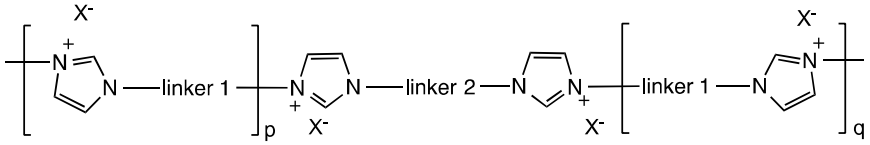
efficacy, high selectivity and fast killing kinetics against a broad range of bacteria and fungi. In this invention, a new series of imidazolium polymers and oligomers with various degradable linkers has been developed. The new imidazolium materials retain the excellent antimicrobial property of the previously reported materials against broad range of microbes, yet possess essential degradability and non-resistance properties. The new imidazolium materials have tuneable degradation profiles under different conditions which would have wide applications in agricultural and environmental disinfection.

Accordingly, there is a need for a new imidazolium compound that addresses or alleviates one or more disadvantages mentioned above. There is a need to provide an antimicrobial compound having desirable properties.

Summary

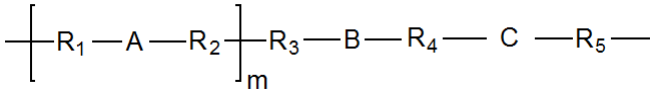
There is provided an oligomer of formula (I)



Formula (I)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;

p and q are independently an integer from 2 to 6, that is, 2, 3, 4, 5, or 6;

linker 2 is 

;

m is 0 or 1;

A is independently aryl or heteroaryl;

B is independently O, N or S;

C is independently aryl or heteroaryl;

R_1 is a bond or alkyl;

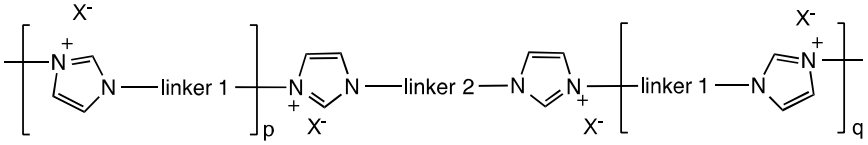
R_2 is a bond, alkoxy or amine;

R_3 is carbonyl, bond or alkyl;

R_4 is bond or alkyl; R_5 is alkyl; and

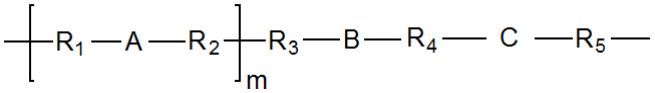
X is a halide selected from fluoride, chloride and bromide.

According to a first aspect, there is provided an oligomer of formula (I)



Formula (I)

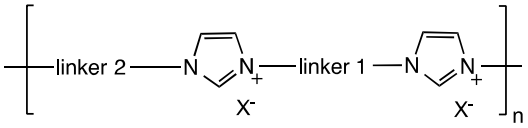
wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;
p and q are independently an integer from 2 to 6, that is, 2, 3, 4, 5, or 6;

linker 2 is 

;

m is 0 or 1;
A is independently aryl or heteroaryl;
B is independently O, NH or S;
C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl; R_5 is alkyl; and
X is a halide selected from fluoride, chloride and bromide.

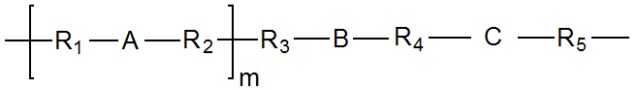
There is provided an oligomer or a polymer of formula (II)



Formula (II)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;

n is an integer from 3 to 30, that is, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 or 30;

linker 2 is 

;

m is 0 or 1;

A is independently aryl or heteroaryl;

B is independently O, N or S;

C is independently aryl or heteroaryl;

R_1 is a bond or alkyl;

R_2 is a bond, alkoxy or amine;

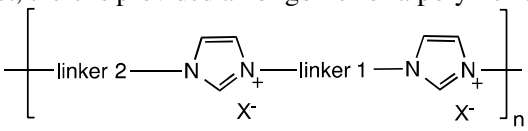
R_3 is carbonyl, bond or alkyl;

R_4 is bond or alkyl;

R_5 is alkyl; and

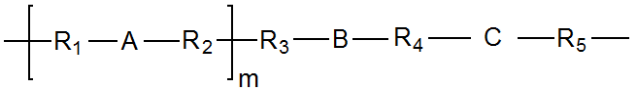
X is a halide selected from fluoride, chloride and bromide.

