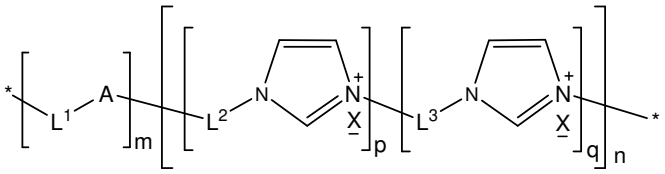
applications, cationic polymers have limited residual toxicity since they are more difficult to permeate through skin. Compared to low-molecular-weight QACs, cationic polymers have higher positive charge density which promotes initial adsorption onto the negatively charged bacterial surfaces and disruption of cellular membranes, resulting in significantly enhanced antibacterial activity. However, a drawback for some of the cationic polymers is that they can lead to hemolysis, which is one of the more harmful side effects of many cationic polymers.

Accordingly, there is a need for a new series of polymers that have antimicrobial properties and which address or alleviate one or more disadvantages mentioned above.

Summary

According to an example, there is provided a polymer having the following Formula (I):



Formula (I)

wherein

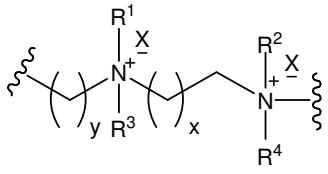
L^1, L^2 and L^3 are independently selected from the group consisting of optionally substituted alkyl, optionally substituted alkenyl, optionally substituted alkynyl, optionally substituted aryl, optionally substituted alkenylalkyl, optionally substituted alkylalkenyl, optionally substituted alkylalkenylalkyl, optionally substituted arylalkyl, optionally substituted arylalkenyl, optionally substituted arylalkynyl, optionally substituted alkylaryl, optionally substituted alkenylaryl, and optionally substituted alkynyl aryl;

X is independently selected from a halogen;

n, m and p are independently an integer of at least 1;

q is 0 or an integer of at least 1;

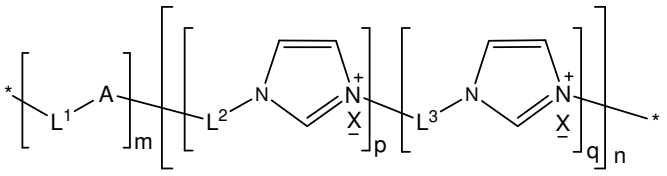
A has the following structure:



wherein R^1, R^2, R^3 and R^4 are independently selected from an optionally substituted alkyl, or any two of R^1, R^2, R^3 and R^4 may be taken together to form at least one bridging group, and

x and y are independently an integer of at least 1, or a salt or hydrate thereof.

In an aspect, there is provided a polymer having the following Formula (I):



Formula (I)

wherein

L^1, and L^2 are independently selected from the group consisting of optionally substituted alkyl, optionally substituted alkenyl, optionally substituted alkynyl, optionally substituted aryl, optionally substituted alkenylalkyl, optionally substituted alkylalkenyl, optionally substituted alkylalkenylalkyl, optionally substituted arylalkyl, optionally substituted arylalkenyl, optionally substituted arylalkynyl, optionally substituted alkylaryl, optionally substituted alkenylaryl, and optionally substituted alkynyl aryl;

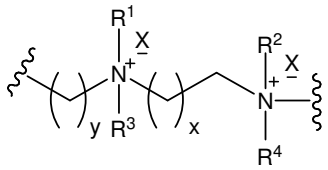
L^3 is arylalkyl, wherein the aryl of the arylalkyl is *ortho*-phenylene;

X is independently selected from a halogen;

n is an integer of at least 2;

m, p and q are independently an integer of at least 1;

A has the following structure:



wherein R^1, R^2, R^3 and R^4 are independently selected from an optionally substituted alkyl, or any two of R^1, R^2, R^3 and R^4 may be taken together to form at least one bridging group, and

x and y are independently an integer of at least 1,

or a salt or hydrate thereof.

Advantageously, the ammonium-imidazolium copolymers as defined herein may display antimicrobial activity against a broad range of microbe or microorganism. More advantageously, the ammonium-imidazolium copolymer may also display antifungal activity a broad range of fungal species. Most of the ammonium-imidazolium copolymers may show much higher activity against fungi compared to single component imidazolium or ammonium polymers. More advantageously, the copolymer may be biocompatible and degradable with non-resistance property. These copolymers may be non-hemolytic.

According to another aspect, there is provided a composition comprising the polymer as defined herein or a salt or hydrate thereof, in association with a carrier.

Advantageously, the ammonium-imidazolium copolymers may not suffer from antimicrobial resistance. More advantageously, the ammonium-imidazolium copolymers may be used against microbe or microorganism that has developed a resistance to conventional antimicrobial drugs.

According to another example, there is provided use of the polymer as defined herein or the composition as defined herein as a non-therapeutic agent for killing or inhibiting the growth of a microorganism.

In another aspect, there is provided a non-therapeutic use of the polymer as defined herein, or the composition as defined herein, as a non-therapeutic agent for killing or inhibiting the growth of a bacterium, fungus or any mixture thereof.

According to another aspect, there is provided a pharmaceutical composition comprising the polymer as defined herein or a pharmaceutically acceptable salt or hydrate thereof, in association with a pharmaceutically acceptable carrier.

According to another example, there is provided a method for killing or inhibiting the growth of a microorganism, the method comprising administering to a subject the polymer as defined herein or the pharmaceutical composition as defined herein.

