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ANTIBACTERIAL AND ANTIFUNGAL PROPERTIES OF ELECTROCHEMICALLY PREPARED ZINC OXIDE FILMS IN PRESENCE AND ABSENCE OF LIGHT

R RENUKA AND S RAMAMURTHY

Central Electrochemical Research Institute, Madras Unit, CSIR Complex, Chennai 600 113. INDIA

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The antibacterial and antifungal properties of zinc oxide films prepared by anodizing of zinc specimens and by oxidation of zinc electroplated coatings are discussed in this paper. The antifungal efficacy of the films were tested against common food and leather spoilage fungi viz., Aspergillus flavus, Aspergillus niger, Aspergillus nidulans, Aspergillus terreus, Penicillium frequentans, Penicillium rubrum, Penicillium perpurogenum, Paecilomyces varioti and the human fungal pathogen, Candida albicans. The bacteria tested include Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeroginosa, Saccharomyces cerevisiae and Escherichia coli. The yeast, Saccharomyces cerevisiae was also included in the test. The effect of light on the antibacterial and antifungal properties are discussed. In presence of light, the biocidal potential is enhanced.

Keywords: **Zinc oxide films, antibacterial and antifungal efficacy,electroplated and anodized specimens, biocidal potential.**

INTRODUCTION

Zinc oxide is known for its disinfecting properties and is used in a variety of personal and biomedical applications. For instance, in anti-ageing cosmetic formulations [1-2], sun screens [3], oil and sebum removal of formulations [4], skin disease prevention formulations [5-6], dental cements and alloys [7-8], hair preparations [9], bandages and dressings [10] and deodorant detergents [11]. ZnO is also used extensively in rubber and certain outdoor oil based paints. In addition to the solubility of ZnO forming zinc ions in the paint medium, it imparts fungistatic properties to both the oil and latex based paints. Formation of zinc soaps by reaction of ZnO with acidic components of paint films has also been shown to improve the flexibility and hardness of the paint film. ZnO has further been shown to render clean, films as compared to those obtained from the low-chalking TiO_2 pigments 12].

In these situations the photoactive nature of zinc oxide is worthy of consideration and a knowledge of the antibacterial and antifungal properties of zinc oxide in the presence and absence of light is essential in order to optimize the zinc oxide content of the formulations particularly in the sun screens, hair preparations and other cosmetics. In the present study zinc oxide films are tested for antibacterial and antifungal efficacy both in presence and absence of light and the results are discussed.

EXPERIMENTAL

Preparation of anodized specimens

Zinc specimens were cut from a zinc plate (99.9%) of 0.002 m thickness. The specimens were anodized potentiostatically in a 0.1 *M* borax solution (*p*H 9.2) with a lead electrode as cathode, at room temperature. The applied oxidation potential on the electrode was 1.4 V versus the lead cathode. By controlling the time of anodizing an oxide thickness of 20 μm was obtained [13].

Preparation of electroplated specimens

A mild steel mesh prior nickel plated was taken as a cathode in a non-cyanide zincate bath and zinc plating was done using a zinc anode (99.9%) at a current density of 40 $mA.cm^{-2}$. The zincate plating bath contained 12.6 $g.l^{-1}$ zinc oxide in 120 $g.l^{-1}$ sodium hydroxide. The plated mesh was thoroughly washed with distilled water and dried well using a hair drier. The electroplated specimens were left as such for a few hours when the zinc coating turned white owing to the formation of zinc oxide.

Antibacterial and antifungal tests

The bacterial culture chosen for the laboratory evaluation was based on the nature of micro-organisms responsible for general infections viz., Streptococcus aureus, Escherichia coli, Bacillus subtilis, Pseudomonas aeroginosa and Saccharomyces cerevisiae. The fungal culture chosen was based on the nature of organisms generally responsible for food and leather spoilage. They were Aspergillus flavus, Aspergillus niger, Aspergillus nidulans, Aspergillus terreus, Penicillium frequentans, Penicillium rubrum, Penicillium perpurogenum, Paecilomyces varioty. We also include the human fungal pathogen, Candida albicans in this test.