According to another aspect, there is provided an oligomer or a polymer of formula (II)



Formula (II)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;
n is an integer from 3 to 30, that is, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 or 30;

linker 2 is 

;

m is 0 or 1;

A is independently aryl or heteroaryl;

B is independently O, NH or S;

C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl;
R_5 is alkyl; and
X is a halide selected from fluoride, chloride and bromide.

Advantageously, the antimicrobial composition as defined herein may display an excellent antimicrobial activity against a broad range of microbes. More advantageously, the oligomer may be degradable and may have non-resistance property. The oligomer described herein may have a degradation profile that can be tuned under different conditions.

According to another aspect, there is provided an antimicrobial composition comprising the oligomer or the polymer as defined herein.

Advantageously, this means that the antimicrobial composition may not suffer from antimicrobial resistance. More advantageously, it may not be necessary to increase the dosage or concentration of the oligomer or polymer when used against the same microbe on the same surface or subject for a long period of time. Hence, the antimicrobial composition may be used against microbes that have developed a resistance to conventional antimicrobial drugs

There is provided an antimicrobial composition as defined herein for use in inhibiting microbial activity or for use in treating a microbial infection or disease.

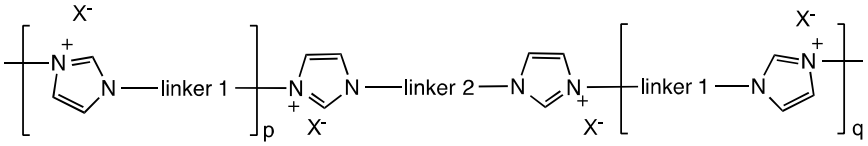
According to another aspect, there is provided an antimicrobial composition as defined herein for use in treating a microbial infection or disease.

According to another aspect, there is provided use of the antimicrobial composition as defined herein in the manufacture of a medicament for treating a microbial infection or disease.

There is provided a method of inhibiting a microbial activity or treating a microbial infection or disease comprising administering the antimicrobial composition as defined herein to a subject or applying the antimicrobial composition as defined herein on a surface.

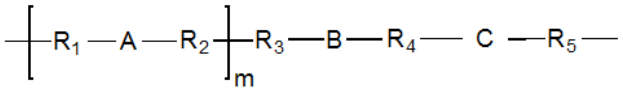
According to another aspect, there is provided an *in vitro* method of inhibiting a microbial activity comprising applying the antimicrobial composition as defined herein on a surface.

There is provided a method preparing an oligomer of formula (I)



Formula (I)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;
p and q are independently an integer from 2 to 6, that is 2, 3, 4, 5 or 6;

linker 2 is 

;

m is 0 or 1;
A is independently aryl or heteroaryl;
B is independently O, N or S;
C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl;
R_5 is alkyl;
X is halide selected from fluoride, chloride and bromide,
said method comprising the steps of:

a) providing a di-imidazole unit bearing linker 2 of Formula (III)



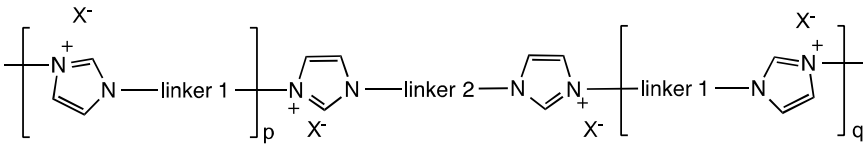
;

Formula (III)

b) mixing the di-imidazole of Formula (III) with an imidazolium salt that is dissolved in a suitable solvent to form a mixture; and

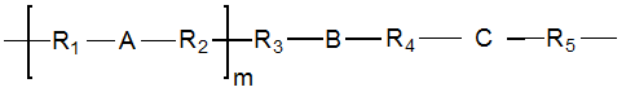
c) stirring the mixture obtained in step (b) under conditions to obtain said oligomer.

According to another aspect, there is provided a method of preparing an oligomer of formula (I)



Formula (I)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;
p and q are independently an integer from 2 to 6, that is 2, 3, 4, 5 or 6;

linker 2 is  ;

m is 0 or 1;
A is independently aryl or heteroaryl;
B is independently O, NH or S;
C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl;
R_5 is alkyl;
X is halide selected from fluoride, chloride and bromide,
said method comprising the steps of:

a) providing a di-imidazole unit bearing linker 2 of Formula (III)

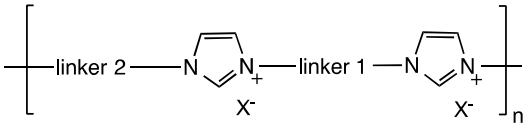


;

Formula (III)

b) mixing the di-imidazole of Formula (III) with an imidazolium salt that is dissolved in a suitable solvent to form a mixture; and
c) stirring the mixture obtained in step (b) under conditions to obtain said oligomer.

