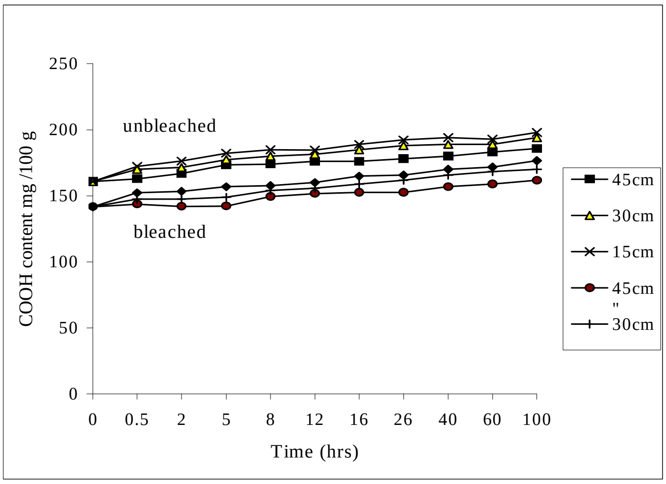

Fig (10): Carboxyl content of unbleached and bleached bagasse pulp at 365 nm at different distances.

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