

**POLYIMIDAZOLIUM-BASED CATIONIC ANTIMICROBIAL POLYMERS RETAIN
EFFICACY IN THE PRESENCE OF ANIONIC SURFACTANTS**

Field of Invention

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The current invention relates to antimicrobial compositions and use of the antimicrobial compositions, and more particularly relates to polyimidazolium-based cationic antimicrobial compositions.

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Background

The listing or discussion of a prior-published document in this specification should not necessarily be taken as an acknowledgement that the document is part of the state of the art or is common general knowledge.

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In recent years, infectious diseases are among the most critical threats to global health and the situation has been worsened by the rise of antimicrobial resistance (AMR) (*Science* **2016**, 351 (6268), aad3292). Natural antimicrobial peptides (AMPs) and their synthetic mimics demonstrate great potential in killing bacteria with fast kill-kinetics and a low propensity for resistance to emerge, and so some consider AMPs as the “next-generation of antimicrobials” to tackle the global AMR problem (*Expert opinion on biological therapy* **2014**, 14 (1), 11-14). Despite the recent development of antimicrobial peptides and polymers, their application is still limited, and fouling problems remain a particular concern for antimicrobials due to their cationic and hydrophobic nature (*International journal of molecular sciences* **2019**, 20 (11), 2747). Many AMPs have been reported to show reduced efficacy in a complex physiological environment with high concentrations of salt and proteins (*Nature reviews Drug discovery* **2020**, 19 (5), 311-332). For example, a physiological concentration level of albumin suppressed the antimicrobial activity of lactoferricin-derived small cationic antibacterial tripeptides by 10-fold (*Journal of medicinal chemistry* **2007**, 50 (14), 3334-3339). The antibacterial activity of LL-37 is deactivated by glycosaminoglycans in wound fluid where glycosaminoglycans are present in significant concentrations (*Journal of Antimicrobial Chemotherapy* **2006**, 57 (2), 260-265). This holds true for other synthetic cationic antimicrobial polymers, where serum protein could significantly diminish the antimicrobial activity (*Polymer composites—polyolefin fractionation—polymeric peptidomimetics—collagens* **2010**, 141-172). The poor bioavailability of AMPs as a result of protein binding in complex physiological environments, prevents them from reaching their intended targets *in vivo* and significantly limits their application in healthcare (*Trends in pharmacological sciences* **2011**, 32 (2), 116-

124; *Nature reviews Drug discovery* **2010**, 9 (12), 929-939; *Analytical and bioanalytical chemistry* **2010**, 398(1), 53-66).

Besides healthcare, antimicrobial peptides and polymers have been widely used in other industries, such as the fast-moving consumer goods (FMCG) industry and the food industry (Kerry, J. P., *New packaging technologies, materials and formats for fast-moving consumer products*. In *Innovations in food packaging*, Elsevier: 2014; pp 549-584; *Polymers* **2019**, 11 (3), 560). However, their activity may also be affected by confounding factors present in the local environment. For example, anionic surfactants are a commonly used laundry surfactant due to their good cleaning ability and low cost (*Heliyon* **2020**, 6 (5), e03861). However, the negatively charged surfactant could bind to positively charged quaternary compounds (QUATs), leading to inactivation of the latter. Cationic-substituted cellulose showed significant binding with anionic sodium dodecyl sulfate, a common detergent component used in the laundry industry (*Journal of Colloid and Interface Science* **1976**, 55 (1), 73-79). Hence, there is an unmet need to identify antimicrobial compounds that remain effective in anionic surfactants.

Nisin, an AMP widely used as a food preservative, showed reduced efficacy in dairy products such as milk and fresh cheeses, possibly due to it partitioning into fat globules and/or forming a complex with anionic casein (*Journal of Dairy Science* **2020**, 103 (3), 2041-2052). Cationic acrylate polymer Eudragit E100 forms complexes with casein in milk via electrostatic interactions (*Journal of agricultural and food chemistry* **2003**, 51 (15), 4417-4423). ϵ -polylysine (ϵ -PL), a potent food-grade antimicrobial, could associate with anionic substances in compositionally complex systems, leading to sediment formation and reduced antimicrobial activity (*Journal of agricultural and food chemistry* **2012**, 60 (7), 1837-1844). It is apparent that retaining the fast-bactericidal efficacy in complex environments remains a highly desirable yet unachieved target in the development of new antimicrobials.

Summary of Invention

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It has been surprisingly found that linear antibacterial polyimidazolium salts (PIMs) have a fast killing property against different bacteria even in the presence of anionic surfactants commonly used in laundry detergents and other washing liquids. In the current disclosure, the PIM series are developed into antimicrobial laundry additives for use in FMCG products, and said products themselves. As shown herein, PIMs retain excellent efficacy in complex environments (e.g., detergents) where the excessive confounding factors such as anionic

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surfactants resulted in the failure of many potentially commercial cationic antimicrobials. Thus, the current invention provides a solution to the unmet need of fast bactericidal antimicrobials in FMCG, and potentially more industries with similar needs.

5 The current invention highlights the potential of PIMs as a platform technology with wider applications in many other industry sectors, including the food industry. The utility of the PIMs and their potential application in the FMCG industry and the food industry was further explored by examining their antimicrobial performance in very challenging conditions with excessive confounding factors.

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Further tests disclosed herein have shown that polyethyleneimine (PEI) has a good synergy with the PIM series of compounds, allowing one to reduce the required PIM concentration in an effective combination. This invention also discloses that ULMW PIM (ultralow molecular weight polyimidazolium salts) with a molecular weight of from 1200 Da to 1500 Da may exhibit
15 the best performance of the molecular weights tested. This formulation also exhibited good repeatability while retaining antibacterial efficacy over a long period of time with different batches of polymer. The bactericidal efficacy of PIM1 as a laundry additive in the presence of commercial anionic surfactant was also identified and disclosed herein. It is noted that other PIMs may also be used.

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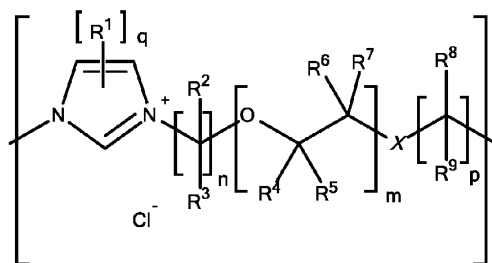
Aspects and embodiments of the invention will be discussed by reference to the following numbered clauses.

1. An antimicrobial composition, comprising:
25 a cationic polymer; and
at least one anionic surfactant.
2. The antimicrobial composition according to Clause 1, wherein a relative concentration of the cationic polymer to the at least one anionic surfactant is from 1:1 to 1:5, such as from
30 1:1.5 to 1:3, such as about 1:2.
3. The antimicrobial composition according to Clause 1 or Clause 2, wherein the cationic polymer has a number average molecular weight of less than 3,500 Daltons, such as less than 2,500 Daltons, such as from 800 to 2,000 Daltons such as from 1,000 to 1,600 Daltons, such
35 as from 1,200 to 1,500 Daltons.

4. The antimicrobial composition according to any one of the preceding clauses, wherein the cationic polymer is selected from one or more of the group consisting of a polyazolium and an oligoazolium, optionally wherein:

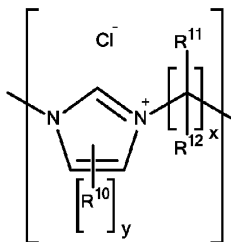
- the polyazolium, when present, is selected from one or more of the group consisting of a polyimidazolium, a polytriazolium, and a polythiazolium; and/or
- the oligoazolium, when present, is selected from one or more of the group consisting of an oligoimidazolium, an oligotriazolium, and an oligothiazolium.

5. The antimicrobial composition according to any one of the preceding clauses, wherein the cationic polymer is a polyimidazolium or an oligoimidazolium having a repeating unit of formula (I):



(I)

- or is a copolymer comprising the repeating unit of formula (I) and a repeating unit of formula (II):



(II)

wherein:

- Cl⁻ in each of formula (I) and (II) represents a chloride counterion or any other suitable counterion;
- R¹ and R¹⁰, when present, independently represent C₁₋₆ alkyl;

each R^2 to R^8 and R^{11} independently represent H or C_{1-6} alkyl;
each R^9 and R^{12} independently represents H, C_{1-6} alkyl or CO_2R^{13} ;
 R^{13} represents H or C_{1-6} alkyl;
X represents $CR^{14}R^{15}$, O or S;

- 5 R^{14} and R^{15} independently represent H, C_{1-6} alkyl or CO_2R^{13} ;
m is a number selected from 0 to 5;
n is a number selected from 2 to 10;
p is a number selected from 0 to 5;
q is a number selected from 0 to 3;
10 x is a number selected from 2 to 10;
y is a number selected from 0 to 3; and
solvates thereof,
provided that, when the polyimidazolium is a copolymer, the repeating unit of formula (I) and the repeating unit of formula (II) are not the same.

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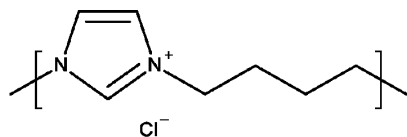
6. The antimicrobial composite material according to Clause 5, wherein:
 R^1 and R^{10} , when present, independently represent C_{1-3} alkyl;
each R^2 to R^8 and R^{11} independently represents H or methyl;
each R^9 and R^{12} independently represents H, C_{1-3} alkyl or CO_2R^{13} ;
20 R^{13} represents H or C_{1-3} alkyl;
X represents $CR^{14}R^{15}$ or O;
 R^{14} and R^{15} independently represent H, C_{1-3} alkyl or CO_2R^{13} ;
m is a number selected from 0 to 4;
n is a number selected from 2 to 8;
25 p is a number selected from 0 to 3;
q is a number selected from 0 to 1;
x is a number selected from 2 to 8; and
y is a number selected from 0 to 1.

- 30 7. The antimicrobial composition according to Clause 5 or Clause 6, wherein:
each R^2 to R^8 and R^{11} independently represents H;
each R^9 and R^{12} independently represents H, methyl or CO_2H ;
X represents $CR^{14}R^{15}$ or O;
 R^{14} and R^{15} independently represent H, methyl or CO_2H ;
35 m is a number selected from 0 to 3;
n is a number selected from 2 to 7;
p is a number selected from 0 to 2;

q and y are 0; and
x is a number selected from 2 to 7.

8. The antimicrobial composition according to any one of Clauses 5 to 7, wherein:
- 5 each R^2 to R^8 and R^{11} independently represents H;
each R^9 and R^{12} independently represents H, methyl or CO_2H ;
X represents $\text{CR}^{14}\text{R}^{15}$ or O;
 R^{14} and R^{15} independently represent H, methyl or CO_2H ;
m is a number selected from 0 to 2;
- 10 n is a number selected from 2 to 7;
p is a number selected from 0 to 2;
q and y are 0; and
x is a number selected from 2 to 7.
- 15 9. The antimicrobial composition according to any one of Clauses 5 to 8, wherein the polyimidazolium is independently chain-terminated at each chain terminus by a group selected from OH, NH_2 , a zwitterionic species and a hydrazine group.
10. The antimicrobial composition according to any one of Clauses 5 to 9, wherein the
- 20 polyimidazolium has the repeating unit of formula (I).
11. The antimicrobial composition according to Clause 10, wherein:
- each of R^2 to R^8 are H;
each R^9 represents H, methyl or CO_2H ;
- 25 X represents CH_2 or O;
m is a number selected from 0 to 2;
n is a number selected from 2 to 6;
p is a number selected from 0 to 2;
q is 0.
- 30 12. The antimicrobial composition according to any one of Clauses 5 to 11, wherein one or both of the following apply:
- (ia) when X is O, p is 1 or 2; and
(ib) the polyimidazolium is terminated by amino (NH_2) groups.
- 35 13. The antimicrobial composition according to any one of Clauses 5 to 12, wherein the repeating unit of formula (I) is selected from the group consisting of:

(i)

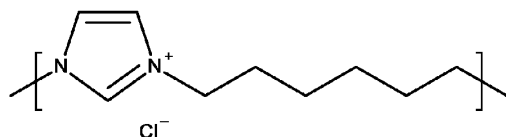
, where Cl⁻ represents a chloride counterion or

any other suitable counterion;

optionally wherein the number average molecular weight of the polymer is from 500 to 2,500

5 Daltons;

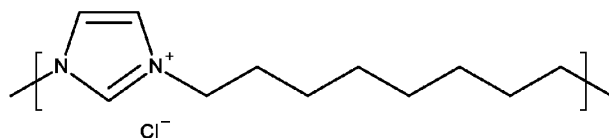
(ii)

, where Cl⁻ represents a chloride

counterion or any other suitable counterion, optionally wherein the number average molecular

10 weight of the polymer is from 500 to 2,500 Daltons;

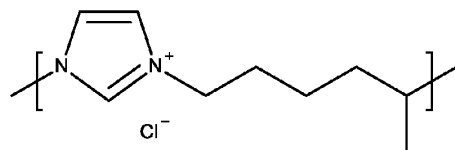
(iii)

, where Cl⁻ represents a

chloride counterion or any other suitable counterion, optionally wherein the number average

15 molecular weight of the polymer is from 500 to 2,500 Daltons;

