Scientific Research Publishing

Green and Sustainable Chemistry, 2018, 8, 32-38
http://www.scirp.org/journal/gsc
ISSN Online: 2160-696X
ISSN Print: 2160-6951

Evaluation of the Antimicrobial Efficacy of Titanium Dioxide Nanoparticles on the Surfaces of Public Toilets

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How to cite this paper: Ahmed, O.B. (2018) Evaluation of the Antimicrobial Efficacy of Titanium Dioxide Nanoparticles on the Surfaces of Public Toilets. *Green and Sustainable Chemistry*, **8**, 32-38.
https://doi.org/10.4236/gsc.2018.81003

Received: December 17, 2017
Accepted: January 31, 2018
Published: February 2, 2018

Abstract

The infection control in surfaces of public toilets environment is a matter of great concern and a major challenge, especially during mass gatherings. The present study aimed to evaluate the antimicrobial efficacy of titanium dioxide nanoparticles coating on environmental surfaces of public toilets during Hajj time. A pilot study has been designed to evaluate the antimicrobial efficacy of titanium dioxide nanoparticles on the surfaces of public toilets. The results showed a significant reduction in colony-count of the test samples. Maximum average reduction count of test microbes of the seats and walls reached (99.7%) while that of the doors reached (99.1%) which was statistically significant (P value = 0.001). It was concluded that there was a marked effect of a mixed TiO2 coating on reducing the microbial count at the surfaces of public toilets environments. Further research on efficacy against specific organisms, intestinal parasites, fungi, viruses and bacteriophage is recommended.

Keywords

Titanium Dioxide, Public Toilets, Colony Count, Nanoparticles

1. Introduction

Public bathrooms have the most amounts of hidden germs even cleaned because this space is shared with a whole lot of people who may have infectious diseases [1]. Health experts point out that even clean-looking, bathrooms are dangerous if not being well disinfected. In the best conditions, they may produce bacteria that become a source for many infections [1] [2]. So that the infection control in surfaces of public toilets environment is a matter of great concern and a major challenge, especially in crowded area because such environments can be potential sources for other epidemic diseases. During Hajj, more than 2.5 million people from different parts of the world were gathered in Makkah. The toilets should be adequate in number, conveniently located, well provided, safe, easily accessible, free of infections. Routine cleaning and manual disinfection in the public toilets are often insufficient. Because many chemicals are of limited use and do not meet all the required criteria. Many types of disinfectants products are available but with moderate or even insufficient antimicrobial action [3] [4]. The introduction of optimal cleansing products and processes is critical to control and prevent infections [5]. Further efforts are required to improve the traditional methods in decontamination of toilet surfaces. New methodologies and techniques are needed with "permanent" antimicrobial effect without risk of generating micro-organisms resistance [6] [7]. Titanium dioxide (TiO_2) is non-toxic, available, cost effective, chemically stable and with favorable properties [8]. It is a semiconductor and has been proved to be an excellent photocatalyst degrading organic pollutants and effective antibiotic against bacteria, fungi, viruses, and bacteriophage [9]. Once subjected to light, the negative electrons and oxygen atom will combine into O^{2-}; the positive holes and water will generate hydroxyl radicals (OH^-) [10]. Both of O^{2-} and OH^- molecules are reactive, so they will combine with any organic material around the surface of the photocatalyst and turn into carbon dioxide and water. The consequence of this reaction is the decomposition of organic matters, removal of odor, killing of microorganisms [8] [10]. There are no studies to date, to the author knowledge, which evaluate the efficacy of TiO_2 in the public toilet environment. So the aim of the present pilot study was to evaluate the antimicrobial efficacy of titanium dioxide nanoparticles coating on environmental surfaces on selected public toilets.

2. Materials and Methods

A pilot study has been designed to evaluate the microbial count of surfaces in toilets after coating with titanium dioxide. The microbiological survey was conducted in four public toilets (two tests and two controls) in Makkah during Hajj time. Three surfaces (seats, walls, and doors) within each toilet were selected for sampling. All surfaces were assayed once time daily. The Four toilets were thoroughly cleaned using a detergent solution and left to dry. Cultures were taken before and after coating from marked sites per toilet (seats, walls, and doors). The sampling area was delineated with a sterile stainless steel template which exposed a surface area of 50 cm^2 [11]. All surfaces were swabbed using plain cotton swabs and inoculated into vials containing 1 mL of sterile water. After sampling, the swabs were labeled and transported to the Microbiology Laboratory at environment and health research department, Umm Alqura University, 15 to 45 min of sampling and stored at 4˚C until testing. All samples were analyzed within 1 h of arrival at the laboratory. Each vail (1 ml) was plated on aerobic count Petrifilm plates (3 M Microbiology), and plates were incubated at 32˚C for 48 h. Upon the completion of incubation, plates were counted on a standard colony counter. The two test toilets then were coated using a high-pressure spraying system. First, a primer was sprayed on all surfaces and left to dry, then the mixed TiO_2 coating, containing silver supported zeolite, peroxotitanic acid and water (Miracle Titanium MVX, Maeda Kougyou, Kitakyushu, Japan), was applied on exactly the same surfaces as the primer. After at least 2 h of drying, the toilets could be used by people. Cultures were taken again after one day and then every 2 days in the first week, afterwards cultures were collected weekly for two months.