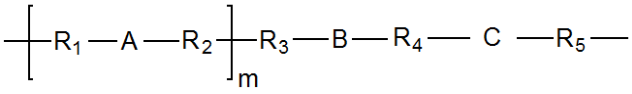
There is provided a method of preparing the oligomer or the polymer of Formula (II)



Formula (II)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;

n is an integer from 3 to 30, that is 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 or 30;

linker 2 is 

;

m is 0 or 1;

A is independently aryl or heteroaryl;

B is independently O, N or S;

C is independently aryl or heteroaryl;

R_1 is a bond or alkyl;

R_2 is a bond, alkoxy or amine;

R_3 is carbonyl, bond or alkyl;

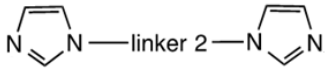
R_4 is bond or alkyl;

R_5 is alkyl; and

X is halide selected from fluoride, chloride and bromide,

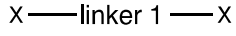
said method comprising the steps of:

a) mixing a di-imidazole unit bearing linker 2 of Formula (III):



Formula III

with a precursor bearing linker 1 of Formula (IV):

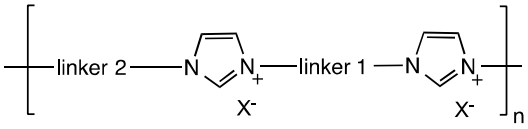


Formula IV

b) in a suitable solvent to form a mixture; and

stirring the mixture obtained in step (a) under conditions to obtain said polymer.

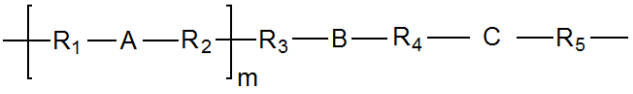
According to another aspect, there is provided a method of preparing the oligomer or the polymer of Formula (II)



Formula (II)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;

n is an integer from 3 to 30, that is 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 or 30;

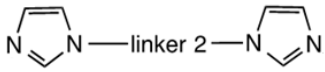
linker 2 is 

;

m is 0 or 1;

A is independently aryl or heteroaryl;
B is independently O, NH or S;
C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl;
R_5 is alkyl; and
X is halide selected from fluoride, chloride and bromide,
said method comprising the steps of:

a) mixing a di-imidazole unit bearing linker 2 of Formula (III):



Formula III

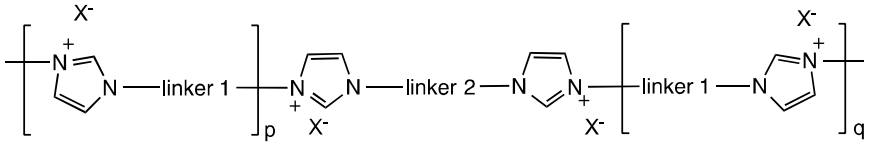
with a precursor bearing linker 1 of Formula (IV):



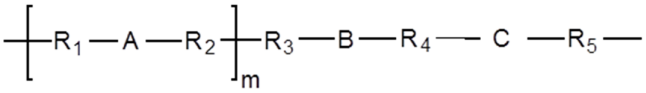
Formula IV

in a suitable solvent to form a mixture; and
stirring the mixture obtained in step (a) under conditions to obtain said polymer.

There is provided an antimicrobial gel comprising an oligomer of formula (I)



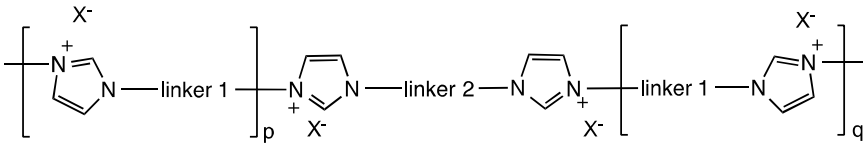
Formula (I)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;
p and q are independently an integer from 2 to 6, that is 2, 3, 4, 5, or 6;
linker 2 is 

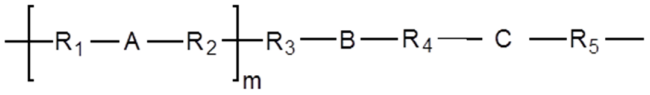
;
m is 0 or 1;

A is independently aryl or heteroaryl;
B is independently O, N or S;
C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl;
R_5 is alkyl; and
X is halide selected from fluoride, chloride and bromide.

