Antimicrobial property and water-triggered release characteristics of zinc sulphate-polyvinyl acetate adhesive blend

To cite this article: E J B Marasigan et al 2019 J. Phys.: Conf. Ser. 1191 012036

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Antimicrobial property and water-triggered release characteristics of zinc sulphate-polyvinyl acetate adhesive blend

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Abstract. Water-triggered antimicrobial blends are beneficial in inhibiting the growth of microorganisms in moist environment. In this study, zinc sulfate-polyvinyl acetate blend was fabricated by mixing polyvinyl acetate adhesive to zinc sulfate solution. Zinc sulfate served as the antimicrobial component while polyvinyl acetate adhesive served as the binder and water soluble component. White and translucent blends are produced in the study. The results of Disc Diffusion method showed that the zinc sulfate polyvinyl acetate blend has an antimicrobial property against Escherichia coli. Conductivity measurements show that the conductivity increases through time due to the release of zinc ions in water. Results show that the sample with higher amount of zinc sulfate solution has higher saturation conductivity and longer saturation time. Lastly, color analysis shows that the transmittance of the samples decreases as the amount of ZnSO₄ solution added in the blend increases.

1. Introduction
Wet environments are conducive for the growth of microorganisms which may cause various diseases. Escherichia coli (gram negative) is one of these harmful microorganisms which can be found in the intestines of animals and humans. Consumption of contaminated water such as water from the faucet, rivers, lakes, pools, etc. can be a source of Escherichia coli which may cause various diseases.

Antimicrobial agents are used to prevent the growth of such disease-causing microorganisms. Some antimicrobial products include soap, cream, antibiotics [1-3], some of which are expensive and are hard to find. There are studies which deal with formulating antimicrobial agents which are cheap and effective [4, 5]. Embedding of antimicrobial agents to different materials such as papers, textiles, films, and fibers have also been investigated in different studies [5-8].

Water-triggered antimicrobial composites usually have two integral components: the water-soluble component and the antimicrobial component [4]. As the water-soluble component interacts with water, the antimicrobial components will be released. Polyvinyl acetate (PVAc) has been used as the water-soluble component [4, 9-10] and when dissolved in water, it can release the encapsulated antimicrobial agents.

Zinc-based materials [11-15] have antimicrobial properties. Zinc sulfate is a colorless crystalline solid which is noncombustible and commonly used as an astringent in lotions and eye drops. It also inhibits sphalerite flotation by replacing zinc for the attached activating copper ions [16]. It is a zinc-containing salt that can be easily dissolve by water.
In this study, we incorporate zinc sulfate solution into polyvinyl acetate adhesive matrix. We characterize its antimicrobial activity, determine the rate of release of zinc ions in aqueous solution, and perform a color analysis on the blend.

2. Methodology

2.1 Preparation of samples

A 0.5 M zinc sulfate solution was prepared by dissolving 14.38 grams of zinc sulfate heptahydrate (ZnSO₄·7H₂O) salts in 100mL of distilled water. Varying ratios by volume of polyvinyl acetate to zinc sulfate solution were combined – 100:0, 95:5, 90:10, 80:20, 70:30, and 60:40. The PVAc served as the water-soluble binder and the ZnSO₄ served as the antimicrobial agent. All samples were coated in acetate film and were air dried. The samples were prepared in 10.00mm diameter discs.

2.2 Characterization

The antimicrobial activity was determined through Disc Diffusion Method using Escherichia coli (Gram-negative) as test microorganism. The test reference for this method was US Pharmacopeia 30-NF 25, 2007 Biological Reactivity Tests, In vitro.

Conductivity measurements were done to investigate water-triggered release characteristics. The samples were submerged in a beaker filled with water. The OAKTON PC 510 pH/conductivity bench meter was used to monitor the conductivity of water and determine the rate of release of zinc ions.

The data acquisition for the color analysis was performed through the use of the USB Red Tide Spectrometer. Logger Pro software was used to obtain the transmission of each sample in the color spectrum.