A culture of these organisms were being preserved in the laboratory and a mixed culture each of bacteria and yeast/fungi were prepared as and when required. In the laboratory evaluation of the antifungal potential, an inoculum containing Czapeck Dox's medium of composition ($g.l^{-1}$) of water; sucrose 30; $NaNO_3$ 20; K_2HPO_4 1.0; $MgSO_4$ 0.5; KCl 0.5; $FeSO_4$ 0.01; agar 15 was used; the pH of the medium was 7.2. For the antimicrobial tests, a nutrient agar medium of composition ($g.l^{-1}$),peptic digest of animal tissue: 5.0, sodium chloride: 5.0; beef extract: 1.5; yeast extract: 1.5; agar: 15; the pH of the medium was 7.4. The bacterial and fungal density was 10^2 cells/ml. The zinc oxide specimens were autoclaved and placed in the two developed agar plates one for the bacteria and the other for the fungi. The specimens were examined for the bacterial and fungal growth at periodic time intervals through microscopic examination and the diameter of the inhibition zone developed around the strip was measured.

The experimental set up for the investigation of effect of light on the antibacterial and antifungal efficacy [14] is shown in Fig. 1. A fluorescent tube lamp was used as the light source. A Carl zeiss Axio lab binocular microscope fitted with an occular microscope was used for the examination of the developed plates.

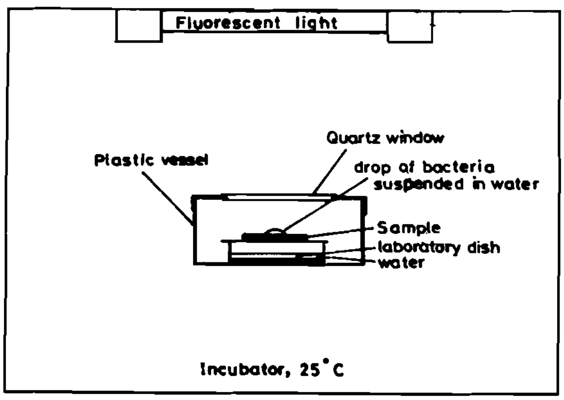

Fig. 1: Experimental setup for studying the effect of light on antibacterial and antifungal efficacy of ZnO films

RESULTS AND DISCUSSION

The results of the antifungal and antibacterial efficacy tests made on agar plate are presented in Tables I and II respectively.

There is some difference between the biocidal potency of zinc oxide films prepared by anodizing and that of the films prepared by oxidation of zinc electroplated coatings. The latter type shows a better biocidal potency than the former. This is probably due to the more porous nature of the zinc oxide coating in the latter type.

TABLE I: Antifungal properties of 20 μm thickness zinc oxide films

Fungus	inhibition zone, m	
	anodized zinc specimen	oxidized zinc plated specimen
Aspergillus flavus	0.0020	0.0050
Aspergillus niger	0.0015	0.0050
Aspergillus terreus	0.0020	0.0040
Aspergillus nidulans	0.0008	0.0015
Penicillium frequentans	0.0020	0.0040
Penicillium rubrum	0.0015	0.0050
Penicillium perpurogenum	0.0020	0.0050
Paecilomyces varioti	0.0008	0.0015
Candida albicans	0.0009	0.0020

TABLE II: Antibacterial properties of 20 μm thickness zinc oxide films

Bacteria/yeast	inhibition zone, m	
	anodized zinc specimen	oxidized zinc plated specimen
Staphylococcus aureus	0.0009	0.003
Escherichia coli	0.0008	0.002
Bacillus subtilis	0.0008	0.003
Pseudomonas aeroginosa	0.0008	0.004
Saccharomyces cerevisiae	0.0008	0.004

The effect of light on the antibacterial and antifungal properties of zinc oxide films is shown in Figs. 2 and 3 respectively. The duration of contact time is seen to be very important in the photoeffect on biocidal potency. The

