There is an unmet need to provide active, long-term resistance to a broad range of bacteria, mold, mildew, and other harmful micro-organisms to prevent collateral effects of illness and/or product spoilage due to infection. Examples of target end-use applications where it is critical to prevent infection and product spoilage from surface contact in sensitive environments includes: hospitals and health care facilities; kitchens and food processing and storage areas; dairies; breweries; bathroom and rest room facilities; hotels; school, recreation, amusement, and sports facilities. While existing anti-microbial additives may provide some degree of anti-microbial action, their effectiveness in such formulated products as paints and coatings is limited by the amounts ofmaterial required to achieve anti-microbial action, which exceeds: (1) cost constraints for the formulated product; (2) usage limitations relative to non-target toxicity; (3) the practicallimits for incorporation in the formulated product; and (4) which may be limited by the mechanism for delivery to the surface of the article to be protected.

It is, therefore, desired that antimicrobial chemical compositions be formulated in a manner that provide a desired active, long-term resistance to a broad range of microorganisms, including bacteria, mold, mildew, and other micro-biological species to prevent collateral effects of illness and product spoilage, when compared to known antimicrobial chemical compositions, thereby meeting the needs of certain end-use applications. It is desired that such antimicrobial chemical compositions be engineered in a manner facilitating the ability to effectively customize, adjust and/or tailor changes in the performance characteristics of the formulations for the purpose of effectively addressing the specific antimicrobial needs associated with different end-use applications. It is further desired that such antimicrobial chemical compositions be formulated from readily available materials, and/or be made by methods, that facilitate manufacturing the chemical compositions in a manner that does not require the use of exotic equipment, that is not unduly labor intensive, and that is economically feasible.

SUMMARY ~~OF THE INVENTION~~

In a first aspect of the present disclosure, there is provided an antimicrobial chemical composition comprising:

a complex comprising a bioactive constituent that is a metal ion, wherein the complex releases the bioactive constituent at a rate upon contact of the complex with moisture; and

a binder polymer forming a bulk matrix of the composition, wherein the complex is disposed within bulk matrix, and wherein the bulk matrix enables the bioactive constituent that is released from the complex to diffuse therethrough at a rate;

wherein the rate of release of the bioactive constituent from the complex is the same or different from the rate of diffusion of the bioactive constituent through the bulk matrix,

wherein the complex comprises amorphous aluminum phosphate, wherein the complex has a porosity, and wherein the rate of release of the bioactive constituent is a function of the porosity.

In a second aspect of the present disclosure, there is provided an antimicrobial chemical composition comprising:

a binding polymer; and

a bioactive-aluminum phosphate complex dispersed within the binding polymer, the complex comprising an aluminum phosphate polymer and a bioactive material comprising a bioactive constituent that is a metal ion;

wherein the aluminum phosphate complex has an engineered porosity that, when the composition is cured, provides a controlled delivery of the bioactive constituent when exposed to moisture,

wherein the aluminum phosphate polymer comprises amorphous aluminum phosphate.

In a third aspect of the present disclosure, there is provided a primer coating formed from the chemical composition recited in the second aspect.

In a fourth aspect of the present disclosure, there is provided a mid-coat or top-coat of a coating system formed from the chemical composition recited in the second aspect.

In a fifth aspect of the present disclosure, there is provided a system for providing antimicrobial protection comprising a coating composition applied to substrate and cured to form a film, the coating composition comprising a binding polymer with a bioactive-aluminum phosphate complex dispersed therein, wherein the complex comprises an amorphous aluminum phosphate combined with a bioactive material, and wherein the complex is engineered to provide a controlled delivery of a bioactive constituent that is a metal ion when exposed to moisture.

In a sixth aspect of the present disclosure, there is provided a method for making an antimicrobial chemical composition, wherein the composition when cured provides a controlled delivery of a bioactive constituent derived from the bioactive material upon exposure to moisture, the method comprising adding a polymer binding material to a bioactive-aluminum phosphate complex prepared according to a method for making a bioactive-aluminum phosphate complex comprising the steps of:

forming an amorphous aluminum phosphate by combining an aluminum source, with a phosphate source in an aqueous solution at suitable pH to form a dispersion of aluminum phosphate; and

adding a bioactive material during or after the step of forming so that the bioactive material is combined with the aluminum phosphate to form the bioactive-aluminum phosphate complex, the complex being capable of releasing a bioactive constituent that is a metal ion,

wherein during the step of forming, the dispersion comprises amorphous aluminum phosphate.