3. Results and Discussion

Zinc sulfate polyvinyl acetate composite shows antimicrobial activity for the E. coli test organism as shown in table 1. All the samples tested against E. coli show complete inhibitory activity within their respective zone of inhibition. Mupirocin and clindamycin were used as a positive control and the sample free disc was used for negative control for E. coli.

To investigate the water-triggered release characteristics, the samples were submerged in water. The water conductivity was monitored through time to determine the rate of release of zinc ions. PVAc molecules were dissolved as soon as the sample was submerged in the water. This dissolution of the PVAc molecules resulted to the release of zinc ions. Figure 1 shows the conductivity over

| Sample/Control            | Zone of Inhibition (mm) | Reactivity* | Inhibitory Activity |
|---------------------------|-------------------------|-------------|---------------------|
| ZnSO₄.PVAc composite (100:0) | 11.28                   | Mild        | Complete            |
| ZnSO₄.PVAc composite (95:5)   | 14.84                   | Moderate    | Complete            |
| ZnSO₄.PVAc composite (90:10)  | 14.97                   | Moderate    | Complete            |
| ZnSO₄.PVAc composite (80:20)  | 11.82                   | Mild        | Complete            |
| ZnSO₄.PVAc composite (70:30)  | 14.52                   | Moderate    | Complete            |
| ZnSO₄.PVAc composite (60:40)  | 16.90                   | Moderate    | Complete            |
| Positive control: Mupirocin | 22.94                   | Severe      | Complete            |
| Positive control: Clindamycin 2 ug | 22.88           | Severe      | Complete            |
| Negative control: Sample-free disc | 0                 | None        | Negative            |

*Reactivity Rating: None – no detectable zone around or under specimen; Mild – zone limited under the specimen; Moderate – zone extends 5 to 10 mm beyond specimen; Severe – zone extends greater than 10 mm beyond specimen.
saturation conductivity ($\mu S/\mu S_{sat}$) versus time over saturation time ($t/\text{tsat}$) of the samples with 0%, 5%, 10%, 20%, 30%, and 40% zinc sulphate solution. It can be observed that after some time, the conductivity reading becomes constant. This is where the saturation conductivity occurs where all the zinc ions are released in the water which resulted to a constant reading in the conductivity.

Table 2 shows the summary of the saturation conductivity and the saturation time of PVAc-ZnSO$_4$ blend containing 0%, 5%, 10%, 20%, 30%, and 40% of ZnSO$_4$ solution. The sample with 40% of ZnSO$_4$ has the highest value of saturation conductivity and has the longest time for the water to be completely saturated. As the amount of zinc sulphate in the solution increases, the saturation conductivity also increases. This is because as the amount of zinc sulfate was increased, the amount of zinc ions released in the water also increases resulting to an increase in the conductivity value.

For the color analysis, figure 2 shows the transmittance of each of the sample. A white, translucent, paste-like blend, that contains polyvinyl acetate adhesive and zinc sulfate solution, was fabricated. The wavelength from 390 nm to 700 nm was used in this part of the experiment. Based from the graph, it can be observed that the transmittance of the sample with 10% and 20% ZnSO$_4$ is higher compared with the other samples. While the samples with 30% and 40% ZnSO$_4$ tends to have a lower transmittance. As the amount of PVAc in the blend decreases, less PVAc molecules block the the incident light, thereby, increasing the transmittance of the sample. However, beyond the 20% ZnSO$_4$+H$_2$O concentration, the amount of ZnSO$_4$ salt is accountable for the low average transmittance.
4. Conclusion

PVAc-ZnSO4 composites were prepared and were deposited in films. Different ratios of PVAc to ZnSO4 were used in the experiment. The PVAc served as the water-soluble binder and the ZnSO4 served as the antimicrobial agent. Tests showed that the composite has antimicrobial activity against Escherichia coli. The conductivity of water containing the composite increases as time progresses due to the release of zinc ions. Samples with higher amount of ZnSO4 solution reach higher value of saturation conductivity. Color analysis shows that the transmittance of the samples decreases as the amount of ZnSO4 solution added in the blend increases.

Acknowledgement

This research is funded by the Collaborative Research Project of the Institute of Mathematical Sciences and Physics, University of the Philippines Los Baños.

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