According to another aspect, there is provided an antimicrobial gel comprising an oligomer of formula (I)



Formula (I)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;
p and q are independently an integer from 2 to 6, that is 2, 3, 4, 5, or 6;
linker 2 is 

;
m is 0 or 1;
A is independently aryl or heteroaryl;
B is independently O, NH or S;
C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl;
R_5 is alkyl; and
X is halide selected from fluoride, chloride and bromide.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term ‘oligomer’ as used herein refers to an oligomer whose molecules consist of relatively few repeating units, up to five in total of the same repeating units i.e. a repeating unit may be imidazolium, linker 1 or linker 2 of Formula (I), linker 1 or linker 2 of Formula (II), Formula (I), Formula (II) or any combinations thereof.

The term ‘polymer’ as used herein refers to a large molecule, or macromolecule, composed of many repeated units, up 30 in total of the same repeating units i.e. a repeating unit may be imidazolium, linker 1 or linker 2 of Formula (II), Formula (II) or any combinations thereof.

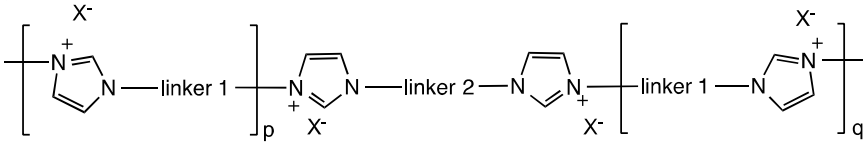
The term “degradation” as used herein refers to the ability of a compound to decompose under certain conditions, especially complex substances such as polymers and proteins, by stages, exhibiting well-defined intermediate products. During the degradation process, it is the conversion of the active oligomers to less active degradation product(s) that is indicative of the changes to the MIC values. Upon the degradation process, these intermediate products derived from the degradation process will be labelled as degradation products. These certain conditions can be neutral and/or basic conditions.

"Alkyl" as a group or part of a group refers to a straight or branched aliphatic hydrocarbon group to be interpreted broadly, having from 1 to 16 carbon atoms, eg, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 or 16 carbon atoms, preferably a C_1–C_{16} alkyl, C_1–C_{12} alkyl, more preferably a C_1-C_{10} alkyl, most preferably C_1-C_6 alkyl unless otherwise noted. Examples of suitable straight and branched alkyl substituents include but is not limited to, methyl, ethyl, 1-propyl, isopropyl, 1-butyl, 2-butyl, isobutyl, tert-butyl, amyl, 1,2-dimethylpropyl, 1,1-dimethylpropyl, pentyl, isopentyl, hexyl, 4-methylpentyl, 1-methylpentyl, 2-methylpentyl, 3-methylpentyl, 2,2-dimethylbutyl, 3,3-dimethylbutyl, 1,2-dimethylbutyl, 1,3-dimethylbutyl, 5-methylheptyl, 1-methylheptyl, octyl, nonyl, decyl, undecyl, 2,2,3-trimethyl-undecyl, dodecyl, 2,2-dimethyl-dodecyl, tridecyl, 2-methyl-tridecyl, 2-methyl-tridecyl, tetradecyl, 2-methyl-tetradecyl, pentadecyl, 2-methyl-pentadecyl, hexadecyl, 2-methyl-hexadecyl and the like. The alkyl may be optionally substituted with one or more groups as defined under the term "optionally substituted" below.

"Aryl" as a group or part of a group to be interpreted broadly denotes (i) an optionally substituted monocyclic, or fused polycyclic, aromatic carbocycle (ring structure having ring atoms that are all carbon) preferably having from 5 to 12 atoms per ring, wherein the optionally

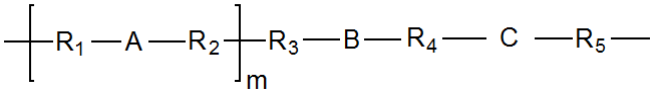
Claims

1. An oligomer of formula (I)



Formula (I)

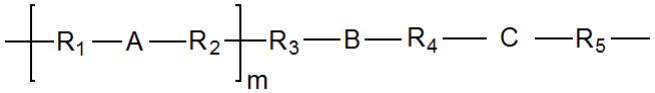
wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;
p and q are independently an integer from 2 to 6, that is, 2, 3, 4, 5, or 6;

linker 2 is 

;

m is 0 or 1;
A is independently aryl or heteroaryl;
B is independently O, NH or S;
C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl; R_5 is alkyl; and
X is a halide selected from fluoride, chloride and bromide.