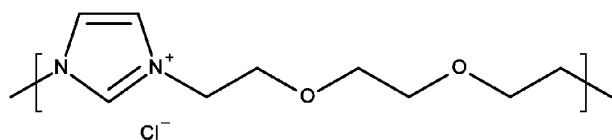
(iv)

, where Cl⁻ represents a chloride counterion

or any other suitable counterion, optionally wherein the number average molecular weight of

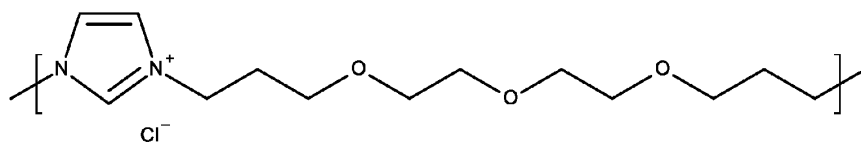
20 the polymer is from 500 to 2,000 Daltons;

(v)



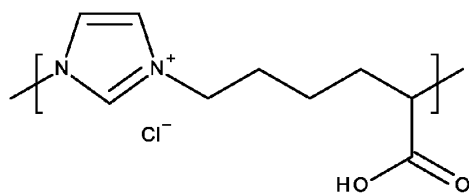
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 1,000 to 2,500 Daltons;

(vi)



where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 1,000 to 2,500 Daltons; and

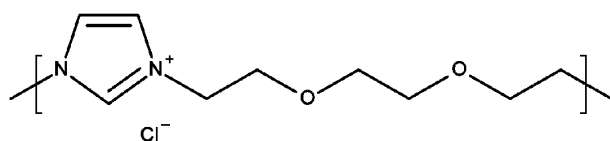
(vii)



, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,000 Daltons,

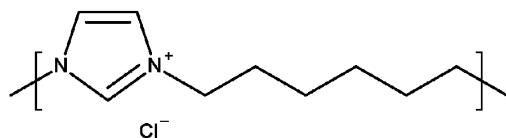
optionally wherein the repeating unit of formula (I) and formula (II) are selected from the group consisting of:

(i)



as the repeating unit of

formula (I) and

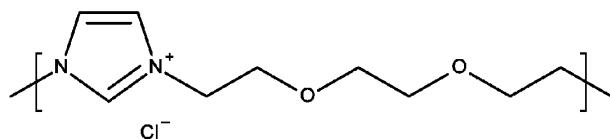


as the repeating unit of formula (II),

where Cl⁻ represents a chloride counterion or any other suitable counterion, optionally wherein

5 the number average molecular weight of the copolymer is from 1,000 to 2,500 Daltons; and

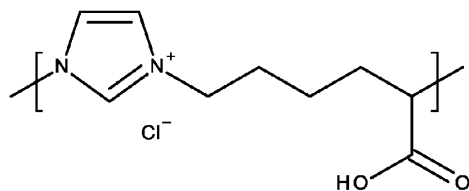
(ii)



as the repeating unit of

formula (I) and

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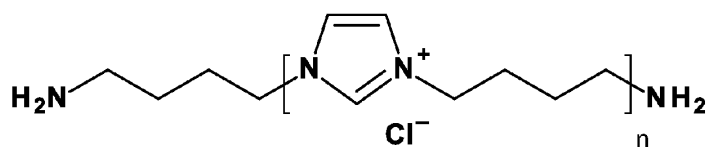


as the repeating unit of formula (II), where

Cl⁻ represents a chloride counterion or any other suitable counterion in formula (I) and (II), optionally wherein the number average molecular weight of the copolymer is from 1,000 to 2,500 Daltons.

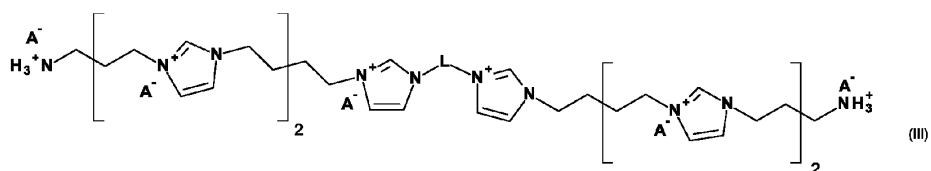
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14. The antimicrobial composition according to any one of Clauses 5 to 13, wherein the polyimidazolium is:



, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight is from 1,200 to 1,500 Daltons.

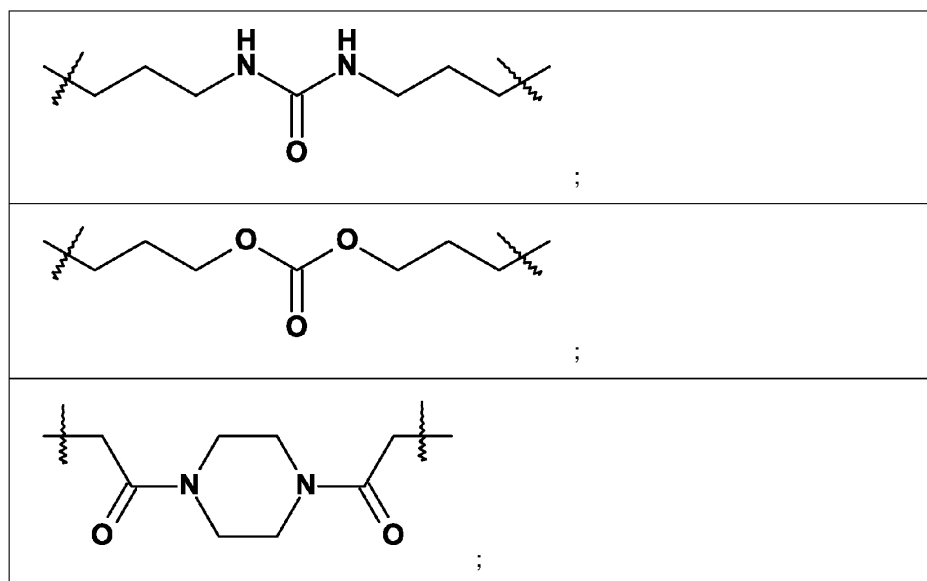
- 5 15. The antimicrobial composition according to any one of Clauses 1 to 5, wherein the cationic polymer is an oligoimidazolium that is a compound of formula (III):

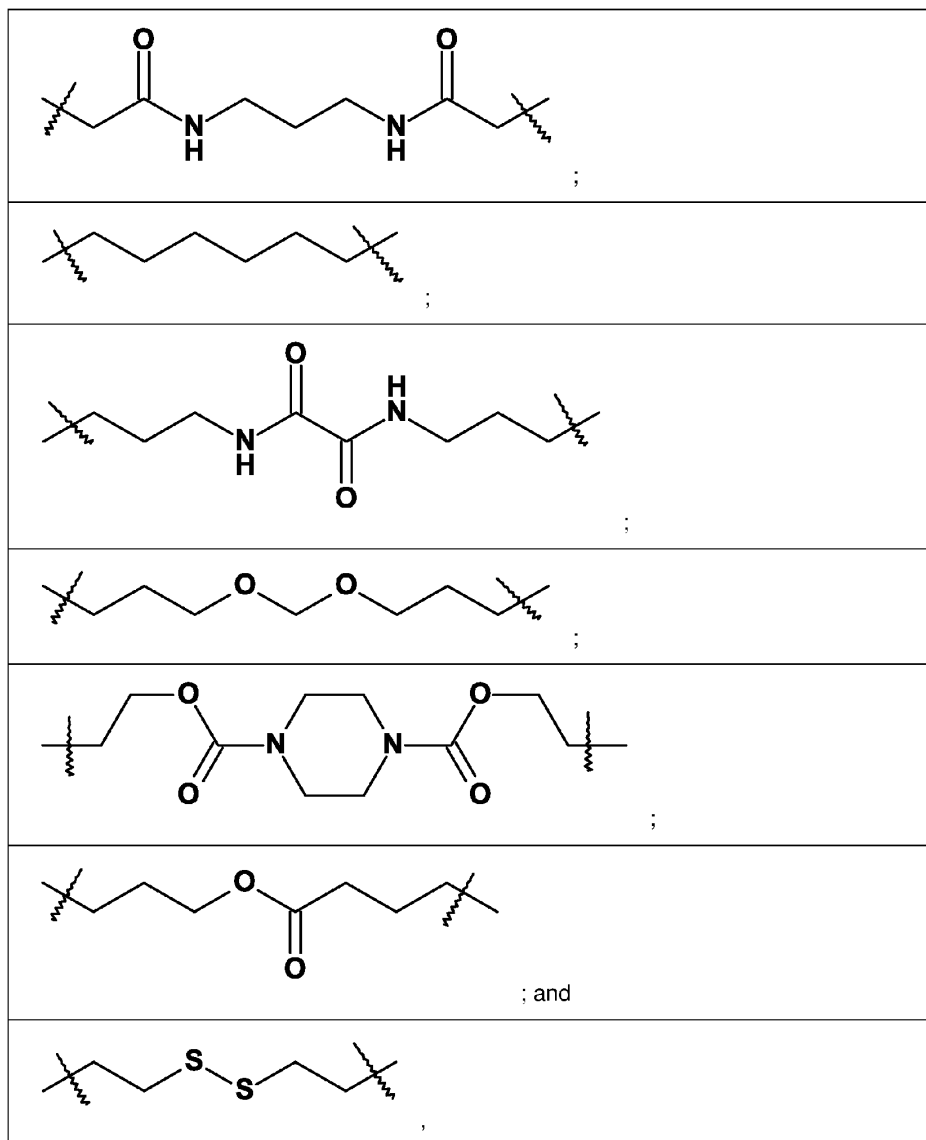


10 where:

A is any suitable counterion, such as Cl^- , Br^- and the like; and

L represents a linker selected from:





where the wiggly lines represent the point of attachment to the rest of the molecule.

16. The antimicrobial composition according to any one of the preceding clauses, wherein
- 5 the at least one anionic surfactant is selected from one or more of the group consisting of sodium dodecylbenzene sulfonate (SBDS), sodium lauryl sulfate (SLS), sodium laureth sulfate (SLES), sodium coco sulfate (SCS).

17. The antimicrobial composition according to any one of the preceding clauses, wherein the antimicrobial composition further comprises a compound that comprises one or both of an amino group and an ammonium group.
- 5 18. The antimicrobial composition according to Clause 17, wherein the compound that comprises one or both of an amino group and an ammonium group is a polymeric compound comprising a plurality of amino and/or a plurality of ammonium groups.
- 10 19. The antimicrobial composition according to Clause 18, wherein the number average molecular weight of the polymeric compound comprising a plurality of amino and/or a plurality of ammonium groups is from 10 kDaltons to 600 kDaltons, such as from 20,000 Daltons to 30,000 Daltons, such as 25,000 Daltons.
- 15 20. The antimicrobial composition according to Clause 18 or Clause 19, wherein the compound that comprises one or both of an amino group and an ammonium group is a polyethyleneimine.
- 20 21. The antimicrobial composition according to Clause 20, wherein the polyethyleneimine is a branched polyethyleneimine.
22. The antimicrobial composition according to Clause 20 or Clause 21, wherein the number average molecular weight of the polyethyleneimine is from 20,000 Daltons to 30,000 Daltons, such as 25,000 Daltons.
- 25 23. The antimicrobial composition according to any one of Clauses 17 to 22, wherein a relative concentration of the compound that comprises one or both of an amino group and an ammonium group to the at least one anionic surfactant is from 1:1 to 1:5, such as from 1:1.5 to 1:3, such as about 1:2.
- 30 24. The antimicrobial composition according to any one of Clauses 17 to 22, wherein a relative concentration of the cationic polymer to the compound that comprises one or both of an amino group and an ammonium group is from 1:0.1 to 1:10, such as from 1:0.5 to 1:5, such as about 1:1.
- 35 25. The antimicrobial composition according to any one of the preceding clauses, wherein the composition is a laundry detergent.

26. Use of an antimicrobial composition according to any one of Clauses 1 to 24 as a detergent for washing an object, optionally wherein the object is an animal or human, a clothing article or a surface.

- 5 27. A method of using an antimicrobial composition according to any one of Clauses 1 to 24 as a detergent for washing an object, comprising the steps of:
- (a) providing an antimicrobial composition according to any one of Clauses 1 to 24; and
 - (b) contacting the object with the antimicrobial composition and water for a period of time under conditions to effect washing of the object, optionally wherein the object is an animal or
- 10 human, a clothing article or a surface.

Drawings

FIG. 1 depicts the ^1H nuclear magnetic resonance (NMR) spectrum of PIM1-ULMW-Batch1 in deuterated water (D_2O) (300 MHz).

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FIG. 2 depicts the gel permeation chromatography (GPC) of PIM1-ULMW-Batch1.

FIG. 3 depicts the ^1H NMR spectrum of PIM1-LMW in D_2O (300 MHz).

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FIG. 4 depicts the GPC of PIM1-LMW.

FIG. 5 depicts the ^1H NMR spectrum of PIM1-HMW in D_2O (300 MHz).

25 FIG. 6 depicts the GPC of PIM1-HMW.

FIG. 7 depicts the illustrations of the steps in the P&G (Procter & Gamble) cloth antibacterial testing.