3. Statistical Analysis

Statistics were performed using SPSS 22 for windows to perform independent t-tests analyses to identify significant differences between controls and tests. ANOVA test analysis was performed to identify significant bacterial reduction between doors, walls and seats after TiO_2 coating.

4. Results

After the application of TiO_2, the results showed a significant dropping in log cfus/50 cm^2 of the test samples while the controls have almost remained high or without changes (**Figures 1-3**) which was statistically significant (p value = 0.00). Maximum average reduction count of the seats and walls reached (99.7%) while that of the doors reached (99.1%) with significant P value (0.001) as showed in **Table 1**.

5. Discussion

The present pilot study evaluated effects of a TiO_2 coating on surface contamination of selected public toilets surfaces (walls, doors and seats). The results showed that the level of the bacterial count of the pre-coating swabs taken from all surfaces (tests and controls) was close and very high. That is not surprising

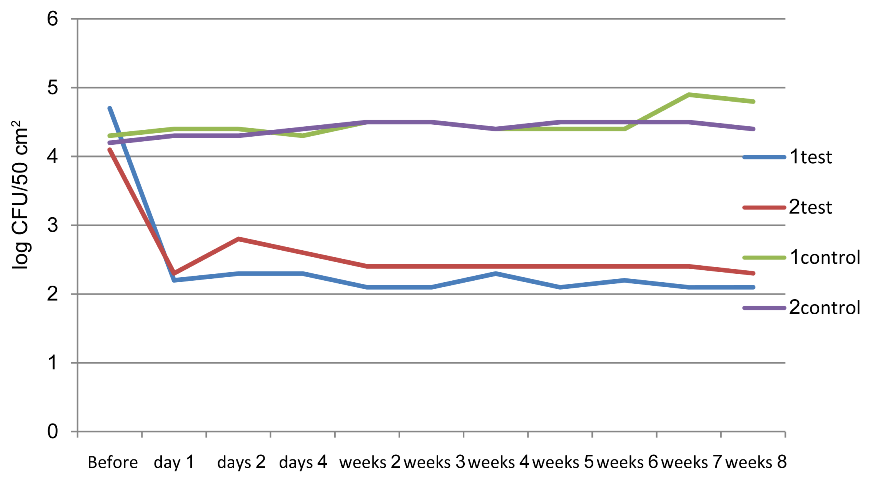

Figure 1. Reduction in Bacterial count of the walls surfaces after coating with TiO_2.

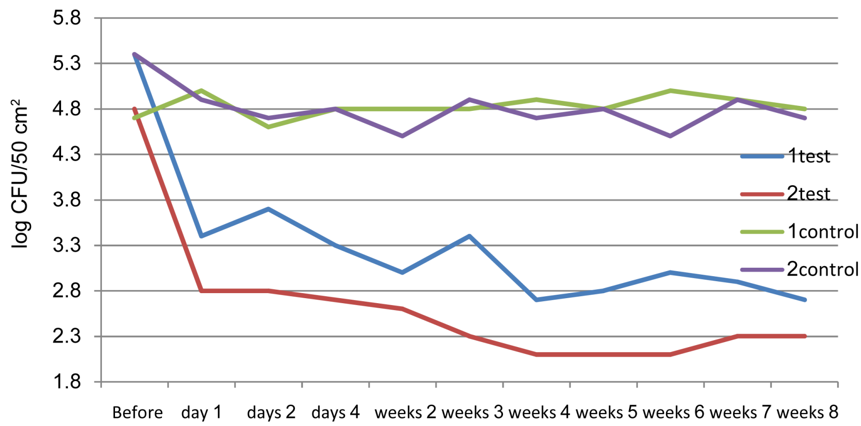

Figure 2. Reduction in Bacterial count of the seats surfaces after coating with TiO_2.