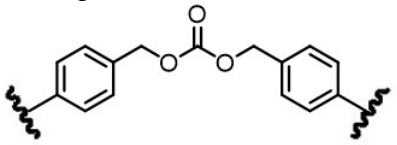
2. The oligomer of claim 1, wherein linker 2 is



;

m is 0 or 1;
A is aryl;
B is O or NH;
C is aryl;
R_1 is a bond, alkyl or absence;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl; and
R_5 is alkyl.

3. The oligomer of claim 1, wherein linker 2 is selected from the group consisting of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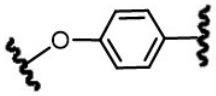
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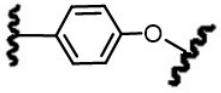
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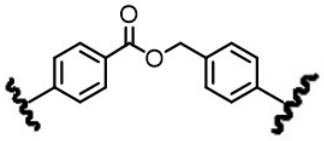
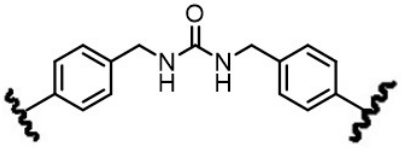

, and

.

4. The oligomer of any one of claims 1 to 3, wherein when linker 1 is alkyl-aryl-alkyl, said alkyl-aryl-alkyl is a C_{1-6}alkyl-phenyl-C_{1-6}alkyl.

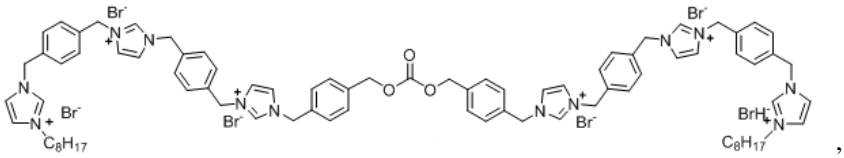
5. The oligomer of claim 4, wherein said C_{1-6}alkyl-phenyl-C_{1-6}alkyl is selected from the group consisting of *o*-xylene, *m*-xylene, *p*-xylene.

6. The oligomer of any one of claims 1 to 5, wherein the oligomer has a terminal group.

7. The oligomer of claim 6, wherein the terminal group is alkyl.

8. The oligomer of claim 7, wherein the alkyl group is a C_{1-14}-alkyl.

9. The oligomer of any one of claims 1 to 8, wherein the oligomer of formula (I) is selected from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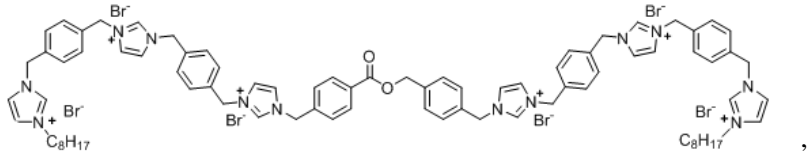
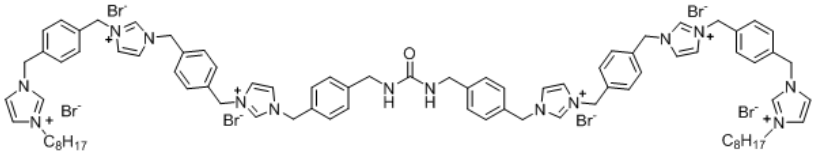
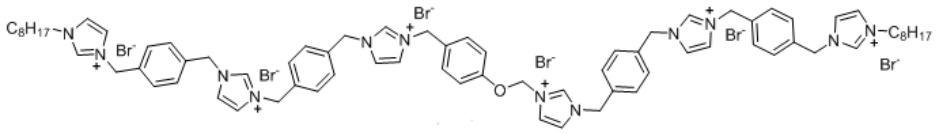
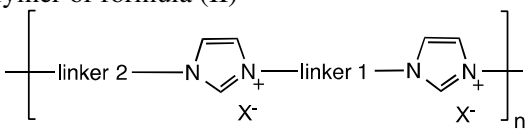

,


, and



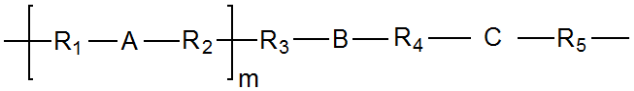
10. An oligomer or a polymer of formula (II)



Formula (II)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;

n is an integer from 3 to 30, that is, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 or 30;

linker 2 is 

;

m is 0 or 1;

A is independently aryl or heteroaryl;

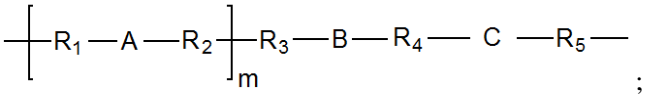
B is independently O, NH or S;

C is independently aryl or heteroaryl;