30 FIG. 8 depicts the summary of PIM (LMW) synergistic results with (a) various PEI polymers and (b) various quaternary ammonium salts or chelating agents. The detailed information of each compound is listed out in Table 5. The details of the sample entries are shown herein:

(a) #1: PIM 50ppm; #2: PIM 100ppm; #3: PEI2 (Branched, 25kDa) 75ppm; #4: PIM 50ppm + PEI1 (Linear, 20kDa) 50ppm; #5: PIM 50ppm + PEI2 (Branched, 25kDa) 50ppm; #6: PIM 25ppm + PEI2 (Branched, 25kDa) 75ppm; #7: PIM 50ppm + PEI2 (Branched, 60kDa) 50ppm; #8: PIM 50ppm + PEI2 (Branched, 600kDa) 50ppm. (b) #9: PIM 50ppm + BAC 50ppm; #10: PIM 50ppm + LonzaBac 50ppm; #11: PIM 50ppm + S100 (Tama) 50ppm; #12: PIM 50ppm +

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BTMS 50ppm; #13: PIM 50ppm + ZPB 50ppm; #14: PIM 50ppm + PCDMA (structure provided in Table 5 below) 50ppm; #15: PIM 50ppm + HPNO 50ppm; #16: PIM 50ppm + HIDS 50ppm. (BAC: benzylkonium chloride; LonzaBac: bis(3-aminopropyl)dodecylamine; BTMS: behentrimonium methosulfate (and) cetearyl alcohol (quat surfactant); ZPB: trans-sulphated ethoxylated hexamethylene diamine quaternary zwitterion).

FIG. 9 depicts the absorption effect of PIM1-ULMW (left) and PIM1-HMW (right) onto cloth,

FIG. 10 depicts the ^1H NMR spectrum of PIM1-ULMW-Batch2 in D_2O (300 MHz).

FIG. 11 depicts the GPC of PIM1-ULMW-Batch2.

FIG. 12 depicts the ^1H NMR spectrum of PIM1-ULMW-Batch3 in D_2O (300 MHz).

FIG. 13 depicts the GPC of PIM1-ULMW-Batch3.

FIG. 14 depicts the ^1H NMR spectrum of PIM1-ULMW-Batch4 in D_2O (300 MHz).

FIG. 15 depicts the GPC of PIM1-ULMW-Batch4.

FIG. 16 depicts the cytotoxicity of PIM1-ULMW from different batches against 3T3 cells. As will be appreciated, these are batches of the same material and broadly show similar results.

Description

Reading Keys

Brown – SP107940SG Application as filed.pdf

Purple - Statements of Invention_pw9.docx

A series of identified compounds has surprisingly shown fast killing property against microbials even in the presence of anionic surfactants commonly used in laundry detergents, personal care products, and other products in the fast-moving consumer goods (FMCG) industry and food industry. These compounds retain excellent efficacy in the presence of different confounding factors (e.g., anionic surfactants or proteins) in complex environments that could fail many other cationic antimicrobials.

Thus, in a first aspect of the invention, there is provided an antimicrobial composition, comprising:

a cationic polymer, and
at least one anionic surfactant.

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In embodiments herein, the word "comprising" may be interpreted as requiring the features mentioned, but not limiting the presence of other features. Alternatively, the word "comprising" may also relate to the situation where only the components/features listed are intended to be present (e.g. the word "comprising" may be replaced by the phrases "consists of" or "consists essentially of"). It is explicitly contemplated that both the broader and narrower interpretations
10 essentially of"). It is explicitly contemplated that both the broader and narrower interpretations can be applied to all aspects and embodiments of the present invention. In other words, the word "comprising" and synonyms thereof may be replaced by the phrase "consisting of" or the phrase "consists essentially of" or synonyms thereof and *vice versa*.

15 As used herein, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a composition" includes mixtures of two or more such compositions, reference to "a first repeating unit" includes a plurality of said repeating units and does not exclude the possibility of further (different) repeating units also being present, and the like.

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When used herein, the term "antimicrobial composition" is intended to refer to an antimicrobial composition that requires the components listed above, but which may also contain additional components. The antimicrobial compositions disclosed herein have been found to exhibit excellent antimicrobial properties against a range of bacteria species. The antimicrobial
25 composition may also exhibit a pronounced antimicrobial action, especially against pathogenic Gram-positive and Gram-negative bacteria and so may also act against bacteria of skin flora, e.g. *Corynebacterium xerosis* (bacteria that cause body odour), and also against yeasts and moulds. They are therefore also suitable in the disinfection of the skin and mucosa and also of integumentary appendages (hair), and so may also be suitable in the disinfection of the
30 hands and of wounds.

The term "Gram-positive bacteria" refers to bacteria having cell walls with high amounts of peptidoglycan. Gram-positive bacteria are identified by their tendency to retain crystal violet and stain dark blue or violet in the Gram staining protocol.

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The term "Gram-negative bacteria" refers to bacteria having thinner peptidoglycan layers which do not retain the crystal violet stain in the Gram staining protocol and instead retain the

counterstain, typically safranin. Gram-negative bacteria stain red or pink in the Gram staining protocol.

When used herein, the term "cationic polymer" is intended to refer to a polymer having a net cationic charge. As will be appreciated, the cationic polymer should be a material that exhibits antimicrobial activity. Non-limiting examples of suitable cationic polymers are polysaccharides, proteins and synthetic polymers. Cationic polysaccharides include cationic cellulose derivatives, cationic guar gum derivatives, chitosan and derivatives, and cationic starches. Suitable cationic polysaccharides include cationically modified cellulose, particularly cationic hydroxyethylcellulose and cationic hydroxypropylcellulose. Synthetic polymers include a polyazolium (e.g. polyimidazolium (PIM), a polytriazolium, a polythiazolium), polydiallyl dimethylammonium chloride (PDADMAC), polyMETformin (PMET), polyallylamine (PAH), a linear or branched polyethyleneimine (PEI), a poly(L-lysine) (PLL), a poly(L-arginine) (PLA), a polyvinylamine homo- or copolymer, a poly(vinylbenzyl-tri-C₁-C₄-alkylammonium salt), a polymer of an aliphatic or araliphatic dihalide and an aliphatic N,N,N',N'-tetra-C₁-C₄-alkyl-alkylenediamine, a poly(vinylpyridin) or poly(vinylpyridinium salt), a poly (N,N-diallyl-N,N-di-C₁-C₄-alkyl-ammoniumhalide), a homo- or copolymer of a quaternized di-C₁-C₄-alkyl-aminoethyl acrylate or methacrylate, POLYQUAD™, a polyaminoamide, S100 (Tama), Behentrimonium methosulfate (BTMS), trans-sulphated ethoxylated hexamethylene diamine quaternary zwitterion (ZPB), PCDMA (see Table 5 for structure), and the like. Particular cationic polymers that may be referred to may be a polyazolium (e.g. one or more of the group consisting of a polyimidazolium (PIM), a polytriazolium, a polythiazolium). Yet more particular cationic polymers that may be mentioned herein may be a polyimidazolium.

When used herein, the term "anionic surfactant" is intended to refer to a surfactant having a net anionic charge. Any suitable anionic surfactant may be used herein. In particular embodiments of the invention, the at least one anionic surfactant may be selected from one or more of the group consisting of sodium dodecylbenzene sulfonate (SDS), sodium lauryl sulfate (SLS), sodium laureth sulfate (SLES), sodium coco sulfate (SCS). For example, the at least one anionic surfactant may be SDS.

In embodiments of the invention that may be mentioned herein, relative concentration of the cationic polymer to the at least one anionic surfactant may be from 1:1 to 1:5, such as from 1:1.5 to 1:3, such as about 1:2.

For the avoidance of doubt, it is explicitly contemplated that where a number of numerical ranges related to the same feature are cited herein, that the end points for each range are

intended to be combined in any order to provide further contemplated (and implicitly disclosed) ranges. Thus, in relation to the above related numerical ranges, there is disclosed ratios of:

from 1:1 to 1:1.5, from 1:1 to 1:2; from 1:1 to 1:3; from 1:1 to 1:5;

from 1:1.5 to 1:2; from 1:1.5 to 1:3; from 1:1.5 to 1:5;

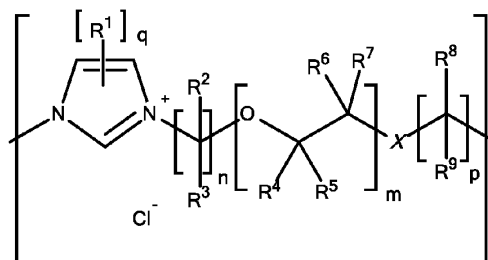
- 5 from 1:2 to 1:3; from 1:2 to 1:5; and
from 1:3 to 1:5.

In embodiments of the invention that may be mentioned herein, the cationic polymer may have a number average molecular weight (M_n) of less than 3,500 Daltons, such as less than 2,500
10 Daltons, such as less than 2,000 Daltons, such as less than 1,500 Daltons, such as from 800 to 2,000 Daltons, such as from 1,000 to 1,600 Daltons, such as from 1,200 to 1,500 Daltons. As will be appreciated, these molecular weight ranges may be viewed as providing an oligomeric material instead of a polymeric material. For the avoidance of doubt, it is specifically intended that oligomeric materials may also be referred to herein as being the cationic polymer.

- 15 As such, the terms may potentially be used herein interchangeably. For the further avoidance of doubt, the cationic polymer may be referred to in some instances as an oligoazolium (e.g. one or more of the group consisting of an oligoimidazolium (PIM), an oligotriazolium, an oligothiazolium). Yet more particular cationic oligomers that may be mentioned herein may be an oligoimidazolium.

20

When the cationic polymer is a polyimidazolium (or oligoimidazolium), it may be a material that exhibits a repeating unit of formula (I):

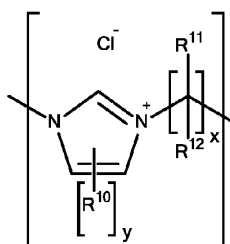


(I)

25

or is a copolymer (or co-oligomer) comprising the repeating unit of formula (I) and a repeating unit of formula (II):

18



(II)

wherein:

Cl⁻ represents a chloride counterion or any other suitable counterion in formula (I) and (II);

5 R¹ and R¹⁰, when present, independently represent C₁₋₆ alkyl;

each R² to R⁸ and R¹¹ independently represent H or C₁₋₆ alkyl;

each R⁹ and R¹² independently represents H, C₁₋₆ alkyl or CO₂R¹³;

R¹³ represents H or C₁₋₆ alkyl;

X represents CR¹⁴R¹⁵, O or S;

10 R¹⁴ and R¹⁵ independently represent H, C₁₋₆ alkyl or CO₂R¹³;

m is a number selected from 0 to 5;

n is a number selected from 2 to 10;

p is a number selected from 0 to 5;

q is a number selected from 0 to 3;

15 x is a number selected from 2 to 10;

y is a number selected from 0 to 3; and

solvates thereof,

provided that, when the polyimidazolium (or oligoimidazolium) is a copolymer (or co-oligomer), the repeating unit of formula (I) and the repeating unit of formula (II) are not the

20 same.

Unless otherwise stated, the term "alkyl" refers to an unbranched or branched, acyclic, saturated or unsaturated (so forming, for example, an alkenyl or alkynyl) hydrocarbyl radical, which may be substituted or unsubstituted (with, for example, one or more halo atoms). Where

25 the term "alkyl" refers to an acyclic group, it is preferably C₁₋₁₀ alkyl and, more preferably, C₁₋₆ alkyl (such as ethyl, propyl, (e.g. n-propyl or isopropyl), butyl (e.g. branched or unbranched butyl), pentyl or, more preferably, methyl. Where the term "alkyl" is a cyclic group (which may

be where the group "cycloalkyl" is specified), it is preferably C₃₋₁₂ cycloalkyl and, more preferably, C₅₋₁₀ (e.g. C₅₋₇) cycloalkyl. In more particular embodiments of the invention, the

30 term "alkyl" refers to an unbranched or branched, acyclic, saturated hydrocarbyl radical.

For example, when used herein, the term “C₁₋₃ alkyl” may refer to, for example, ethyl, propyl, (e.g. n-propyl or isopropyl), or more preferably, methyl. Derivatives of C₁₋₃ alkyl may refer to substituted C₁₋₃ alkyl groups. Examples of substituted C₁₋₃ alkyl groups that may be mentioned
 5 herein include, but are not limited to halo (e.g. Br, Cl or, more particularly F). A particular derivative that may be mentioned herein is CF₃.

In particular embodiments that may be mentioned herein, one or more of the following may apply.

10 R¹ and R¹⁰, when present, independently represent C₁₋₃ alkyl;
 each R² to R⁸ and R¹¹ independently represents H or methyl;
 each R⁹ and R¹² independently represents H, C₁₋₃ alkyl or CO₂R¹³;
 R¹³ represents H or C₁₋₃ alkyl;
 X represents CR¹⁴R¹⁵ or O;

15 R¹⁴ and R¹⁵ independently represent H, C₁₋₃ alkyl or CO₂R¹³;
 m is a number selected from 0 to 4;
 n is a number selected from 2 to 8;
 p is a number selected from 0 to 3;
 q is a number selected from 0 to 1;

20 x is a number selected from 2 to 8;
 y is a number selected from 0 to 1.

In particular embodiments that may be mentioned herein, one or more of the following may apply.

25 each R² to R⁸ and R¹¹ independently represents H;
 each R⁹ and R¹² independently represents H, methyl or CO₂H;
 X represents CR¹⁴R¹⁵ or O;
 R¹⁴ and R¹⁵ independently represent H, methyl or CO₂H;
 m is a number selected from 0 to 3;

30 n is a number selected from 2 to 7;
 p is a number selected from 0 to 2;
 q and y are 0;
 x is a number selected from 2 to 7.

