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Natural and organo-montmorillonite as antibacterial nanoclays for cotton garment

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ABSTRACT

Here, antibacterial activities of the powder and colloidal forms of natural and organo-montmorillonite (Mt) and also clay mineral and the cotton fabrics treated with various Mt and clay mineral were investigated against *S. aurous* as Gram-positive and *E. coli* as Gram-negative bacteria based on AATCC 100 standard method. The durability of the treated cotton fabrics was also studied against home laundering. The cell cytotoxicity of natural and modified montmorillonite was assessed through MTT against cell fibroblast of human skin. The natural and organo-Mt in powder and colloid forms and also on the cotton fabrics indicated good antibacterial activities however clay mineral showed no antibacterial properties. Further, the kinetic of bacteria killing of treated cotton fabrics followed Chick–Watson model. Natural montmorillonite indicated lower cytotoxicity in comparison of cell viability of natural and modified montmorillonite with human skin cell.

Introduction

Researchers have investigated in antibacterial agents containing various original and synthetic materials to find a solution to eliminate microbial diseases [1]. The textile materials such as cotton are a suitable place for bacteria growth. Antimicrobial agents based on silver compounds are widely used to control the growth of bacteria, fungi, molds, and algae [2]. Inorganic antimicrobial agents involve Ag ion and other metallic ions have high antibacterial activity. Nanometals such as copper, zinc and silver nanoparticles are synthesized through reduction can be employed as antibacterial agents for different material. Nevertheless, the applications of inorganic antibacterial agent are limited, especially heavy metals because of serious environmental problems and may be harmful to human skin. Hence, it is important to develop antimicrobial agent with low cost, high antibacterial activity and high durability [3,4].

The mechanism of antibacterial activity of metals such as copper, zinc, cobalt, silver and other metallic ions are based on the contact of metal with the inner protein of bacteria. A silver ion liberates and then reacts with the sulfur groups of proteins of bacteria leads to death of the bacteria [5–7].

Silicate clays have attracted much more attention due to their non-toxic, environmental friendly characteristics and prepared by intercalation with organic salt with antimicrobial properties [8]. Silicate clays such as montmorillonite (Mt) and mica have the best structure and properties for being utilized in textile industry. Mt with the chemical structure of $(Na, Ca)_{0.33}\cdot(Al, Mg)_2\cdot(Si_4O_{10})\cdot(OH)_{2n}\cdot H_2O$, composed of soft mineral, and mostly crystal silicate groups [9,10].

Modification of Mt with organic salt such as fatty acid or quaternary ammoniums or phosphoniums led to application of Mt in nanocomposite synthesis for improved properties [11]. Mt clay intercalated with quaternary phosphonium salt (tetradecyl tributyl phosphonium bromide – TDTB) indicated dependency of antimicrobial activity of organically modified clay to TDTB, surface charge and particle size of Mt. Mt-TDTB exhibited the highest antimicrobial activity because of releasing of organic antimicrobials [12]. Quaternary ammonium salts have positive charges in the N atom damaging the cellular membrane decomposing bacteria cells. Most of the bacterial surfaces have negative charge and are absorbed by the cationic compounds breaking the

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Table 1
Reduction of different bacteria against various compounds.

Samples	Reduction (%) *S. aureus*	Reduction (%) *E. coli*
MC W	0.00	0.00
MC P	0.00	0.00
NC10 W	99.40	97.35
NC10 P	97.02	94.06
NCN W	83.03	80.54
NCN P	79.76	76.83
Desized	0.00	0.00
MC	0.00	0.00
NCO	99.48	100.00
NC N	60.00	62.00

cytoplasm membrane and penetrating into microbial cell leading to the death of the cell [13].

Nanocomposite based on organically modified Mt in comparison virgin polymer exhibited remarkable improvements in properties such as higher strength and heat resistance, lower gas permeability and flammability, higher biodegradability, adsorption of waste water in textile dyeing and hazardous waste [14–16]. Organoclay with antibacterial activity was achieved from Ca-montmorillonite and chlorhexidine acetates. Chlorhexidine acetates with cationic structure increased antibacterial activity of clay [17].