R_1 is a bond or alkyl;

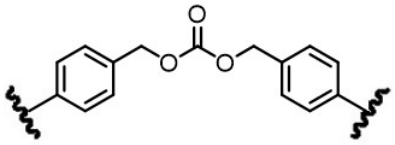
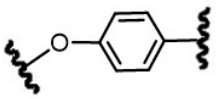
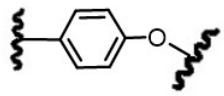
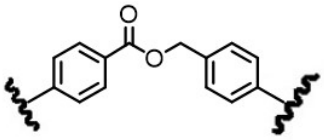
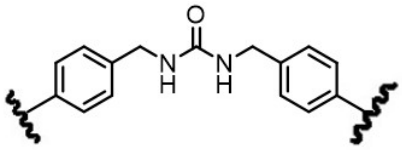
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl;
R_5 is alkyl; and
X is a halide selected from fluoride, chloride and bromide.

11. The oligomer or the polymer of claim 10, wherein linker 2 is



;

m is 0 or 1;
A is aryl;
B is O or NH;
C is aryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl; and
R_5 is alkyl.

12. The oligomer or the polymer of claim 10 or 11, wherein linker 2 is selected from the group consisting of  ,  ,  ,  , and  ..

13. The oligomer or the polymer of any one of claims 10 to 12, wherein when linker 1 is alkyl-aryl-alkyl, said alkyl-aryl-alkyl is a C_{1-6}alkyl-phenyl-C_{1-6}alkyl.

14. The oligomer or the polymer of claim 13, wherein said C_{1-6}alkyl-phenyl-C_{1-6}alkyl is selected from the group consisting of *o*-xylene, *m*-xylene, *p*-xylene.

15. The oligomer or the polymer of any one of claims 10 to 14, wherein the polymer has a terminal group selected from the group consisting of linker 2, an imidazolium ring and a combination thereof.

16. An antimicrobial composition comprising the oligomer or the polymer as defined in any one of claims 1 to 15.

17. An antimicrobial composition of claim 16 for use in treating a microbial infection or disease.

18. The antimicrobial composition for use of claim 17, wherein said antimicrobial composition inhibits the activity or treats the infection or disease caused by a microbe that is selected from the group consisting of *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa, Bacillus subtilius, Klebsiella pneumonia, Cryptococcus neoformans* and *Candida albicans*.

19. The antimicrobial composition for use of claim 18, wherein when said microbe is contacted with said antimicrobial composition at a defined concentration, the microbial activity of said microbe is reduced to 1%, preferably to 0.5%, more preferably to 0.1%.

20. The antimicrobial composition for use of claim 19, wherein said defined concentration of said antimicrobial composition is in the range of 1 μg/ml to 100 μg/ml.

21. The antimicrobial composition for use of claim 19 or 20, wherein the reduction of the microbial activity is achieved within a duration of 0.5 minutes to 120 minutes.

22. The antimicrobial composition for use of any one of claims 18 to 21, wherein the microbe is not resistant to said antimicrobial composition.

23. Use of the antimicrobial composition of claim 16 in the manufacture of a medicament for treating a microbial infection or disease.

24. The use of claim 23, wherein the microbial infection or disease is caused by a microbe that is selected from the group consisting of *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa, Bacillus subtilius, Klebsiella pneumonia, Cryptococcus neoformans*and *Candida albicans*.

25. An *in vitro* method of inhibiting a microbial activity comprising applying the antimicrobial composition of claim 16 on a surface.

26. The *in vitro* method of claim 24, wherein said antimicrobial composition inhibits the activity caused by a microbe that is selected from the group consisting of *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa, Bacillus subtilius, Klebsiella pneumonia, Cryptococcus neoformans* and *Candida albicans*.

27. The *in vitro* method of claim 26, wherein when said microbe is contacted with said antimicrobial composition at a defined concentration, the microbial activity is reduced to 1%.

28. The *in vitro* method of claim 27, wherein said defined concentration of said antimicrobial composition is in the range of 1 μg/ml to 100 μg/ml.

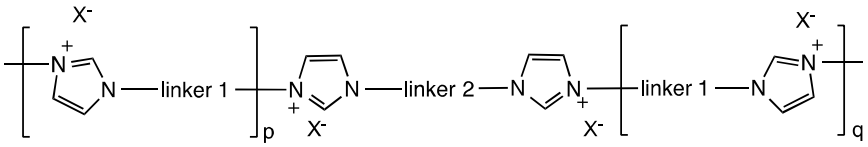
29. The oligomer or polymer of any one of claims 1 to 15, wherein said oligomer or polymer is capable of being cleaved at linker 2.