35 In yet further embodiments that may be mentioned herein, one or more of the following may apply.
 each R² to R⁸ and R¹¹ independently represents H;

each R^9 and R^{12} independently represents H, methyl or CO_2H ;

X represents $CR^{14}R^{15}$ or O;

R^{14} and R^{15} independently represent H, methyl or CO_2H ;

m is a number selected from 0 to 2;

5 n is a number selected from 2 to 7;

p is a number selected from 0 to 2;

q and y are 0;

x is a number selected from 2 to 7.

10 The polyimidazolium (or oligoimidazolium) may be chain-terminated in any suitable manner. For example, the polyimidazolium (or oligoimidazolium) may be independently chain-terminated at each chain terminus by a group selected from OH, NH_2 , a zwitterionic species and a hydrazine group.

15 In particular embodiments of the invention, the polyimidazolium (or oligoimidazolium) may have the repeating unit of formula (I). That is, the polyimidazolium (or oligoimidazolium) may be a homopolymeric material. Any suitable homopolymeric material may be used. For example, the polyimidazolium (or oligoimidazolium) having the repeating unit of formula (I) may be one in which one or more of the following apply:

20 each of R^2 to R^8 are H;

each R^9 represents H, methyl or CO_2H ;

X represents CH_2 or O;

m is a number selected from 0 to 2 (e.g. 0 or 1, or 1 or 2);

n is a number selected from 2 to 6;

25 p is a number selected from 0 to 2 (e.g. 0 or 1, or 1 or 2);

q is 0.

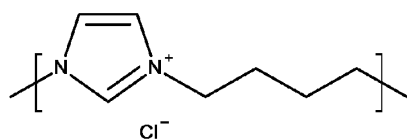
In certain embodiments of the above arrangements, the polyimidazolium (or oligoimidazolium) may be one in which one or both of the following apply:

30 (ia) when X is O, p is 1 or 2; and

(ib) the polyimidazolium (or oligoimidazolium) is terminated by amino (NH_2) groups.

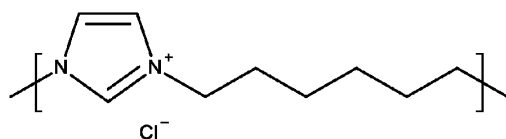
In particular embodiments that may be mentioned herein, the repeating unit of formula (I) may be selected from the group consisting of:

35 (i)



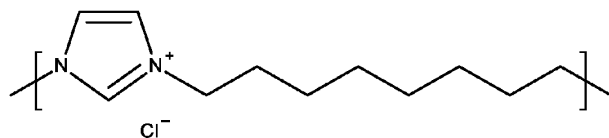
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,500 Daltons;

5 (ii)



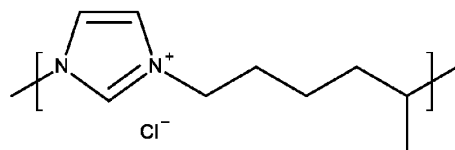
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,500 Daltons;

10 (iii)



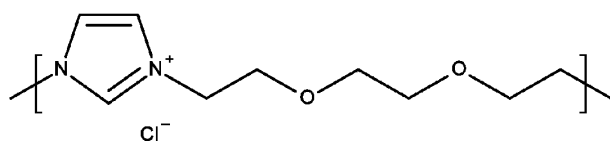
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,500 Daltons;

15 (iv)



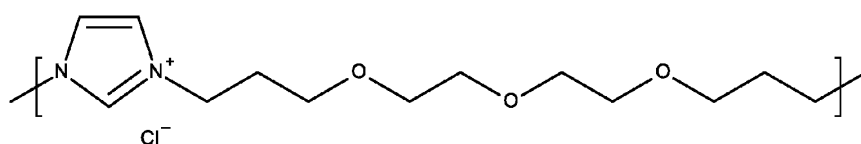
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,000 Daltons;

20 (v)



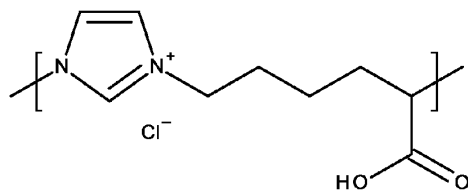
, where Cl⁻ represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 1,000 to 2,500 Daltons;

5 (vi)



where Cl⁻ represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 1,000 to 2,500 Daltons; and

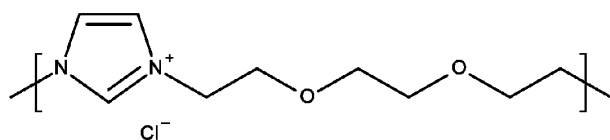
10 (vii)



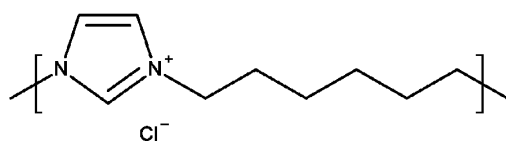
, where Cl⁻ represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,000 Daltons.

15 In alternative or additional embodiments of the invention, the repeating unit of formula (I) and formula (II) may be selected from the group consisting of:

(i)



as the repeating unit of formula (I) and

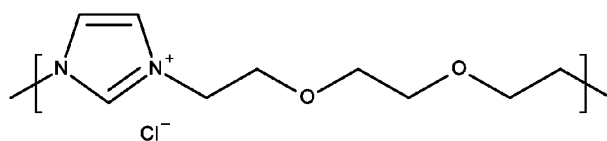


as the repeating unit of formula (II),

where Cl⁻ represents a chloride counterion or any other suitable counterion in formula (I) and (II), optionally wherein the number average molecular weight of the copolymer is from 1,000 to 2,500 Daltons; and

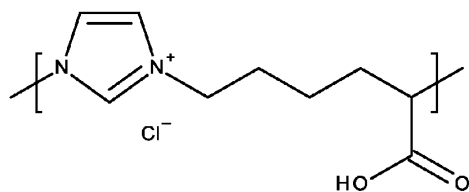
5

(ii)



as the repeating unit of

formula (I) and

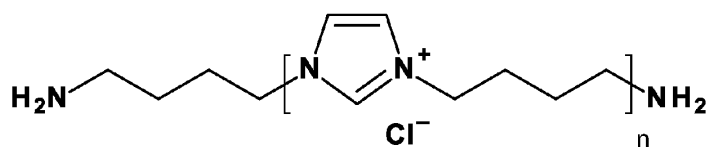


10

as the repeating unit of formula (II), where

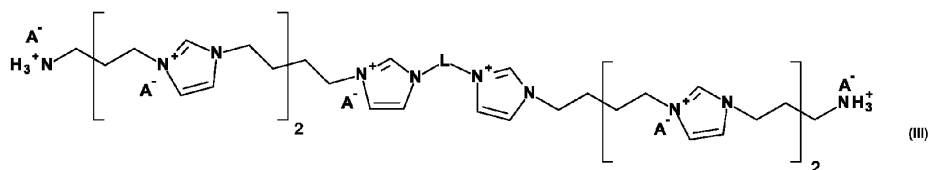
Cl⁻ represents in formula (I) and (II) a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the copolymer is from 1,000 to 2,500 Daltons.

15 In yet more particular embodiments of the invention, the polyimidazolium (or oligoimidazolium) may be:

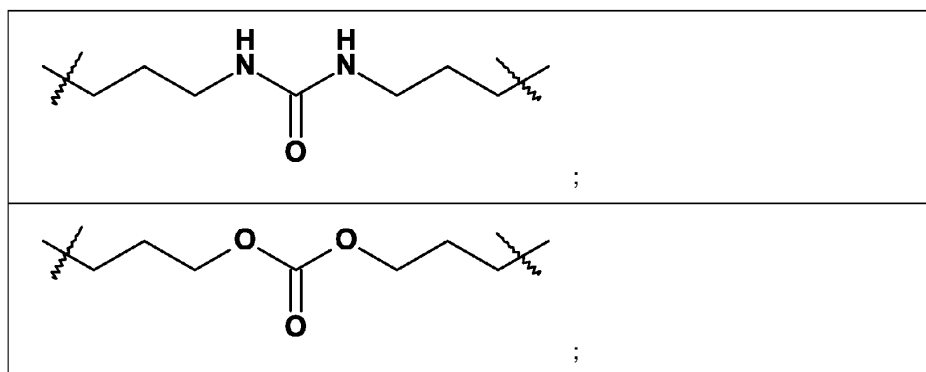


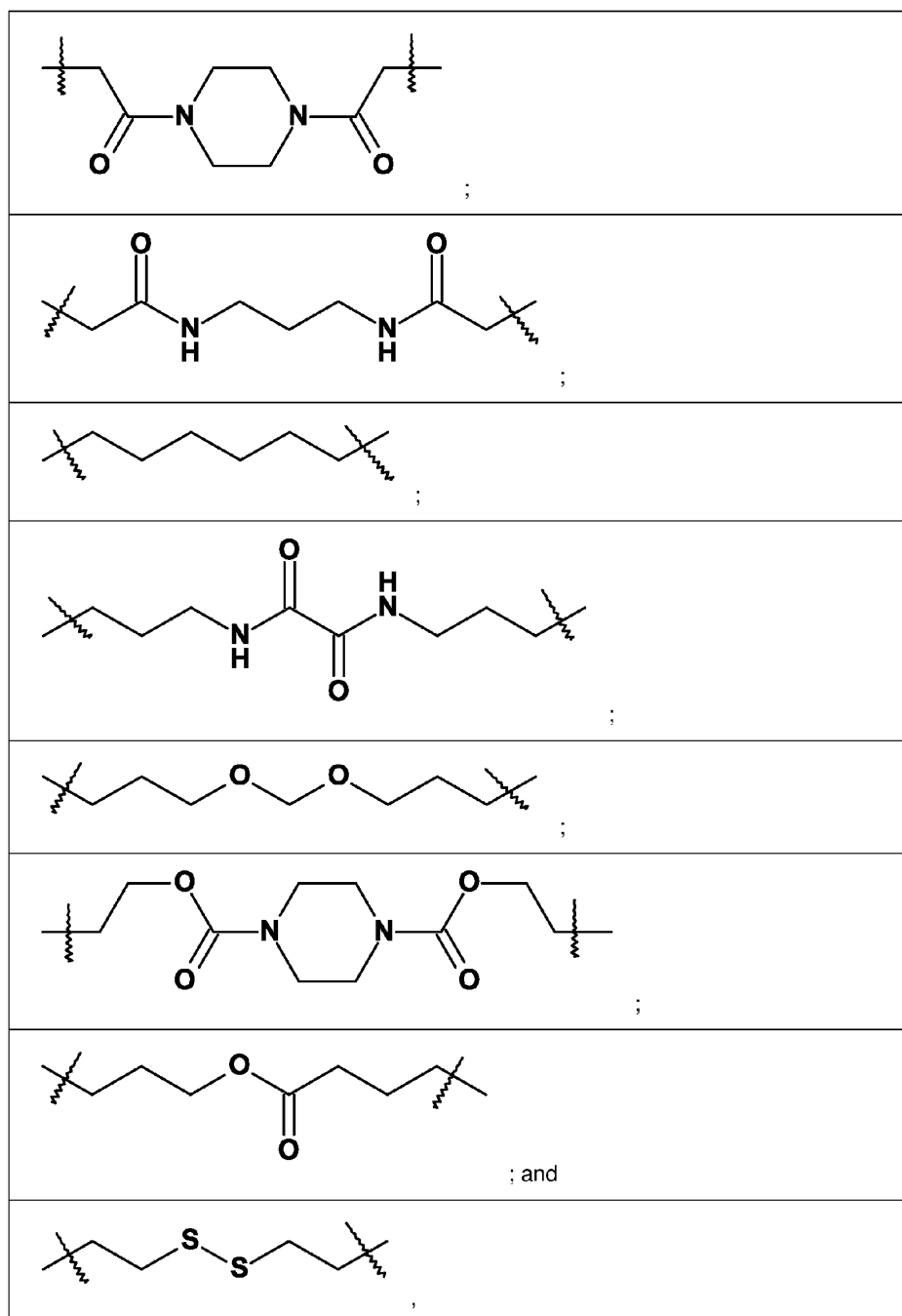
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight is from 1,200 to 1,500 Daltons.

- 5 As noted hereinbefore, the Cl^- counterion used above is only a representative counterion and may instead be any other suitable counterion (e.g. a pharmaceutically acceptable counterion). Examples of other counterions that may be mentioned herein and which are explicitly contemplated include, but are not limited to Br^- .
- 10 In certain embodiments, the cationic polymer may be an oligoimidazolium that is a compound of formula (III):



- 15 where:
 A is any suitable counterion, such as Cl^- , Br^- and the like; and
 L represents a linker selected from:





where the wiggly lines represent the point of attachment to the rest of the molecule.

