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RESEARCH ARTICLE

Antibacterial Activity of Titanium dioxide Nanoparticles Infused in Ceramic Tiles

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ABSTRACT

In damp environments, indoor building materials are among the main proliferation substrates for microorganisms. Photocatalytic coatings, including nanoparticles of titanium dioxide (TiO_2), could be a way to prevent microbial proliferation that grow on indoor building materials as titanium dioxide under ultraviolet light produces a strong oxidative effect and may therefore be used as a photocatalytic disinfectant.

This paper studies the inactivation of *Escherichia coli* and *Staphylococcus aureus* bacteria by photocatalysis involving titanium dioxide nanoparticles infused in ceramic coatings and investigates different parameters that significantly influence the antibacterial activity. The antibacterial activity of titanium dioxide was evaluated through by using different concentration of titanium dioxide treated with ceramic plates. The results confirmed the major effect of the photocatalytic disinfection ability as the bacterial titers were dramatically reduced by the photocatalytic reaction. Even with a low intensity of UV-A (0.01 mW cm−2), a bacterial reduction was observed within a short irradiation time. These results show that titanium dioxide photocatalysis could be used to inactivate microorganisms

Keywords- Titanium dioxide, Antimicrobial activity, Ceramic Coatings, Photocatalysis.

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INTRODUCTION

Microorganisms are present everywhere in our environment in air, water, on surfaces, and on individuals of all kinds. Microorganisms are very numerous: 1 gram of earth may contain up to twenty-five billion microorganisms which is equivalent to four times the population of our planet. Conditions for the development of microorganisms in ceramics products are related to the presence of nutritive elements under the influence of temperature, moisture, and pH of the medium. Under favourable conditions, putting together these various factors, one estimates that the populations of microorganisms can double every twenty minutes. With the rapid development of global industry, steadily worsening environmental pollution and energy shortages have raised awareness of a potential global crisis. So, it is urgent to develop a simple and effective method to address these current issues.[2]

Photocatalysis is an emerging technology that has a wide range of applications as degradation of organics and dyes, antibacterial action, and fuel generation through water splitting and carbon dioxide reduction. [3]

Since the discovery and development of Photocatalytic properties in the 1970s, titanium dioxide has been well researched leading to a better understanding of photocatalytic reactions. Titanium oxide has been widely investigated for photocatalysis in removal of environmental pollutants, H_2 evolution and CO_2 reduction since 1972. It is generally accepted that the photocatalytic activity is affected by the light absorption, charge creation/recombination rate and surface reactivity.[10]

Photo-catalytically reactive titanium dioxide is widely used as a self-cleaning and self-disinfecting material in many applications to keep environments biologically clean[5],[10]

Irradiation with ultraviolet light generates reactive oxygen species on the surface of the titanium dioxide, including hydroxyl and superoxide radicals which have strong oxidative activity and destroy organic compounds. This photocatalytic oxidizing power has been applied for the removal of several toxic substances from the water and air.[8],[9]

In this study, antibacterial activity of titanium dioxide infused with ceramic tiles against *Escherichia coli* and *Staphylococcus aureus* was studied by a test study based on ISO 27447 and JIS R 1702.

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EXPERIMENTAL METHODS

2.1. Selection of sample:

The ceramic tile was cut to a dimension of 50±2 mm x 50±2 mm; with a thickness of 10 mm. Six samples were used named as Sample 1, 2, 3, 4, 5 and 6, with different concentration of titanium dioxide treatment.

The concentration of different samples is given in Table-1.

Table 1-Concentration of titanium dioxide (TiO_2)

Sample Number	Concentration of TiO_2
01	Standard Control
02	0.5g/l
03	1g/l
04	1.5g/l
05	2g/l
06	3g/l

Size of the Glass Pane (Non- Treated Specimen)- The glass pane used as a non-treated Specimen was cut to a dimension of 50±2 mm x 50±2 mm; with a thickness of 10mm.

2.2 Bacterial cultures

Pure strains of the bacterial cultures were sub-cultured in the Nutrient Broth. The cell cultures were incubated for 24 hours prior to use. The cultures used in the experiment were *Staphylococcus aureus* ATCC 6538, and *Escherichia coli* ATCC 10536.