In a seventh aspect of the present disclosure, there is provided a method for making an antimicrobial chemical composition comprising a bioactive material dispersed within an aluminum phosphate, the method comprising the steps of:

forming an aluminum phosphate by combining an aluminum source, with a phosphate source in an aqueous solution at suitable pH to form a dispersion of aluminum phosphate;

adding a bioactive material during or after the step of forming so that the bioactive material is disposed in the aluminum phosphate forming a bioactive-aluminum phosphate complex; and

combining a polymer binding material with the bioactive-aluminum phosphate complex to form the antimicrobial chemical composition;

wherein the composition when cured provides a controlled delivery of a bioactive constituent that is a metal ion derived from the bioactive material upon exposure to moisture of from 10 to 900 ppm,

wherein during the step of forming, the dispersion comprises amorphous aluminum phosphate.

In an eighth aspect of the present disclosure, there is provided a method for making an antimicrobial chemical composition comprising a bioactive material combined with an aluminum phosphate, the method comprising the steps of:

forming an aluminum phosphate by combining an aluminum source, with a phosphate source in an aqueous solution at suitable pH to form a dispersion of aluminum phosphate;

adding a bioactive material to the amorphous aluminum phosphate after the step of forming to provide a complex wherein the bioactive material is physically incorporated in the aluminum phosphate to form a bioactive-aluminum phosphate complex; and

combining a polymer binding material with the complex to form the antimicrobial chemical composition;

wherein the composition when cured provides a controlled delivery of a bioactive constituent that is a metal ion derived from the bioactive material of 100 ppm or greater upon exposure to moisture,

wherein during the step of forming, the dispersion comprises amorphous aluminum phosphate.

In a ninth aspect of the present disclosure, there is provided a method for making an antimicrobial chemical composition comprising a bioactive material combined with aluminum phosphate, the method comprising the steps of:

combining aluminum hydroxide and phosphoric acid to form a solution comprising an acidic aluminum phosphate condensate;

combining a bioactive material during or after the step of forming the acidic aluminum phosphate condensate to form mixture comprising a bioactive-aluminum phosphate complex comprising the bioactive material that is a metal ion; and

and further comprising the step of adding a neutralizing agent to the acidic aluminum phosphate complex to increase its pH; and

combining a polymer binding material with the complex to form the chemical composition, wherein the complex comprises amorphous aluminum phosphate.

In a tenth aspect of the present disclosure, there is provided a method for making an antimicrobial chemical composition comprising a bioactive material combined with an amorphous aluminum phosphate, the method comprising the steps of:

combining a bioactive material with aluminum nitrate and phosphoric acid to form a solution, and neutralizing the solution to form a gel comprising amorphous aluminum phosphate, wherein the gel comprises a bioactive constituent of the bioactive material incorporated into a backbone of the amorphous aluminum phosphate, thereby forming a bioactive-aluminum phosphate complex, the bioactive constituent being a metal ion; and

combining a polymer binding material with the complex to form the chemical composition.

In an eleventh aspect, there is provided a method for making an antimicrobial chemical composition comprising a bioactive material combined with aluminum phosphate, wherein the bioactive material comprises a metal salt, the method comprising the steps of:

combining a bioactive material with aluminum hydroxide to form a mixture, and wherein before the step of combining, a complex is formed by combining the metal salt with a ligand;

adding the mixture to phosphoric acid to form a bioactive-aluminum phosphate complex comprising the bioactive material; and

combining a polymer binding material with the complex to form the chemical composition, wherein the complex comprises amorphous aluminum phosphate.

Antimicrobial chemical compositions as described herein generally comprise an aluminum phosphate (AIP) solid that is dispersed within a binding polymer. One or more bioactive materials are disposed within or combined with the AIP to form a bioactive-AIP complex. A feature ofthe complex is that it is specifically engineered such that, when the composition is provided in the form of a dried film or composite, it