- In certain embodiments that may be mentioned herein, the antimicrobial composition may further comprise a compound that comprises one or both of an amino group and an ammonium group. It is believed that the inclusion of such an additional compound may act in a synergistic manner with the cationic polymer and/or enable one to use a lower concentration of the cationic polymer in the antimicrobial composition, while retaining useable antimicrobial activity. This may be beneficial because the cationic polymer may be a material that has high potency, and hence possible toxicity, so reducing the amount of it in the composition may be useful.
- When used herein, the term "amine/ammonium-containing compound" is intended to refer to a compound which comprises one or more amine functional groups, and/or one or more ammonium functional groups. In particular embodiments that may be mentioned herein, the compound that comprises one or both of an amino group and an ammonium group may be a polymeric compound comprising a plurality of amino and/or a plurality of ammonium groups.
- In such embodiments, the polymeric compound comprising a plurality of amino and/or a plurality of ammonium groups may be one that has a number average molecular weight that is significantly higher than that of the cationic polymer referred to herein. This may be a number average molecular weight that 2, 3, 4, 5, 6, 7, 8, or even greater than 10X the number average molecular weight of the cationic polymer. For example, the number average molecular weight of the polymeric compound comprising a plurality of amino and/or a plurality of ammonium groups may be from 10 kDaltons to 600 kDaltons, such as from 20,000 Daltons to 30,000 Daltons, such as 25,000 Daltons.
- In particular embodiments that may be mentioned herein, the amine/ammonium-containing compound may be selected from one or more of the group consisting of polyimidazolium (PIM), polydiallyl dimethylammonium chloride (PDADMAC), polyMETformin (PMET), polyallylamine (PAH), a linear or branched polyethyleneimine (PEI), a poly(L-lysine) (PLL), a poly(L-arginine) (PLA), a polyvinylamine homo- or copolymer, a poly(vinylbenzyl-tri-C₁-C₄-alkylammonium salt), a polymer of an aliphatic or araliphatic dihalide and an aliphatic N,N,N',N'-tetra-C₁-C₄-alkyl-alkylenediamine, a poly(vinylpyridin) or poly(vinylpyridinium salt), a poly (N,N-diallyl-N,N-di-C₁-C₄-alkyl-ammoniumhalide), a homo- or copolymer of a quaternized di-C₁-C₄-alkyl-aminoethyl acrylate or methacrylate, POLYQUAD™, a polyaminoamide, benzylkonium chloride (BAC), bis (3-aminopropyl)dodecylamine (LonzaBac), S100 (Tama), behentrimonium methosulfate (BTMS), trans-sulphated ethoxylated hexamethylene diamine quaternary zwitterion (ZPB), PCDMA, 2-pyridinol-1-oxide (HPNO), tetrasodium 3-hydroxy-2,2'-iminodisuccinate (HIDS). For the avoidance of doubt, the "amine/ammonium-containing compound" is intended to be different to the cationic polymer.

In particular embodiments of the invention, the compound that comprises one or both of an amino group and an ammonium group may be a polyethyleneimine. In yet more particular embodiments of the invention, the polyethyleneimine may be a branched polyethyleneimine
5 (e.g. as shown in the example section herein). The polyethyleneimines if used herein may have any suitable number average molecular weight (e.g. as discussed above). In particular embodiments of the invention, the number average molecular weight of the polyethyleneimine may be from 20,000 Daltons to 30,000 Daltons, such as 25,000 Daltons.

10 Any suitable amount of the compound that comprises one or both of an amino group may be used in compositions that contain this additional component. For example, a relative concentration of the compound that comprises one or both of an amino group and an ammonium group to the at least one anionic surfactant may be from 1:1 to 1:5, such as from 1:1.5 to 1:3, such as about 1:2. Additionally or alternatively, a relative concentration of the
15 cationic polymer to the compound that comprises one or both of an amino group and an ammonium group may be from 1:0.1 to 1:10, such as from 1:0.5 to 1:5, such as about 1:1.

The antimicrobial composition may be used as antimicrobial active ingredients in personal care preparations, for example antiseptics, shampoos, bath additives, hair-care products,
20 liquid and solid soaps (based on synthetic surfactants and salts of saturated and/or unsaturated fatty acids), lotions and creams and other aqueous or alcoholic solutions, e.g. cleansing solutions for the skin. More particularly the antimicrobial composition may be used as a detergent, such as a laundry detergent.

25 The antimicrobial composition disclosed herein has a pronounced antimicrobial action, especially against pathogenic gram-positive and gram-negative bacteria and so may also act against bacteria of skin flora, e.g. *Corynebacterium xerosis* (bacteria that cause body odour), and also against yeasts and moulds. They are therefore also suitable in the disinfection of the skin and mucosa and also of integumentary appendages (hair), and so may also be suitable
30 in the disinfection of the hands and of wounds.

It will be appreciated that the antimicrobial composition may also contain additional tolerable carriers and/or adjuvants. Said composition may in particular be in the form of a laundry detergent or in the form of a solid or liquid soap, though other compositions as described
35 hereinabove are also contemplated.

In more particular examples, the antimicrobial composition may be presented in the form of a detergent composition, such as a laundry detergent.

In certain embodiments, the cationic polymer may simply be added to a commercially available detergent (i.e. a laundry detergent) in a suitable amount (e.g. as discussed herein) to provide a suitable relative concentration ratio between it and the anionic surfactant(s) in the commercially available detergent. In additional or alternative embodiments, the cationic polymer and the compound that comprises one or both of an amino group and an ammonium group may be added to a commercially available detergent in suitable relative amounts as discussed herein.

The detergent composition may be used after dilution with water in 50- to 1500-fold excess by volume and heating the dilution at 20 to 60° C, preferably 25 to 40° C, to achieve at least one effect selected from bleaching, washing, bacteria elimination and deodorization. To achieve at least one effect selected from higher bleaching, washing, bacteria elimination and deodorization, dilution of the detergent composition with water in 100- to 1000-fold excess by volume may be more preferable.

Depending upon the form of the detergent composition, it will comprise, in addition to the polymer or copolymer of the invention, further constituents, for example sequestering agents, colourings, perfume oils, thickening or solidifying (consistency regulator) agents, emollients, UV absorbers, skin-protective agents, antioxidants, additives that improve mechanical properties, such as dicarboxylic acids and/or Al, Zn, Ca and Mg salts of C₁₄-C₂₂ fatty acids, and optionally preservatives.

The detergent composition may be formulated as a water-in-oil or oil-in-water emulsion, as an alcoholic or alcohol-containing formulation, as a vesicular dispersion of an ionic or non-ionic amphiphilic lipid, as a gel, a solid stick or as an aerosol formulation.

As a water-in-oil or oil-in-water emulsion, the detergent composition may comprise from 5 to 50 wt% of an oily phase, from 5 to 20 wt% of an emulsifier and from 30 to 90 wt% water. The oily phase may contain any oil suitable for cosmetic formulations, e.g. one or more hydrocarbon oils, a wax, a natural oil, a silicone oil, a fatty acid ester or a fatty alcohol. Preferred mono- or poly-ols are ethanol, isopropanol, propylene glycol, hexylene glycol, glycerol and sorbitol.

The pH value of the detergent composition of the invention at 20° C may be from 4 to 7, preferably from 4.3 to 6.5, more preferably from 4.6 to 6.5, even more preferably from 5 to 6. Any suitable pH adjusting agent may be used herein as required, acids, for example inorganic acids such as hydrochloric acid and sulfuric acid or organic acids such as citric acid, succinic acid, malic acid, fumaric acid, tartaric acid, malonic acid and maleic acid, or alkalis, for example sodium hydroxide, potassium hydroxide, ammonia or derivatives thereof, amine salts (monoethanolamine, diethanolamine, triethanolamine etc.), and sodium carbonate and potassium carbonate, can be used alone or as a mixture thereof. Among these compounds, an inorganic acid selected from hydrochloric acid and sulfuric acid or an inorganic base selected from sodium hydroxide and potassium hydroxide is preferably used.

The detergent composition may be prepared through a step of mixing the antimicrobial composition with a personal care product or cleaning product. The antimicrobial composition may be added together with the further constituents at the time of preparation of the detergent composition.

The detergent composition may be formulated according to conventional methods. For example, provide the sulfated surfactant in a batch. Blend in the organic acid with an agitator. Once blended, add 80% of the water. Titrate with base to desired pH. Add the other ingredients (e.g., antimicrobial compositions, polymers, nonionic surfactant, chelants, dyes, perfumes, etc.). Measure pH and adjust as needed with base. Balance with the remaining water.

In a second aspect of the invention, there is provided a use of the compositions of the invention as a detergent for washing an object, optionally the object is an animal or human, or clothing article, or a surface.

The compositions of the invention may be used to clean, treat, and/or pretreat an object. In embodiments of the invention, method of using the compositions comprising the step of contacting the object with the compositions of the invention.

In particular embodiments of the invention, at least a portion of the object is contacted with the aforementioned compositions, in neat form or diluted in a liquor, e.g., a wash liquor, and then the object may be optionally washed and/or rinsed.

In particular embodiments of the invention, at least a portion of the object is optionally washed and/or rinsed, contacted with the aforementioned compositions, and then optionally washed and/or rinsed.

In particular embodiments of the invention, the compositions is applied onto the soiled object and left to act on the object before the object is washed. The compositions of the invention may remain in contact with the object until dry or for a longer period of time, or for a period of
 5 1 minute to 24 hours, or 1 minute to 1 hour, or 5 minutes to 30 minutes.

For avoidance of doubt, washing includes, but is not limited to, scrubbing, brushing, and mechanical agitation. Typically after washing and/or rinsing, the object is dried.

10 In embodiments of the invention, compositions may be used in washing of the object in combination with another cleaning device. Non-limiting examples of cleaning device include fabric laundering automatic washing machine, dishwasher, floor mopping device, steam cleaner, carpet cleaner, pressure washer, window cleaner, ultrasonic cleaner.

15 In embodiments of the invention, compositions may be used in washing of fiber products such as clothing article. The fiber products may comprise most any fabric capable of being laundered or treated. The washing may take place, for example, in a conventional fabric laundering automatic washing machine or by a hand washing method. An effective amount of the composition may be added to water to form aqueous laundering solutions that may
 20 comprise at least 1 ppm up to about 100 ppm, such as from 10 to 50 ppm of the composition.

Further aspects and embodiments of the invention are described in the following numbered statements.

- 25 1. An antimicrobial composition comprising:
- (a) a cationic polymer;
 - (b) at least one anionic surfactant;
 - and optionally,
 - (c) an amine/ammonium-containing compound.

30

2. The antimicrobial composition according to Statement 1, wherein the cationic polymer is PIM1.

PIM1



3. The antimicrobial composition according to Statement 2, wherein PIM1 has a molecular weight from 1200 to 1500 Da.
- 5 4. The antimicrobial composition according to Statements 1 to 3, wherein the at least one anionic surfactant comprises Sodium Dodecylbenzene Sulfonate (SDBS).
5. The antimicrobial composition according to Statements 1 to 4, wherein the amine/ammonium-containing compound comprises polyethyleneimine (PEI).

10

Further aspects and embodiments of the invention will now be discussed by reference to the following non-limiting embodiments.

Examples

15

Materials

The materials were obtained from commercial sources, such as Sigma Aldrich, TCI, and the like.

20

Example 1. Preparation and Characterization of PIM

A series of poly(alkylated imidazoliums) (PIM) via a one-step Debus–Radziszewski (DR) reaction was synthesized. It was found that the molecular weight of PIM would be tuned by the amount of diamine and selection of solvent. Herein, PIM polymers with three different molecular weights were synthesized: (1) ultralow molecular weight (ULMW, < 2 kDa); (2) low molecular weight (LMW, ~ 3.5 kDa); and high molecular weight (HMW, ~10 kDa).

25

Synthesis of PIM1

30 The antibacterial linear polyimidazolium salts (PIM) were synthesized by poly-Radziszewski Reaction. The optimized molecular weight of PIM1 was obtained by varying the different proportions of 1,4-diaminobutane and the solvent (HCl or Acetic acid/tetrahydrofuran(THF)).

As a typical polymerization procedure for ultralow molecular weight of PIM (ULMW PIM): a first solution of 1,4-diaminobutane (70.52 g, 0.8 mol), 200 mL deionised (DI) water, and concentrated HCl (133.6 mL) was added into a 1000 mL round flask immersed in an ice bath and maintained for 30 min. The HCl was added carefully and slowly while keeping the flask

35

immersed in the ice bath. Next, a mixture of formaldehyde (64.92 g of 37% formaldehyde solution, 0.8 mol) and glyoxal (116 g of 40% glyoxal, 0.8 mol) was added dropwise to the first mixture over 10 min at 0 °C (in ice water bath). Then, the reaction mixture (which was yellowish in colour) was allowed to warm to room temperature, which then the colour of the reaction mixture turned brown. After allowing the reaction mixture to sit for 24 h at 80°C, the final reaction mixture was directly transferred into a 1K cut-off Spectra/Por®6 dialysis membrane (Repligen, USA) and dialyzed against 5 L acidified water (pH = 3-4). The acidified water was obtained from adding 3 mL of 1M HCl to 5 L of Millipore water, and the acidified water was replaced 3 times over a 24 h duration. The polymer solution in the dialysis bag was transferred to a round bottomed flask. Water was then evaporated with a rotary evaporator (70 °C, 1 h, 120 rpm) and a solid PIM1 in the round bottomed flask was obtained. To transfer the PIM1 for freeze-drying, 10 ml water was added to polymer solution and the concentrated PIM1 solution was decanted into a falcon tube (50 mL) and then freeze-dried at -80 °C to afford pure PIM1 (yield: ~ 1 g). The obtained PIM1 was characterized by gel permeation chromatography (GPC) and nuclear magnetic resonance (NMR).

