ORIGINAL RESEARCH PAPER

Volume-9 | Issue-5 | May-2020 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

EFFICACY OF ENVIRONMENTALLY BENIGN AND DURABLE TIO2 NANOCOMPOSITE AS ANTIMICROBIAL COATING SOLUTION

Microbiology

Krunal Dholiya*

Assistant Professor, Smt GN Pandya Commerce & Science College, Surat, India. *Corresponding Author

ABSTRACT

Since last many years, we are trying to improve our hygiene solutions using various traditional antimicrobial chemicals to make our environment clean but artificial, which created huge problems like damaging the ecosystem, generating antimicrobial resistant species etc. TiO2 is a well-known inhibitory for its bactericidal effect. TiO2 based nanocomposites subjected to light excitation are remarkably effective in eliciting microbial death. Antimicrobial efficacy of the nano TiO2 is expected due to the photocatalytic action which is improved by modifying nano-environment. The TiO2 nanocomposite coating has been applied on the glass plate. The antimicrobial action of the coating was investigated qualitatively and quantitatively against various unicellular life form. Good inhibition was observed with a nanocomposite coating on the quartz plate. The quantitative examination was estimated by survival ratio using CFU on nutrient-rich media. TiO2 nanocomposite is working as a catalyst, not utilized during its action, which means it will provide durable protection. From this study, TiO2 nanocomposite can be a better option over traditional solutions.

KEYWORDS

Photocatalytic, Nanotechnology, hygiene, Ecobactix®, TiO2

INTRODUCTION

One of the major issues around cleaning or hygiene solution is microbes can be absorbed into the pores of porous or semi-porous solid surfaces, enables a significant hazardous pathway for humans (1). This issue of contamination by certain microorganisms in healthcare area may create a deadly condition, i.e. HAIs (Hospital Acquired Infection) (2). It has been estimated and predicted HAIs accounts 7-10% (3).

Generally, it is controlled by using chemical-based compounds which is effective but has many problems too (4). They are not long term in protection that is leaving a new room for new development.

TiO_2 nano particle was tested and reported with excellent antimicrobial activity in the efficient removal of such absorbed microbes (5, 6, 7). TiO_2 nano particle may not show a considerable antimicrobial activity in the form of metal oxide and metal salt alone, because they tended aggregation (8). The silver nano particle has excellent antimicrobial property. Silver nano particles are not a stable and quick release of ions may shorten its effectiveness (9). However, the stability and slow release of metal ions from nano particle are effective properties that can be tuned by appropriate synthesis. For this reason, new methods core-shell have been suggested (10).

One of the most important factors in antimicrobial activity is light for TiO_2 nano particle. TiO_2 nano particle becomes activated against pathogenic bacteria when exposed to ultraviolet (UV) light, photo catalytic action (11). For silver nano particle, various factors effects on the level of antimicrobial action. Silver shows antimicrobial action through oligodynamic action.

TiO_2 has been widely applied as a coating because of its high photo activity, non-toxicity and strong self-cleaning properties, but there are two main problems, activation only under UV light and recombination of generated electron-hole pair (11,12). To solve this problem, we have changed its nano-environment and resulted in nano composite is studied for its antimicrobial action.

EXPERIMENTAL

Materials

Quartz slide for TiO_2 coatings was purchased from Borosil®, India. Ecobactix® (Product of Framtix Holding AB, Sweden), nano-modified TiO_2 nano-coating, as used as TiO_2@Ag coating. Antimicrobial studies were performed using a bacterial strain Escherichia coli and Staphylococcus aureus fungal strain Candida albicans.

Antimicrobial experiments were performed using the Millipore MilliQ system. All microbiology media component was bought from Himedia, Mumbai.

Preparation of coating

Quartz slide was sonicated and cleaned with ethanol to remove all kind of dirt particles. Once the slide is dried, Ecobactix® was spread using high-pressure low volume sprayer, allowed it to dry at room temperature. Once the slide is dried, kept it for incubation for 48 hours.

Evaluation of the antimicrobial activity of coatings:

The antibacterial properties of coatings were determined using the Japanese Industrial Standard JIS Z 2801:2000 (13). E. coli was inoculated on Luria–Bertani (LB) broth and incubated at 37◦C on a rotary shaker. E. coli suspension including 1 × 105 Colony Forming Units (CFU per ml) in phosphate buffer saline was prepared for antibacterial tests. The diluted E. coli inoculum was applied to the coated slide and un coated quartz slide were analyzed as control samples. After the application of the bacterial suspension on the slide, each coating was covered with an aseptic quartz cover slip and incubated in the moist chamber at 37◦C for 4 h. Next, the E. coli suspensions were washed and serial dilutions were prepared in the phosphate buffer saline. Diluted bacterial suspensions were spread on LB agar and incubated at 37◦C for 24 h. Tests were performed under three different conditions, under UV light, under visible light and dark condition. The antibacterial potential of tested plates was calculated as a ratio of growth inhibition against control samples. All samples were tested in triplicate and individually analyzed.