30. The oligomer or polymer of claim 29, wherein cleaving of linker 2 is achieved under neutral or basic conditions.

31. The oligomer or polymer of claim 30, wherein said basic condition is at a pH of more than 7, that is pH 8 to pH 14.

32. The oligomer or polymer of any one of claims 29 to 31, wherein the cleaved oligomer or polymer is inactive against a microbe.

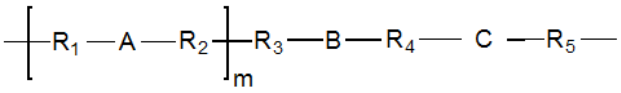
33. A method of preparing an oligomer of formula (I)



Formula (I)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;

p and q are independently an integer from 2 to 6, that is 2, 3, 4, 5 or 6;

linker 2 is  ;

m is 0 or 1;

A is independently aryl or heteroaryl;

B is independently O, NH or S;

C is independently aryl or heteroaryl;

R_1 is a bond or alkyl;

R_2 is a bond, alkoxy or amine;

R_3 is carbonyl, bond or alkyl;

R_4 is bond or alkyl;

R_5 is alkyl;

X is halide selected from fluoride, chloride and bromide,

said method comprising the steps of:

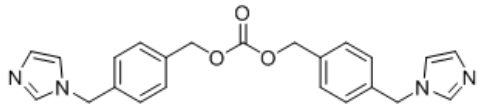
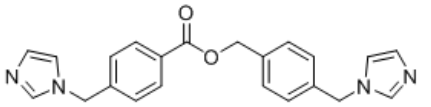
a) providing a di-imidazole unit bearing linker 2 of Formula (III)  ;

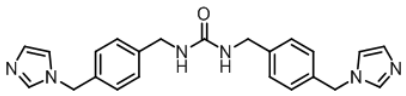
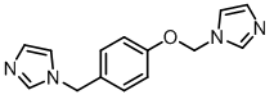
Formula (III)

b) mixing the di-imidazole of Formula (III) with an imidazolium salt that is dissolved in a suitable solvent to form a mixture; and

c) stirring the mixture obtained in step (b) under conditions to obtain said oligomer.

34. The method of claim 33, wherein the di-imidazole unit bearing linker 2 of Formula (III) is selected from the group consisting of

 ,  ,

 and  .

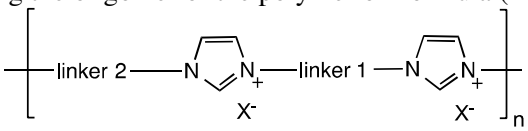
35. The method of claim 33, wherein the imidazolium salt is selected from the group consisting of bisimidazolium salt, trisimidazolium salt, tetraimidazolium salt, pentaimidazolium salt and hexaimidazolium salt.

36. The method of any one of claims 32 to 34, wherein the solvent is selected from the group consisting of dimethylformamide (DMF), dimethyl sulfoxide (DMSO), acetone and acetonitrile.

37. The method of any one of claims 33 to 36, wherein said condition in step (c) comprises a temperature of 20 °C to 30 °C.

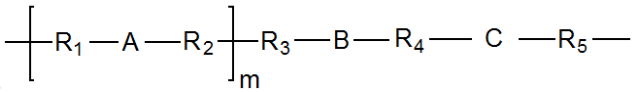
38. The method of any one of claims 33 to 37, wherein said step (c) is undertaken for a time period in the range of 18 hours to 60 hours.

39. A method of preparing the oligomer or the polymer of Formula (II)



Formula (II)

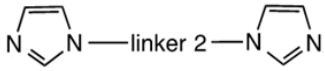
wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;
n is an integer from 3 to 30, that is 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 or 30;

linker 2 is 

;

m is 0 or 1;
A is independently aryl or heteroaryl;
B is independently O, NH or S;
C is independently aryl or heteroaryl;
R_1 is a bond or alkyl;
R_2 is a bond, alkoxy or amine;
R_3 is carbonyl, bond or alkyl;
R_4 is bond or alkyl;
R_5 is alkyl; and
X is halide selected from fluoride, chloride and bromide,
said method comprising the steps of:

a) mixing a di-imidazole unit bearing linker 2 of Formula (III):



Formula III

with a precursor bearing linker 1 of Formula (IV):

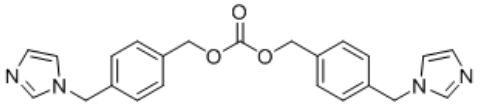


Formula IV

in a suitable solvent to form a mixture; and

b) stirring the mixture obtained in step (a) under conditions to obtain said polymer.