For low molecular weight of PIM (LMW PIM): a first solution of 1,4-diminobutane (5 g, 56.73 mmol) in acetic acid (133.6 mL) was maintained in an ice water bath for 30 min. Next, an acidic solution of formaldehyde (4.60 g of 37% formaldehyde solution, 56.73 mmol) and glyoxal (8.23 g of 40% glyoxal, 56.73 mmol) in acetic acid:THF (200 mL:100 mL) was added dropwise to the first mixture over 10 min at 0 °C (in ice water bath). The following steps were then the same as that of ULMW PIM.

For high molecular weight of PIM (HMW PIM): similar to the synthesis of ULMW PIM1, the only difference from it was the reduced amount of 1,4-diminobutane (0.784 mol).

Nuclear Magnetic Resonance (NMR)

NMR spectra were recorded on either a Bruker Avance DPX 300 (1H and 13C NMR at 300 MHz and 75.47 MHz respectively) or a Bruker Avance III 400 (1H and 13C NMR at 400.13 MHz and 101.62 MHz respectively). The data was processed using TopSpin (version 4.1.3), which referenced the spectra to those of the residual solvents. Chemical shifts (δ) were quoted in parts per million (ppm) and coupling constants (J) were reported to the nearest 0.01 Hz for 1H NMR and 0.1 Hz for 13C NMR along with peak multiplicities using the following abbreviations: s, singlet; d, doublet; t, triplet; q, quartet; qu, quintet; sext, sextet; m, multiplet, and br, broad.

Gel Permeation Chromatography (GPC)

Products were characterized by Waters GPC using a water phase ultra hydrogel column as the stationary phase and sodium acetate/acetic acid buffer (pH = 4.5) as the mobile phase. All samples were dissolved in the buffer solution with approx. 1 mg/mL final concentration and
 5 filtered through a 0.22 µm microfilter before sample analysis.

Minimum Inhibition Concentration (MIC)

Minimum inhibition concentrations (MICs) were measured following a standard broth dilution method with minor modification (Zhong, W.; Shi, Z.; Mahadevegowda, S. H.; Liu, B.; Zhang, K.; Koh, C. H.; Ruan, L.; Chen, Y.; Zeden, M. S.; Pee, C. J. E.; Marimuthu, K.; De, P. P.; Ng, O. T.; Zhu, Y.; Chi, Y. R.; Hammond, P. T.; Yang, L.; Gan, Y. H.; Pethe, K.; Greenberg, E. P.; Grundling, A.; Chan-Park, M. B., Designer broad-spectrum polyimidazolium antibiotics. *Proc Natl Acad Sci USA* **2020**, *117* (49), 31376-31385.), and is set out below. Briefly, subcultures of overnight bacterial strains were grown to mid-log phase, followed by optical
 15 density (OD) check, then diluted to reach 1×10^6 CFU/mL bacteria concentration (CFU: colony forming unit). A two-fold dilution series of polymer solution was prepared in MHB media in a 96 well-plate, and prepared bacteria suspension was added into each well with positive control (MHB media and bacteria suspension without polymer) and sterilized control (only MHB media). The plate was mixed in a shaker incubator for 10 min before moving to a 37 °C
 20 incubator, and was incubated for 18 h, followed by OD measurement. MIC value was noted at the lowest concentration for which 90% bacteria growth inhibition was observed. Agar plating was done to confirm the seeding bacteria concentration. Three independent experiments were conducted for each polymer.

25 The OD measurements were conducted in the manner discussed in *PNAS*, **2020**, *117*, 31376.

Results and Discussions

The NMR and GPC spectra of PIM1-ULMW, PIM1-LMW, and PIM1-HMW were shown in FIGs. 1-2, FIGs. 3-4, and FIGs. 5-6, respectively. Further, PIM polymers showed good antibacterial activity, with MIC₉₀ mostly in range of 1-4 µg/mL against both Gram-positive (MRSA BAA40
 30 and USA300) and Gram-negative (PAO1 and EC8739) bacteria (Table 1).

Table 1. GPC and antibacterial activity of PIM1 with different MW.

Entry	GPC			MIC ₉₀ (µg/ml)			
	Mn	Mw	PDI	PAO1	EC8739	MRSA BAA40	MRSA USA300

PIM1- ULMW- Batch1	1165	1625	1.08	1-2	4	1	1
PIM1- LMW	3542	4673	1.32	2	4	1	1
PIM1- HMW	10582	16437	1.55	1	2-4	1-2	1

Example 2. Antimicrobial Efficacy of LMW PIM1 and HMW PIM1

For screening purpose, we first tested the antimicrobial efficacy of PIM1 as well as other commercially available QUATs in the presence of a commercial anionic laundry detergent surfactant formulation (100 ppm) in a liquid suspension test. Here, PIM1 polymers with two different molecular weights were used: (1) low molecular weight (LMW, ~ 3.5 kDa); and (2) high molecular weight (HMW, ~10 kDa).

Cell Cytotoxicity Assay

In vitro biocompatibility was investigated using 3T3 cell line. Briefly, 3T3 cells were cultured in Dulbecco's Modified Eagle's Medium (DMEM) supplemented with 10% fetal bovine serum (FBS) and 1% antibiotics (penicillin/streptomycin) in 37 °C CO₂ incubator. Cells were harvested when 80% confluence was reached, and cells concentration was counted and calculated with a hemocytometer. 1×10⁴ cells/well were seeded into a 96-well plate and grown for 24 h; followed by 24 h treatment with varied concentration of polymers, cell viability was then qualitatively evaluated with microscopy and quantified via MTT (3-[4,5-dimethylthiazoyl-2-yl]-2,5-diphenyl tetrazolium bromide) assay following manufacture's protocol. The cell viability was expressed as a ratio of cell population size treated with polymer compared to control (cells without polymer treatment).

Liquid Detergent Test

E. coli ATCC8739 bacteria suspension was prepared from 2nd or 3rd subculture on trypticase soy agar (TSA) plates and adjusted to a concentration of 1.5×10⁸ to 5×10⁸ CFU/mL with diluent. Product/polymer solution were prepared in water at desired concentration. The polymer/active compound were prepared and diluted into 8mL working solution containing 125 ppm P&G detergent in a 50 mL falcon tube. 1 mL water were added into the tube and mix well by vortexing for 30 s. 1 mL bacteria suspension were then added to the falcon tube, immediately vortex-mixed and let sit in rack holder at room temperature. The final concentration of detergent in the suspension is 100 ppm. After contact time of 5 min or 10 min, the suspension was mixed (vortex), and 1 mL of the suspension were transferred to a new container with 8 mL

neutralizer (42.8g of modified Letheen broth, 10g of polysorbate 80 (Tween 80), 9.3g of Lecithin in 1L of purified water) and 1 mL water, mixed and let sit for 5 min. After neutralization, 1 mL of the above solution were immediately transferred to a petri dish with duplicate, mixed well with 12-15 mL melted Luria broth (LB) agar (with temperature around 45 °C) and cool to solidify. The plates were incubated at 37 °C for 18-24 h to count the colony.

Cloth Test

The P&G cloth test follows the industrial standard method ASTM E 2274-03 with minor modifications (FIG. 7). 3.8 mL *E. coli* ATCC8739 in 0.85 wt% NaCl suspension (1.5×10^8 to 5×10^8 CFU/mL) were mixed with 0.2 mL horse serum. 20 µL bacteria solution and 10 µL DI water were inoculated onto sterile cloth (3 pieces). The spindle (holder for the bacteria-inoculated cloth) were properly setup and piece of cloth were placed between layer 2 and 3 of the spindle; 2 pieces of cloths were placed between layer 3 and 4. The whole spindle were put into 250 mL detergent solution containing 100 ppm P&G detergent and desired concentration of polymers. The container was sealed well and placed into a washing machine. The container was tumbled in the washing machine for 10 min. Afterwards, the cloth pieces from spindle were removed and put in neutralizer using a sterile tweezer, vortex-mixed at max speed for 1 min before serial diluted to determine colony forming unit (CFU).

Results and Discussions

From Table 2, LMW PIM1 at as low as 50 ppm showed the best performance, and completely eradicated the bacteria both in DI and in the liquid detergent (with $>8 \log_{10}$ reduction). This is superior to all the other commercial antimicrobials including polyethyleneimines (PEIs), many other polycations (such as polydiallyl dimethylammonium chloride (PDADMAC), polyMETformin (PMET), polyallylamine hydrochloride (PAH), and Poly-L-lysine) (*ACS Applied Nano Materials* **2020**, 3 (3), 2654-2664) and other essential oils that have been previously reported. Interestingly, HMW PIM1 showed reduced efficacy compared to LMW PIM1, highlighting that molecular weight affects the killing efficacy probably through fouling.

Table 2. Liquid detergent test of PIMs, PEIs, Polycations and essential oils in deionized water (DI water) and a commercial detergent*.

	Compound	LOG REDUCTION		
			50 ppm	100 ppm
PIMs	LMW PIM	DI Water	8.94	8.94
		Detergent	8.94	8.94
	HMW PIM	DI Water	3.64	3.80
		Detergent	0.92	3.81
PEI	Linear PEI, 20 kDa	DI Water	2.95	8.53

	Compound	LOG REDUCTION		
			50 ppm	100 ppm
Other Polycations**	Branched PEI, 800 Da	Detergent	-0.12	8.26
		DI Water	1.69	1.74
	Branched PEI, 10 kDa	Detergent	-0.12	0.31
		DI Water	3.66	8.53
	Branched PEI, 25 kDa	Detergent	0.05	2.42
		DI Water	3.34	8.53
	PDADMAC	Detergent	0.32	2.26
		DI Water	-	8.64
	PMET	Detergent	-	0.07
		DI Water	-	1.44
	PAH	Detergent	-	0
		DI Water	-	0.9
Essential Oils	Poly-L-lysine	Detergent	-	3.27
		DI Water	-	1.1 ± 1.2
	Thymol	Detergent	-	5.6 ± 2.7
		DI Water	-	-
	Carvacrol	Detergent	50 ppm	200 ppm
		DI Water	0.82	0.82
	Eugenol	Detergent	-0.21	0.82
		DI Water	0.05	0.05
	Isoeugenol	Detergent	-0.06	-0.06
		DI Water	0.02	0.02

* The commercial detergent has an anionic surfactant to non-anionic surfactant mass ratio of 5:3.

** Reference: *ACS Applied Nano Materials* **2020**, 3 (3), 2654-2664

- 5 To ensure reproducibility, we synthesized two more batches of LWM PIM (RR-Batch 6 and RR-Batch 15) and tested on different days, yielding repetitive data with excellent efficacy (Table 3).

Table 3. Liquid detergent test of different batches of LMW PIMs

Batch	Date Tested	LOG REDUCTION			
			50 ppm	100 ppm	200 ppm
LMW PIM (RR Batch 1)	07 July 2018	DI Water	8.94	8.94	-
		Detergent	8.94	8.94	-
LMW PIM (RR Batch 6)	20 June 2018	DI Water	8.56	8.56	-
		Detergent	8.38	8.38	-
LMW PIM (RR Batch 15)	22 November 2018	DI Water	8.67	8.67	8.67
		Detergent	8.90	8.90	8.90

10

The low molecular weight PIM (PIM LMW) were passed to a professional setup to test with the cloth test following industrial standard method ASTM E 2274-03. The preliminary aim of

5 this test is to find a formulation that can achieve more than 2 log₁₀ reduction of *E. coli* bacteria colony forming unit (CFU) on a fabric in 10 min at ≤ 50ppm active ingredient in a liquid detergent (containing 100 ppm of a commercial detergent). The testing results are summarized in Table 4. PIM LWM at 50 ppm alone was not effective to reduce the bacteria count on fabric cloth, but increasing its concentration to 100 ppm could achieve > 2 log₁₀ reduction within 10 minutes.

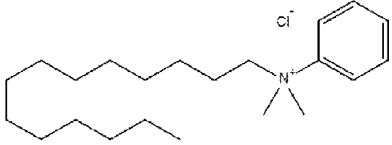
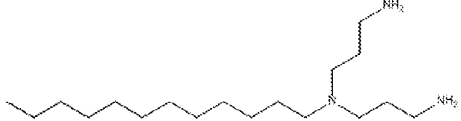
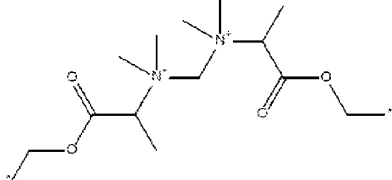
Table 4. P&G testing information of PIM (LMw).

Active 1	ppm	LogR	Experiment Date	Inoculum
PIM (LMw)	50	-0.066	20 July 2018	5.13E+07
		-0.174	4 August 2018	5.28E+07
		0.018	6 July 2018	8.01E+07
PIM (LMw)	100	2.657	6 July 2018	8.01E+07
		2.877	20 July 2018	5.13E+07

10 **Example 3. Synergistic Effect of PIM LMW with Additional Active Agents**

In order to further reduce PIM1 concentration while maintaining efficacy, a few other antimicrobial agents such as polyethyleneimine (PEI) with various molecular weights and architectures (i.e., linear 20 kDa, branched 25 kDa, branched 60 kDa, branched 600 kDa), and other cationic agents (Table 5) were added as the second active agent to attempt to achieve a synergistic effect with PIM.