In vitro Recontamination study

Similar step as per the evaluation of antimicrobial activity, the bacterial suspension has grown on LB broth and fungal culture on Sabroad Dextrose (SD) broth. Next, slides are treated with bacterial and fungal suspension frequently as mentioned in the table. It is done in a controlled environment and on repeated based (14). Details are shown in table 1.

RESULTS

The antimicrobial activity

The antibacterial potential (ABP) of the coated surface was calculated as a percentage of growth inhibition against control samples. The ABP is the number of live E. coli cells (CFU) on Coated surface to the uncoated sample under the same condition. From the observation of three sets, the number of viable bacteria decreased at least three-fold after the 4-hour UV exposure. Remarkably, 2 log AMA (antimicrobial action) was also achieved under visible light exposure. Interestingly, the nanocomposite coatings also had 1 log AMA even in the dark. Detailed results are shown in figure 1.

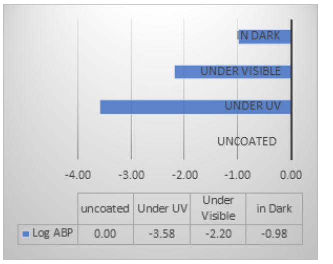

Figure 1: Antimicrobial action under various condition, semi-logarithmic plot: condition against the log of antibacterial potential ratio.

PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

Recontamination study

This study was done under visible light. The effective reduction was observed which was showing the same result again, two-fold reduction. Detailed result is mentioned in table 1.

Table – 1 Revived Cfu/ml In Recontamination Study Initial Concentration Was 0.5 X 10^6 Cfu

Microbes	CFU mL-1 survived after 4 hours of visible light					
	Day 0	Day 2	Day 7	Day 14	Day 30	Day 50
E. coli	250 ± 52	278 ± 72	150 ± 84	300 ± 29	210 ± 56	378 ± 20
S. aureus	438 ± 80	340 ± 102	286 ± 56	440 ± 54	300 ± 86	356 ± 115
C. albican	110 ± 32	130 ± 19	80 ± 34	200 ± 31	98 ± 30	116 ± 20

DISCUSSION

Above result shows, EcobactiX® TiO_2 coatings for antimicrobial touch surfaces applications works excellent even under visible light activation and on recontamination. TiO_2 activates under UV light and generate electron and hole pair. This excitation radiation can be red-shifted by changing nano environment i.e doping (15, 16), composite with another particle (17), core-shell (18) etc. Ecobactix® has already changed the nano environment for optimum action. From chart 1, under visible light is reducing the growth of bacteria. Though it is red shifted still it is showing maximum reduction under UV light that maybe the action of UV light. Result of dark condition, because of the action of oligodynamic action. Photocatalytic action works only under light condition. This proves coating works well in the light as well as in dark condition.

From recontamination study, it is also clear that time is not affecting the action of the coating as it working as a catalytical action which kills bacteria (19). Catalyst doesn't take part in the reaction, so they will not be utilized during the reaction (20). The surface will remain active all the time for the long term until it is covered or removed.

It is not utilized so it is being reused again and again. And being active all the time on the surface, making live protecting surface. Continuously reducing microbes from the applied surface through a combination of photocatalytic and oligodynamic effects. These effects have multiple modes of action which reduce the chance of generating mutants (21). So, it will reduce loads of other antimicrobials on the coated surface and help in creating a sustainable environment too.

CONCLUSION

Modified nano-environment of TiO_2 makes Ecobactix® a good antimicrobial coat. It has a good action in light and dark condition. As it is working on catalytic action, the coating will not be utilized during the reaction. So, it will give long-term protection.

The differences in the level of S. aureus growth inhibition in all experiments for each sample were negligible, which indicates their great antibacterial stability and durability.