40. The method of claim 39, wherein the di-imidazole unit bearing linker 2 of Formula (III) is selected from the group consisting of



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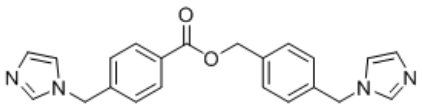

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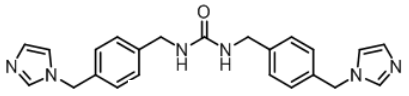
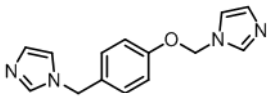
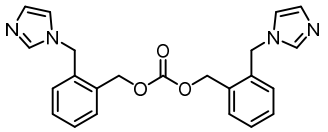
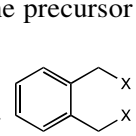
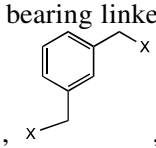
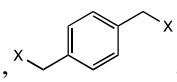
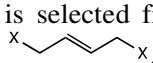
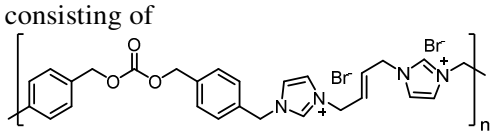
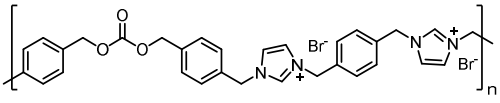
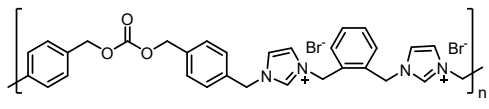
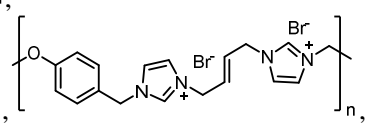
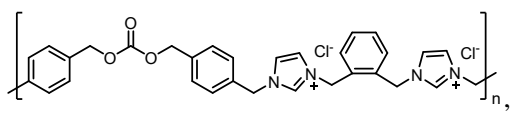
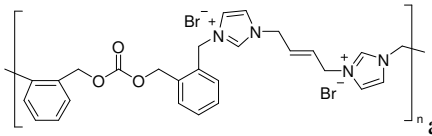
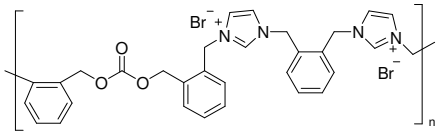
 ,  and  .

41. The method of claim 39 or 40, wherein the precursor bearing linker 1 of Formula (IV) is selected from the group consisting of  ,  ,  , and  .

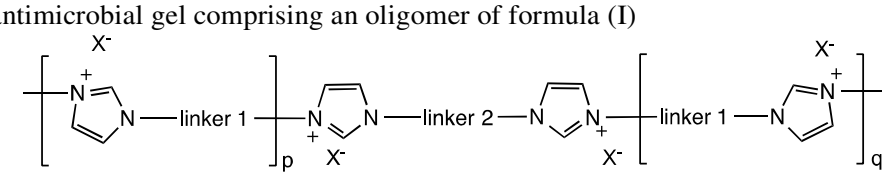
42. The method of claim 39, wherein the polymer of Formula (II) is selected from the group consisting of  ,  ,  ,  ,  ,  and  .

43. The method of any one of claims 39 to 42, wherein said condition in step (b) comprises a temperature of 20 °C to 30 °C.

44. The method of any one of claims 39 to 43, wherein step (b) is undertaken for a period of time in the range of 30 minutes to 48 hours.

45. The method of any one of claims 39 to 44, optionally further comprises the step of heating said mixture.

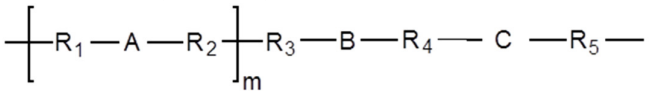
46. An antimicrobial gel comprising an oligomer of formula (I)



Formula (I)

wherein linker 1 is an alkyl-aryl-alkyl group or (C_2-C_8)alkene;

p and q are independently an integer from 2 to 6, that is 2, 3, 4, 5, or 6;

linker 2 is  ;

m is 0 or 1;

A is independently aryl or heteroaryl;

B is independently O, NH or S;

C is independently aryl or heteroaryl;

R_1 is a bond or alkyl;

R_2 is a bond, alkoxy or amine;

R_3 is carbonyl, bond or alkyl;

R_4 is bond or alkyl;

R_5 is alkyl; and

X is halide selected from fluoride, chloride and bromide.

47. The gel of claim 46, wherein the gel is formed in alcohol.