Table 5. Structures of active compound 2 (in FIG. 8b) to achieve synergistic effect with PIM.

Active 2	Active 2 Properties	Chemical Structure
BAC	Benzylkonium chloride	
LonzaBac	Primary amine (diamine); Bis (3-aminopropyl) dodecylamine	
S100 (Tama)	Gemini quat	

Active 2	Active 2 Properties	Chemical Structure
BTMS	Behentrimonium methosulfate (and cetearyl alcohol (quat surfactant))	
ZPB	Trans-sulphated ethoxylated hexamethylene diamine quaternary zwitterion	
PEI 1 Linear	Polyethylenimine (linear, 20kDa)	
PEI Branched	Polyethylenimine (branched) 25kDa, 60kDa and 600kDa	
PCDMA	Chelator; polymer with n=34 repeating units	
HPNO	Chelator 2-pyridinol-1-oxide	
HIDS	Chelator tetrasodium 3-hydroxy-2,2'-iminodisuccinate	

Results and Discussions

The combination of 50 ppm PIM LMW + 50 ppm of 25 kDa branched PEI (Entry #5 of FIG. 8a) achieved the best performance with log reduction of 1.9, 2.2, 1.7 respectively in three independent tests. The tests were done in different days across a period of 20 days, indicating good reproducibility of the data. The next promising combination, 50 ppm PIM LMW + 50 ppm of 60 kDa branched PEI (Entry #7 of FIG. 8a) achieved an average log reduction of 1.5 from three independent tests (0.9, 1.6, 2.0 respectively). The slightly reduced performance indicated that increasing PEI molecular weight to 60 kDa did not improve killing. The synergistic effect of PIM was studied with other quaternary ammonium salts and chelating agents, but the effect was not as significant and none of the combinations achieved the desired efficacy (FIG. 8b). The detailed testing information are listed in Table 5 and Table 6.

Table 6. P&G testing information of PIM (LMw) with different compounds.

Active 1	ppm	Active 2	ppm	LogR	Experiment Date	Inoculum
PIM (LMw)	50	BAC	50	0.868	20 July 2018	5.13E+07
				1.599	4 August 2018	5.28E+07
				0.610	8 August 2018	5.76E+07
PIM (LMw)	50	LonzaBac	50	0.933	3 August 2018	4.53E+07
PIM (LMw)	50	S100 (Tama)	50	0.949	3 August 2018	4.53E+07
PIM (LMw)	50	BTMS	50	1.060	3 August 2018	4.53E+07
PIM (LMw)	50	ZPB	50	0.750	3 August 2018	4.53E+07
PIM (LMw)	50	PEI 1 Linear 20 kDa	50	0.180	20 July 2018	5.10E+07
				3.199	4 August 2018	5.28E+07
PIM (LMw)	50	PEI 2 Branched 25 kDa	50	1.895	20 July 2018	5.13E+07
				2.152	4 August 2018	5.28E+07
				1.689	8 August 2018	5.76E+07
	25		75	1.197	8 August 2018	5.76E+07
	0		75	0.531	8 August 2018	5.76E+07
PIM (LMw)	50	PCDMA	50	0.265	20 July 2018	5.10E+07
PIM (LMw)	50	HPNO	50	0.445	20 July 2018	5.10E+07
PIM (LMw)	50	HIDS	50	0.289	20 July 2018	5.10E+07
PIM (LMw)	50	PEI (60 kDa)	50	0.937	6 September 2018	6.09E+07
PIM (LMw)	50	PEI (60 kDa)	50	1.573	6 September 2018	6.09E+07
PIM (LMw)	50	PEI (60 kDa)	50	1.995	13 September 2018	5.13E+07

PIM (LMw)	50	PEI (600 kDa)	50	2.408	13 September 2018	5.13E+07
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Following industrial standard method ASTM E 2274-03 (E2274-03, A., Standard Test Method for Evaluation of Laundry Sanitizers and Disinfectants. ASTM International: West Conshohocken, 2003), it was identified that PIM1, when used in synergy with polyethyleneimine (PEI) at optimized molecular weight, achieves more than 99% killing (2 log₁₀ reduction) of bacteria on the fabric in 10 minutes. In contrast, all the commonly used commercial antimicrobials tested under the same condition failed to achieve such efficacy.

Example 4. Antimicrobial Efficacy of ULMW PIM1

Inspired by the finding that reducing molecular weight from HMW (10 kDa) to LMW (3.8 kDa) could result in better antibacterial activity, we further tested the performance of ULMW PIM (ULMW, < 2 kDa), based on the protocols mentioned in the previous Examples.

Results and Discussions

We studied the antibacterial efficacy of different molecular weights of PIM polymer (50 ppm) with the synergistic pair PEI in cloth testing (Table 7). The combination of 50 ppm PIM ULMW + 50 ppm of 25 kDa branched PEI achieved the best antibacterial performance with log₁₀ reduction of 2.0. A possible explanation of this result could be due to the different adsorption ability of the three polymers onto the negative charged cotton cloth. We found that the higher molecular weight PIM polymer was more likely to be absorbed onto cloth making the cloth brownish, while the low molecular weight PIM polymer might remain active in solution without much loss caused by the cloth (FIG. 9).

Table 7. Cloth testing results of PIM with different molecular weights and PEI.

Active 1	ppm	Active 2	ppm	Log reduction	Experiment Date
PIM (ULMW)	50	PEI (25 kDa)	50	2.0	17 May 2019
PIM (LMW)	50	PEI (25 kDa)	50	1.0	17 May 2019
PIM (HMW)	50	PEI (25 kDa)	50	0.3	17 May 2019

We further confirmed the reproducibility of this result by synthesizing several batches of ULMW PIM. The NMR and GPC data showed that molecular weights were all less than 2 kDa from different batches (FIGs. 10-15 and Table 8). The antibacterial activity of the four batches remained similar trend. Intriguingly, the ultralow molecular weight of PIM1 polymer showed no

apparent toxicity towards 3T3 mammalian cells with the IC₅₀ (50% inhibition concentration) higher than 1024 µg/mL, demonstrating the excellent biocompatibility (FIG. 16

Table 8. GPC and Antibacterial activity of PIM1-ULMW with different batches.

Entry	GPC			MIC ₉₀ (µg/ml)			
	Mn	Mw	PDI	PAO1	EC8739	MRSA BAA40	MRSA USA300
PIM1-ULMW-Batch1	1165	1625	1.08	1-2	4	1	1
PIM1-ULMW-Batch2	1256	1415	1.13	1	4	1	2
PIM1-ULMW-Batch3	1840	2180	1.18	1	4	1	1-2
PIM1-ULMW-Batch4	1139	1230	1.08	1	2-4	1	1

5

Further industrial cloth test results again showed that the combination of ULMW PIM (50 ppm) and PEI (25 kDa, 50 ppm) could achieve 2.6, 3.3, 3.3 and 3.4 log₁₀ reduction by batch 1, batch 2, batch 3 and batch 4, respectively (Table 9). The tests were done in different days across a period of 1 month with different batches of ULMW PIM polymers, indicating good reproducibility of the data. Moreover, we found that the optimized molecular weight of the ULMW PIM should be at the range of 1200 Da to 1500 Da. Overall, the results showed that the synthesis of PIM1-ULMW are reproducible and have the potential for industrialization.

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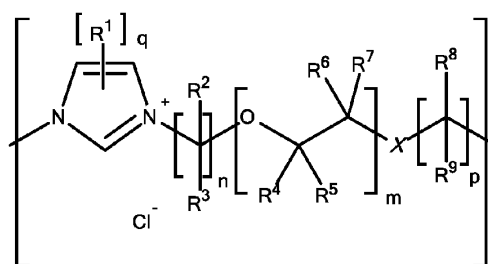
Table 9. Cloth testing results of ULMW PIM with different batches of PIM.

Active 1	ppm	Active 2	ppm	Log reduction	Experiment Date
PIM (ULMW)-B1	50	PEI (25 kDa)	50	2.6	21 May 2019
PIM (ULMW)-B2	50	PEI (25 kDa)	50	3.3	22 May 2019
PIM (ULMW)-B3	50	PEI (25 kDa)	50	3.3	29 May 2019
PIM (ULMW)-B4	50	PEI (25 kDa)	50	3.4	1 July 2019

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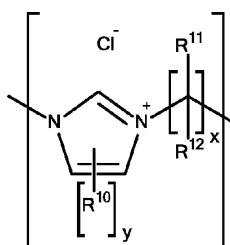
Claims

1. An antimicrobial composition, comprising:
a cationic polymer; and
at least one anionic surfactant.
2. The antimicrobial composition according to Claim 1, wherein a relative concentration of the cationic polymer to the at least one anionic surfactant is from 1:1 to 1:5, such as from 1:1.5 to 1:3, such as about 1:2.
3. The antimicrobial composition according to Claim 1 or Claim 2, wherein the cationic polymer has a number average molecular weight of less than 3,500 Daltons, such as less than 2,500 Daltons, such as from 800 to 2,000 Daltons such as from 1,000 to 1,600 Daltons, such as from 1,200 to 1,500 Daltons.
4. The antimicrobial composition according to any one of the preceding claims, wherein the cationic polymer is selected from one or more of the group consisting of a polyazolium and an oligoazolium, optionally wherein:
the polyazolium, when present, is selected from one or more of the group consisting of a polyimidazolium, a polytriazolium, and a polythiazolium; and/or
the oligoazolium, when present, is selected from one or more of the group consisting of an oligoimidazolium, an oligotriazolium, and an oligothiazolium.
5. The antimicrobial composition according to any one of the preceding claims, wherein the cationic polymer is a polyimidazolium or an oligoimidazolium having a repeating unit of formula (I):



(I)

or is a copolymer comprising the repeating unit of formula (I) and a repeating unit of formula (II):



(II)

wherein:

Cl⁻ in each of formula (I) and (II) represents a chloride counterion or any other suitable counterion;

R¹ and R¹⁰, when present, independently represent C₁₋₆ alkyl;

each R² to R⁸ and R¹¹ independently represent H or C₁₋₆ alkyl;

each R⁹ and R¹² independently represents H, C₁₋₆ alkyl or CO₂R¹³;

R¹³ represents H or C₁₋₆ alkyl;

X represents CR¹⁴R¹⁵, O or S;

R¹⁴ and R¹⁵ independently represent H, C₁₋₆ alkyl or CO₂R¹³;

m is a number selected from 0 to 5;

n is a number selected from 2 to 10;

p is a number selected from 0 to 5;

q is a number selected from 0 to 3;

x is a number selected from 2 to 10;

y is a number selected from 0 to 3; and

solvates thereof,

provided that, when the polyimidazolium is a copolymer, the repeating unit of formula (I) and the repeating unit of formula (II) are not the same.

6. The antimicrobial composite material according to Claim 5, wherein:

R¹ and R¹⁰, when present, independently represent C₁₋₃ alkyl;

each R² to R⁸ and R¹¹ independently represents H or methyl;

each R⁹ and R¹² independently represents H, C₁₋₃ alkyl or CO₂R¹³;

R¹³ represents H or C₁₋₃ alkyl;

X represents CR¹⁴R¹⁵ or O;

R¹⁴ and R¹⁵ independently represent H, C₁₋₃ alkyl or CO₂R¹³;

m is a number selected from 0 to 4;
n is a number selected from 2 to 8;
p is a number selected from 0 to 3;
q is a number selected from 0 to 1;
x is a number selected from 2 to 8; and
y is a number selected from 0 to 1.

7. The antimicrobial composition according to Claim 5 or Claim 6, wherein:
each R^2 to R^8 and R^{11} independently represents H;
each R^9 and R^{12} independently represents H, methyl or CO_2H ;
X represents $\text{CR}^{14}\text{R}^{15}$ or O;
 R^{14} and R^{15} independently represent H, methyl or CO_2H ;
m is a number selected from 0 to 3;
n is a number selected from 2 to 7;
p is a number selected from 0 to 2;
q and y are 0; and
x is a number selected from 2 to 7.

8. The antimicrobial composition according to any one of Claims 5 to 7, wherein:
each R^2 to R^8 and R^{11} independently represents H;
each R^9 and R^{12} independently represents H, methyl or CO_2H ;
X represents $\text{CR}^{14}\text{R}^{15}$ or O;
 R^{14} and R^{15} independently represent H, methyl or CO_2H ;
m is a number selected from 0 to 2;
n is a number selected from 2 to 7;
p is a number selected from 0 to 2;
q and y are 0; and
x is a number selected from 2 to 7.

9. The antimicrobial composition according to any one of Claims 5 to 8, wherein the polyimidazolium is independently chain-terminated at each chain terminus by a group selected from OH, NH_2 , a zwitterionic species and a hydrazine group.

10. The antimicrobial composition according to any one of Claims 5 to 9, wherein the polyimidazolium has the repeating unit of formula (I).

11. The antimicrobial composition according to Claim 10, wherein:

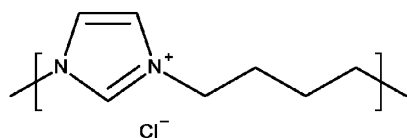
each of R^2 to R^8 are H;
 each R^9 represents H, methyl or CO_2H ;
 X represents CH_2 or O;
 m is a number selected from 0 to 2;
 n is a number selected from 2 to 6;
 p is a number selected from 0 to 2;
 q is 0.