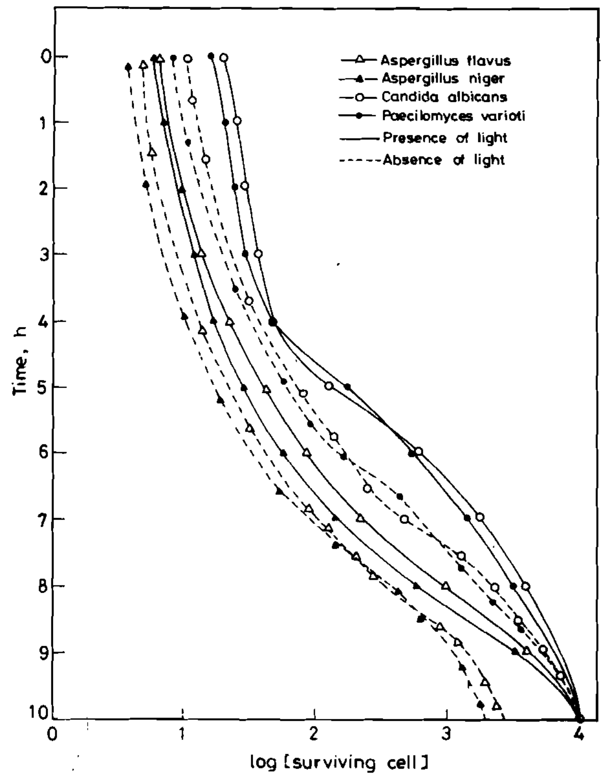

Fig. 2: Effect of light (100 lux) on the antifungal efficacy of ZnO (20 μm thickness)

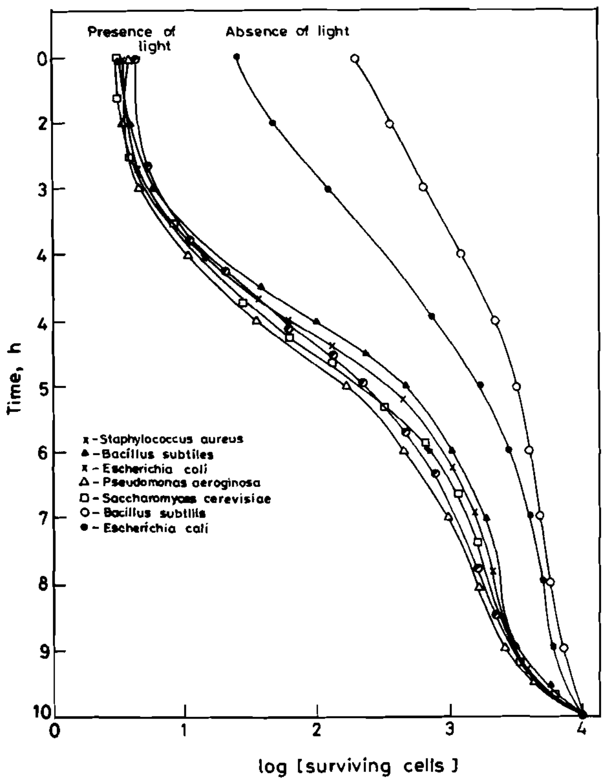

Fig. 3: Effect of light (100 lux) on the antibacterial efficacy of ZnO (20 μm thickness)

enhanced corrosion of zinc oxide in presence of light [13] may be responsible for the enhancement in the biocidal efficacy. The insight one gets here is that the antibacterial or the antifungal features associated with zinc oxide are not diminished in presence of light. In other words an adverse effect of light on zinc oxide biocidal potential has not been indicated.

CONCLUSION

The effect of light on the antibacterial and antifungal efficacy of zinc oxide films is remarkable in that the efficacy is enhanced in presence of light. This observation justifies the inclusion of zinc oxide in sun screen and suntans as light does not bring about any adverse effects on the biocidal potential of zinc oxide.

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