2.3 Film adhesion method

Placing a sterilized moisture control filter paper at the bottom of a sterilized Petri dish adequate quantity of sterilized distilled water was added. Intercalate a glass tube or glass rod to avoid contact between the test piece and the paper filter. The test piece was placed on it with the indoor light-active photocatalyst treated surface up.

150µl of test bacterial suspension was collected with a sterilized pipette and dripped onto each test piece. A film on top of the dripped suspension was placed and the whole film surface was spread. A moisture conservation glass was placed on the top of Petri dish. The petri dishes containing the specimens with bacterial suspension were exposed to ultraviolet light with the intensity of 0.01 mW/cm^3 for eight hours. After the exposure period 10 ml of soybean casein lecithin polysorbate 80 was added to the stomacher bag and mixed well. This washout solution was used to perform the measurement of number of viable cells.

Furthermore, three non-treated and three treated specimens with bacterial suspensions were kept in a dark place for eight hours.

2.4 Recovery of bacteria and calculation of photocatalyst antibacterial activity value with UV irradiation(ΔR).

1 ml of the above solution was used to measure the recovery of the bacteria by performing a pour plate technique using sterile nutrient agar. The plates after performing pour plate technique were incubated for 48 hours at 37°C.

The photocatalyst antibacterial activity value(ΔR) with UV irradiation was calculated using the following formula –

$\Delta R = \log [(B_L/ C_L] - [\log (B_D/ A) - \log (C_D/ A)] = \log [B_L/ C_L] - \log [(B_D/ C_D];$

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where-A is the average number of viable bacteria of non-treated specimen, just after inoculation.

B_L is the average number of viable bacteria of non-treated specimen after UV irradiation of intensity L.

C_L is the average of viable bacteria of photo catalytic treated specimens, after irradiation of Intensity L.

ΔR is the photocatalyst antibacterial activity value with UV irradiation.

B_D is the average number of viable bacteria of non-treated specimens, after being kept in dark place.

C_D is the average number of viable bacteria of photocatalytic treated specimens, after being kept in a dark place.

RESULTS

3.1 Results for selected bacterial cultures

A 24-hour old sub-cultured strain of *Staphylococcus aureus* ATCC 6538, and *Escherichia coli* ATCC 10536 were used.

The cell concentration of the bacteria's (observed in Table 2) was determined before using for the experiment.

Table 2-Concentration of bacterial cultures

Name of the bacteria	CFU/ml
Escherichia coli	5.8 X 10^8
Staphylococcus aureus	5.4 X 10^8

3.2 Photocatalyst antibacterial activity value with UV irradiation

The photocatalyst antibacterial activity value with UV irradiation was calculated and the results are shown as per Table-3.

Table 3-Result for the photocatalyst activity for *Staphylococcus aureus* and *Escherichia coli*

Sample Number	*Staphylococcus aureus*	*Escherichia coli*
01	3.6	3.6
02	3.1	3.3
03	2.0	2.4
04	1.6	1.5
05	0.8	0.7
06	0	0

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DISCUSSION

In the present study, 5 ceramic tiles were treated with titanium dioxide nanoparticles ranging from a concentration of 0.5g/l to 3g/l. In this study a reduction in growth of *Staphylococcus aureus* and *Escherichia coli* was observed with the increase in the concentration of titanium dioxide (as observed in Table 2).

Also in this study, it was observed there was no recovery of the test bacteria's when treated against the titanium dioxide concentration of 3g/l, indicating that the concentration level of titanium dioxide between 2.1g/l to 3g/l is optimum for inhibiting the growth of the test bacteria.

Further studies will be conducted to identify a specific range for the concentration of titanium dioxide nanoparticles to be infused in the ceramic tiles to inhibit the growth of the different species of bacteria and fungi.

In addition, the material tested showed significant antibacterial activities under low UV irradiation.

CONCLUSION

This paper has examined the effect of titanium dioxide photocatalyst on *Staphylococcus aureus* and *Escherichia coli* in terms of antibacterial activity by calculating the photocatalyst antibacterial activity value with UV irradiation by film adhesion method.

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