REFERENCES

1. Or, D., Smets, B. F., Wraith, J. M., Dechesne, A., & Friedman, S. P. (2007). Physical constraints affecting bacterial habitats and activity in unsaturated porous media–a review. Advances in Water Resources, 30(6-7), 1505-1527.
2. Adebayo, O., Labiran, A., & Imarhiagbe, L. (2015). Standard Precautions in clinical practices: A review. Int. J. Health Sci. Res, 5, 521-528.
3. Chinn, R. Y., & Sehulster, L. (2003). Guidelines for environmental infection control in health-care facilities; recommendations of CDC and Healthcare Infection Control Practices Advisory Committee (HICPAC).
4. Wang, D. Y., Van Der Mei, H. C., Ren, Y., Busscher, H. J., & Shi, L. (2019). Lipid-Based Antimicrobial Delivery-Systems for the Treatment of Bacterial Infections. Frontiers in Chemistry, 7.
5. Fu, G., Vary, P. S., & Lin, C. T. (2005). Anatase TiO2 nanocomposites for antimicrobial coatings. The journal of physical chemistry B, 109(18), 8889-8898.
6. Chung, C. J., Lin, H. I., Tsou, H. K., Shi, Z. Y., & He, J. L. (2008). An antimicrobial TiO2 coating for reducing hospital-acquired infection. Journal of Biomedical Materials Research Part B: Applied Biomaterials: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials, 85(1), 220-224.
7. Bodaghi, H., Mostofi, Y., Oromiehie, A., Zamani, Z., Ghanbarzadeh, B., Costa, C., ... & Del Nobile, M. A. (2013). Evaluation of the photocatalytic antimicrobial effects of a TiO2 nanocomposite food packaging film by in vitro and in vivo tests. LWT-Food Science and Technology, 50(2), 702-706.
8. Yu, B., Leung, K. M., Guo, Q., Lau, W. M., & Yang, J. (2011). Synthesis of Ag–TiO2 composite nano thin film for antimicrobial application. Nanotechnology, 22(11), 115603.
9. Nobile, M. D., Cannarsi, M., Altieri, C., Sinigaglia, M., Favia, P., Iacoviello, G., & D'agostino, R. (2004). Effect of Ag-containing nano-composite active packaging system on survival of Alicyclobacillus acidoterrestris. Journal of Food Science, 69(8), E379-E383.
10. Lin, Y., Qiqiang, W., Xiaoming, Z., Zhouping, W., Wenshui, X., & Yuming, D. (2011). Synthesis of Ag/TiO 2 core/shell nanoparticles with antibacterial properties. Bulletin of the Korean Chemical Society, 32(8), 2607-2610.
11. Fujishima, A., Rao, T. N., & Tryk, D. A. (2000). Titanium dioxide photocatalysis. Journal of photochemistry and photobiology C: Photochemistry reviews, 1(1), 1-21.
12. Schneider, J., Matsuoka, M., Takeuchi, M., Zhang, J., Horiuchi, Y., Anpo, M., & Bahnemann, D. W. (2014). Understanding TiO2 photocatalysis: mechanisms and materials. Chemical reviews, 114(19), 9919-9986.
13. Mungkalasiri, J., Bedel, L., Emieux, F., Vettese-Di Cara, A., Freney, J., Maury, F., & Renaud, F. N. (2014). Antibacterial properties of TiO2–Cu composite thin films grown by a one step DLICVD process. Surface and Coatings Technology, 242, 187-194.
14. Dholiya, K. Microbiology of library books: evaluation and effective protection. International Journal of Research and Analytical Reviews, 6 (2), 88-91.
15. Moma, J., & Baloyi, J. (2018). Modified Titanium Dioxide for Photocatalytic Applications. In Photocatalysts-Applications and Attributes. IntechOpen.
16. In, S., Orlov, A., Berg, R., Garcia, F., Pedrosa-Jimenez, S., Tikhov, M. S., ... & Lambert, R. M. (2007). Effective visible light-activated B-doped and B, N-codoped TiO2 photocatalysts. Journal of the American Chemical Society, 129(45), 13790-13791.
17. Kochuveedu, S. T., Kim, D. P., & Kim, D. H. (2012). Surface-plasmon-induced visible light photocatalytic activity of TiO2 nanospheres decorated by Au nanoparticles with controlled configuration. The Journal of Physical Chemistry C, 116(3), 2500-2506.
18. Hu, H., Lin, Y., & Hu, Y. H. (2020). Core-shell structured TiO2 as highly efficient visible light photocatalyst for dye degradation. Catalysis Today, 341, 90-95.
19. Nakata, K., & Fujishima, A. (2012). TiO2 photocatalysis: Design and applications. Journal of photochemistry and photobiology C: Photochemistry Reviews, 13(3), 169-189.
20. Fu, G., Vary, P. S., & Lin, C. T. (2005). Anatase TiO2 nanocomposites for antimicrobial coatings. The journal of physical chemistry B, 109(18), 8889-8898.
21. Guo, C., Wang, K., Hou, S., Wan, L., Lv, J., Zhang, Y., ... & Xu, J. (2017). H2O2 and/or TiO2 photocatalysis under UV irradiation for the removal of antibiotic resistant bacteria and their antibiotic resistance genes. Journal of hazardous materials, 323, 710-718.