To the best of our knowledge there is no report upon the antimicrobial properties of the natural and organo-Mt on textile material. Our current study was aimed to explore the influence of organic salt of intercalated Mt on antimicrobial activities and the influence of several clays (organo-Mt, Mt and mineral) on antibacterial activity of cotton fabric. Herein, modified Mt by quaternary ammonium salt and neutral Mt (with nanostructure layers) and mineral clay (with micron size) was used to evaluate their antimicrobial activities against *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*).

Experimental

Materials

Cloisite® 10A, a modified montmorillonite with quaternary ammonium salt (organo-Mt) and Cloisite® Na^+ as natural montmorillonite (Mt) with mean size of 30–60 nm from SCP Co., USA, clay mineral (CM) with mean size of 15 micron from Iran and nutrient agar culture medium from Merck Co. (Germany) were used. *E. coli* (ATCC 25922) and *S. aureus* (ATCC 6538) were supplied

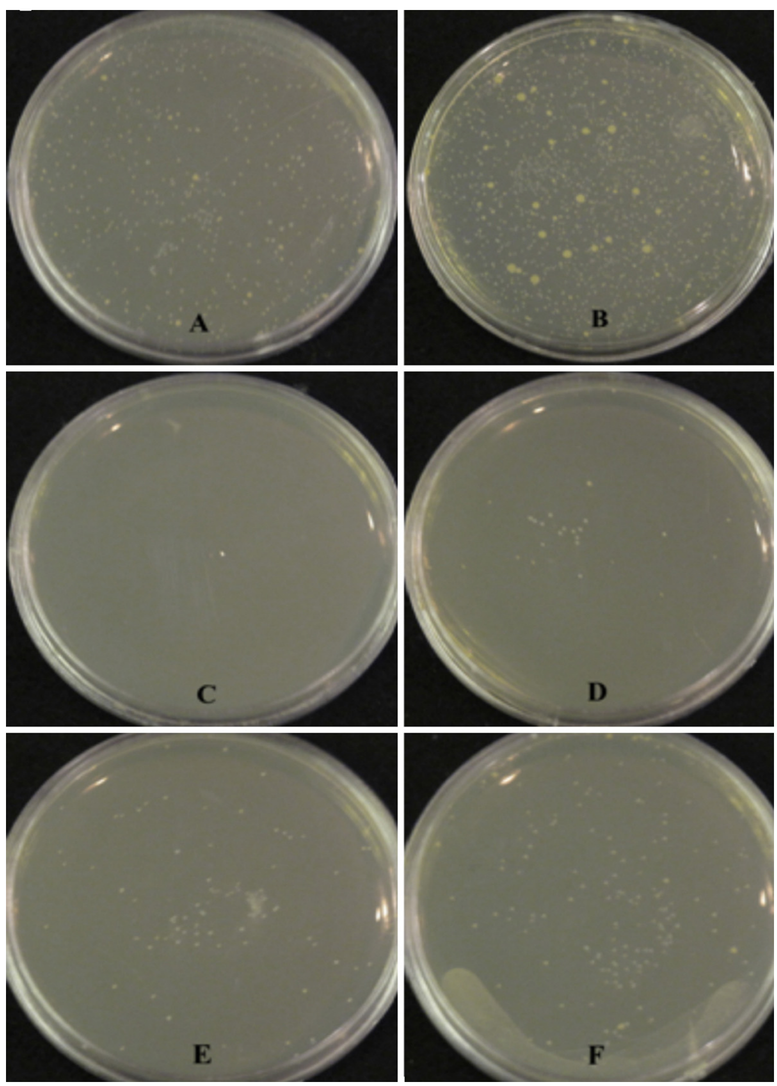

Fig. 1. Comparison of the bacteria colonies growth of various compounds. (A) Control sample, (B) clay mineral, (C) colloidal organo-Mt, (D) organo-Mt powder, (E) colloidal natural Mt sample, (F) powder natural Mt particles.