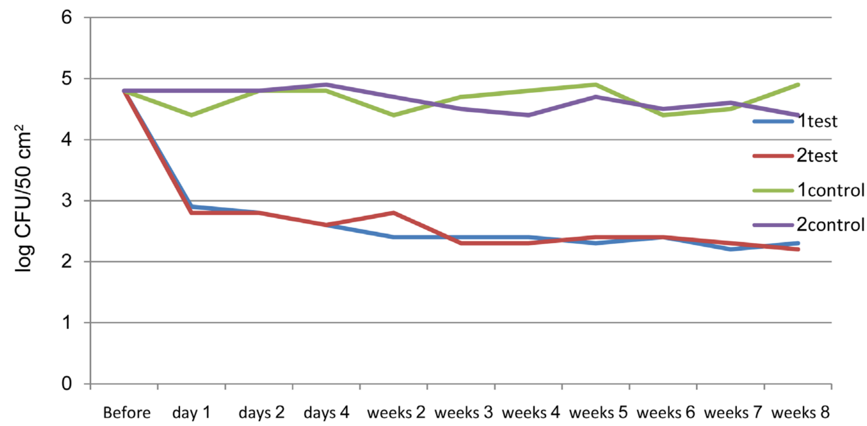

Figure 3. Reduction in Bacterial count of the doors surfaces after coating with TiO_2.

Table 1. The average reduction of bacterial count in different surfaces after coating with TiO_2.

Intervals	Reduction (%)		
	Doors	walls	seats
After one day	99.0	99.0	98.9
After 2 days	97.3	98.5	99.0
After 4 days	98.2	99.2	99.4
After 2 weeks	98.9	99.5	99.3
After 3 weeks	98.9	99.3	99.6
After 4 weeks	98.8	99.8	99.6
After 5 weeks	98.9	99.8	99.6
After 6 weeks	98.8	99.7	99.6
After 7 weeks	98.9	99.7	99.7
After 8 weeks	99.1	99.7	99.7

because bathrooms and toilets contain large numbers of intestinal pathogens in addition to the bacteria that can be shed from the skin, saliva, mucous and nasal secretions [12] [13]. Both detergent- and disinfectant-based cleaning can help to control these pathogens but traditional cleaning methods are notoriously inefficient for decontamination, and new approaches have been proposed, such as self-sanitizing surfaces [7] [14] [15].

Creating "self-disinfecting surfaces" means to coat them with UV-activated TiO_2, which undergoes photocatalytic reactions and oxidizes volatile organic compounds and the microorganisms in the surfaces of public toilets.

After the application of TiO_2, the results of the present study showed a significant reduction in colony-count as compared to the cultures collected before the application of TiO_2 (**Figures 1-3**) while the controls have almost remained high or no changes with significant difference (p value = 0.00). Maximum average reduction count of test microbes of the seats and walls reached (99.7%) while that of the doors reached (99.1%) (**Table 1**) which was statistically significant (P value = 0.001). Although the bacterial count has been increased during the study period due to the excessive usage of the toilets during the study period, the average level of bacteria never returned to those observed before treatment (**Figures 1-3**). No previous studies about creating "self-disinfecting surfaces" in the toilets surfaces but the application has been done in hospital environments in ICU surfaces [16] [17] with marked variations in results. Tamimi *et al.* [16], and Sujata and Jack [18], concluded that the use of TiO_2 for environmental sanitation is effective and could reduce the risk of pathogenic microorganisms and the product was found to have persisted over 15 weeks in reducing the total number of bacteria on surfaces. For instance, Kim *et al.* [19], demonstrated that TiO_2 in combination with UV showed a significant decrease in bacterial count after short time. Kühn *et al.* [20], showed that the bacterial count reduced by approximately 6 logs after treatment with photo catalytic titanium dioxide. Chuaybamroong *et al.* [21] concluded that A 60% - 100% microbe reduction can be achieved to provide better indoor air quality for hospitals, offices, and domestic applications. However, all these studies showed increased efficacy of TiO_2 as an antimicrobial agent in the presence of UV or light. In contrast, de Jong *et al.* [17] and Leng *et al.* [22] reported that a TiO_2 did not influence the microbial colonization of surfaces in an ICU and on the positive culture results. These variations in the results may be due to many factors that influence the efficacy of TiO_2 photocatalysis such as air humidity, UV light intensity and wavelength, thickness of the coating, target organism, initial concentration and composition of the coated surface. The present study was limited by missing some specific information on the characterization of the product. In conclusion, the mixed TiO_2 coating showed good effect of on reducing the microbial count of surfaces in public toilets environments. Further research on efficacy against specific organisms, intestinal parasites, fungi, viruses and bacteriophage is recommended.

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