12. The antimicrobial composition according to any one of Claims 5 to 11, wherein one or both of the following apply:

- (ia) when X is O, p is 1 or 2; and
- (ib) the polyimidazolium is terminated by amino (NH_2) groups.

13. The antimicrobial composition according to any one of Claims 5 to 12, wherein the repeating unit of formula (I) is selected from the group consisting of:

(i)

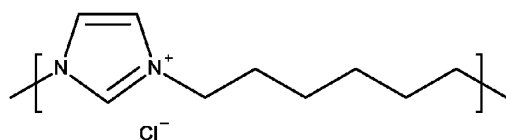


, where Cl^- represents a chloride counterion or

any other suitable counterion;

optionally wherein the number average molecular weight of the polymer is from 500 to 2,500 Daltons;

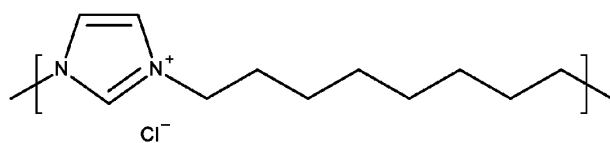
(ii)



, where Cl^- represents a chloride

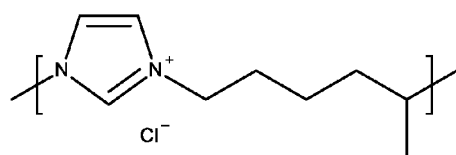
counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,500 Daltons;

(iii)



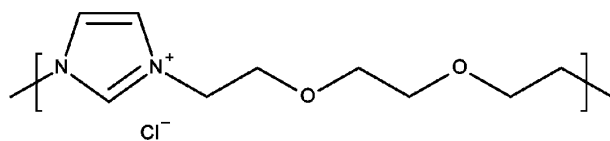
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,500 Daltons;

(iv)



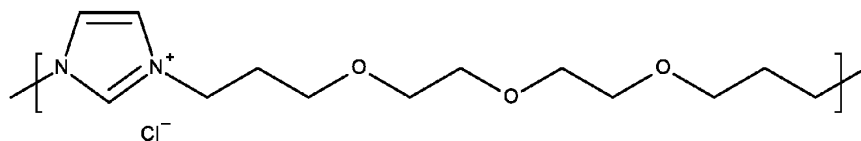
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,000 Daltons;

(v)



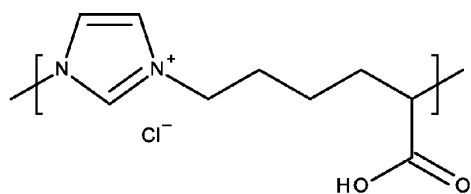
, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 1,000 to 2,500 Daltons;

(vi)



, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 1,000 to 2,500 Daltons; and

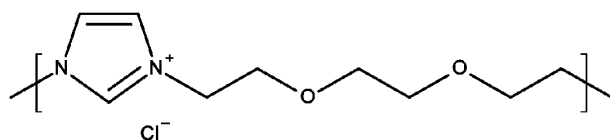
(vii)



, where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the polymer is from 500 to 2,000 Daltons,

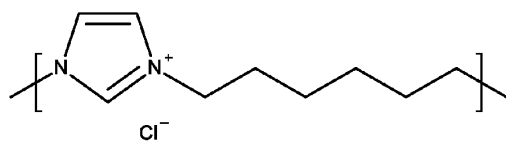
optionally wherein the repeating unit of formula (I) and formula (II) are selected from the group consisting of:

(i)



as the repeating unit of

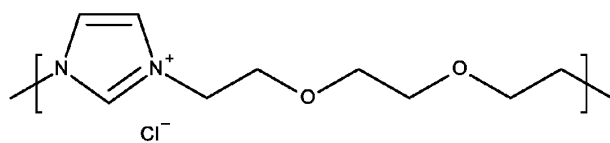
formula (I) and



as the repeating unit of formula (II),

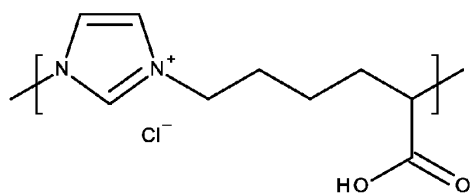
where Cl^- represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight of the copolymer is from 1,000 to 2,500 Daltons; and

(ii)



as the repeating unit of

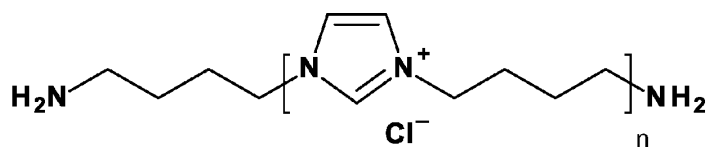
formula (I) and



as the repeating unit of formula (II), where

Cl^- represents a chloride counterion or any other suitable counterion in formula (I) and (II), optionally wherein the number average molecular weight of the copolymer is from 1,000 to 2,500 Daltons.

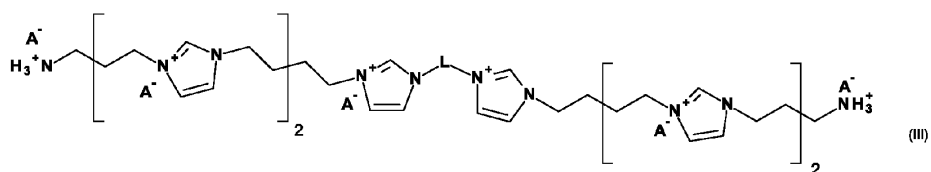
14. The antimicrobial composition according to any one of Claims 5 to 13, wherein the polyimidazolium is:



, where Cl^-

represents a chloride counterion or any other suitable counterion, optionally wherein the number average molecular weight is from 1,200 to 1,500 Daltons.

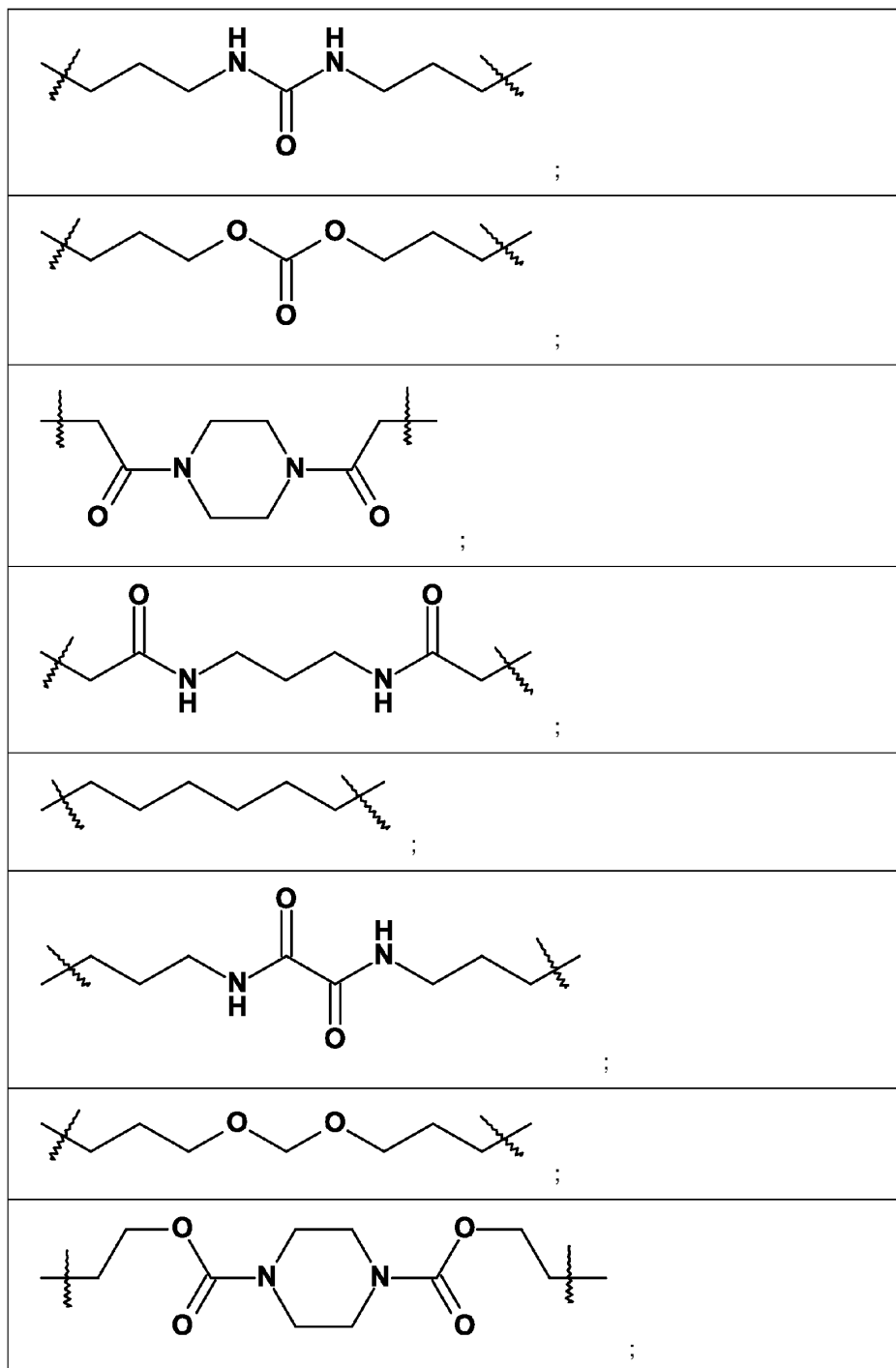
15. The antimicrobial composition according to any one of Claims 1 to 5, wherein the cationic polymer is an oligoimidazolium that is a compound of formula (III):

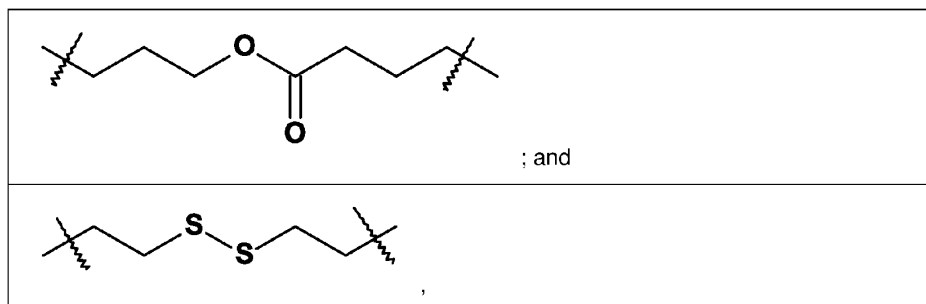


where:

A^- is any suitable counterion, such as Cl^- , Br^- and the like; and

L represents a linker selected from:





where the wiggly lines represent the point of attachment to the rest of the molecule.

16. The antimicrobial composition according to any one of the preceding claims, wherein the at least one anionic surfactant is selected from one or more of the group consisting of sodium dodecylbenzene sulfonate (SBDS), sodium lauryl sulfate (SLS), sodium laureth sulfate (SLES), sodium coco sulfate (SCS).

17. The antimicrobial composition according to any one of the preceding claims, wherein the antimicrobial composition further comprises a compound that comprises one or both of an amino group and an ammonium group.

18. The antimicrobial composition according to Claim 17, wherein the compound that comprises one or both of an amino group and an ammonium group is a polymeric compound comprising a plurality of amino and/or a plurality of ammonium groups.

19. The antimicrobial composition according to Claim 18, wherein the number average molecular weight of the polymeric compound comprising a plurality of amino and/or a plurality of ammonium groups is from 10 kDaltons to 600 kDaltons, such as from 20,000 Daltons to 30,000 Daltons, such as 25,000 Daltons.

20. The antimicrobial composition according to Claim 18 or Claim 19, wherein the compound that comprises one or both of an amino group and an ammonium group is a polyethyleneimine.

21. The antimicrobial composition according to Claim 20, wherein the polyethyleneimine is a branched polyethyleneimine.

22. The antimicrobial composition according to Claim 20 or Claim 21, wherein the number average molecular weight of the polyethyleneimine is from 20,000 Daltons to 30,000 Daltons, such as 25,000 Daltons.

23. The antimicrobial composition according to any one of Claims 17 to 22, wherein a relative concentration of the compound that comprises one or both of an amino group and an ammonium group to the at least one anionic surfactant is from 1:1 to 1:5, such as from 1:1.5 to 1:3, such as about 1:2.

24. The antimicrobial composition according to any one of Claims 17 to 22, wherein a relative concentration of the cationic polymer to the compound that comprises one or both of an amino group and an ammonium group is from 1:0.1 to 1:10, such as from 1:0.5 to 1:5, such as about 1:1.

25. The antimicrobial composition according to any one of the preceding claims, wherein the composition is a laundry detergent.

26. Use of an antimicrobial composition according to any one of Claims 1 to 24 as a detergent for washing an object, optionally wherein the object is an animal or human, a clothing article or a surface.

27. A method of using an antimicrobial composition according to any one of Claims 1 to 24 as a detergent for washing an object, comprising the steps of:

- (a) providing an antimicrobial composition according to any one of Claims 1 to 24; and
- (b) contacting the object with the antimicrobial composition and water for a period of time under conditions to effect washing of the object, optionally wherein the object is an animal or human, a clothing article or a surface.