According to another example, there is provided a polymer as defined herein or a pharmaceutical composition as defined herein, for killing or inhibiting the growth of a microorganism.

In another aspect, there is provided a polymer as defined herein or a pharmaceutical composition as defined herein, for killing or inhibiting the growth of a bacterium, fungus or any mixture thereof.

According to another example, there is provided use of the polymer as defined herein or the pharmaceutical composition as defined herein, in the manufacture of a medicament for killing or inhibiting the growth of a microorganism.

In another aspect, there is provided the use of the polymer as defined herein or the pharmaceutical composition as defined herein, in the manufacture of a medicament for killing or inhibiting the growth of a bacterium, fungus or any mixture thereof.

According to another example, there is provided a method for treating a microbial infection, the method comprising administering to a subject the polymer as defined herein or the pharmaceutical composition as defined herein.

According to another aspect, there is provided a polymer as defined herein or a pharmaceutical composition as defined herein for use as an antibiotic.

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

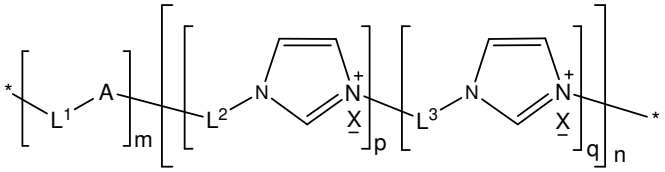
In another aspect, there is provided use of the polymer as defined herein or the pharmaceutical composition as defined herein, in the manufacture of a medicament for treating an infection by a bacterium, fungus or any mixture thereof.

According to another aspect, there is provided a method for preparing the polymer as defined herein, comprising the steps of:

contacting a diamine having the following structure:

Claims

1. A polymer having the following Formula (I):



Formula (I)

wherein

L^1, and L^2 are independently selected from the group consisting of optionally substituted alkyl, optionally substituted alkenyl, optionally substituted alkynyl, optionally substituted aryl, optionally substituted alkenylalkyl, optionally substituted alkylalkenyl, optionally substituted alkylalkenylalkyl, optionally substituted arylalkyl, optionally substituted arylalkenyl, optionally substituted arylalkynyl, optionally substituted alkylaryl, optionally substituted alkenylaryl, and optionally substituted alkynyl aryl;

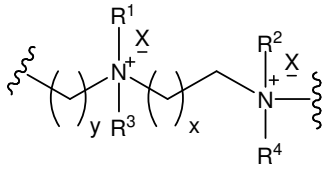
L^3 is arylalkyl, wherein the aryl of the arylalkyl is *ortho*-phenylene;

X is independently selected from a halogen;

n is an integer of at least 2;

m, p and q are independently an integer of at least 1;

A has the following structure:



wherein R^1, R^2, R^3 and R^4 are independently selected from an optionally substituted alkyl, or any two of R^1, R^2, R^3 and R^4 may be taken together to form at least one bridging group, and

x and y are independently an integer of at least 1,

or a salt or hydrate thereof.

2. The polymer according to claim 1, wherein n is an integer between 2 and 50 and m is an integer between 1 and 50.

3. The polymer according to claim 1, wherein x and y are independently an integer between 1 and 5.

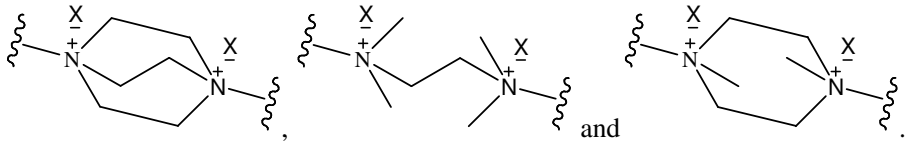
4. The polymer according to claim 3, wherein x and y are independently 1.

5. The polymer according to any one of the preceding claims, wherein any two of R^1, R^2, R^3 and R^4 is taken together to form at least one C_2 to C_5 bridging group.

6. The polymer according to claim 5, wherein R^1 and R^2 are taken together to form an ethenylene group.

7. The polymer according to claim 6, wherein R^3 and R^4 are taken together to form an ethenylene group.

8. The polymer according to any one of claims 5 to 7, wherein A is selected from the group consisting of the following structures:

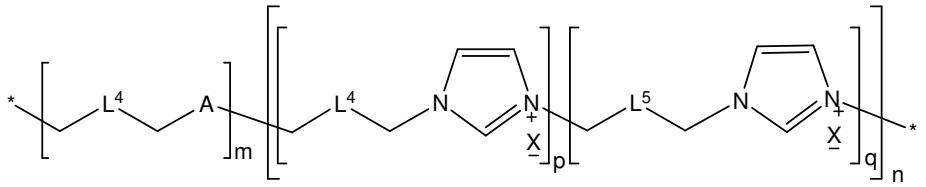


9. The polymer according to any one of the preceding claims, wherein the molar ratio between (L^1 + L^2) and L^3 is in the range of 1:5 to 5:1.

10. The polymer according to any one of the preceding claims, wherein the polymer has a molecular weight in the range of 1000 to 10,000.

11. The polymer according to any one of the preceding claims, wherein the polymer has a polydispersity value in the range of 1.2 to 3.2.

12. The polymer according to any one of the preceding claims, having the following Formula (II):



Formula (II)

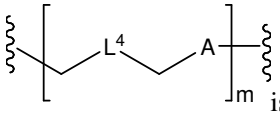
wherein

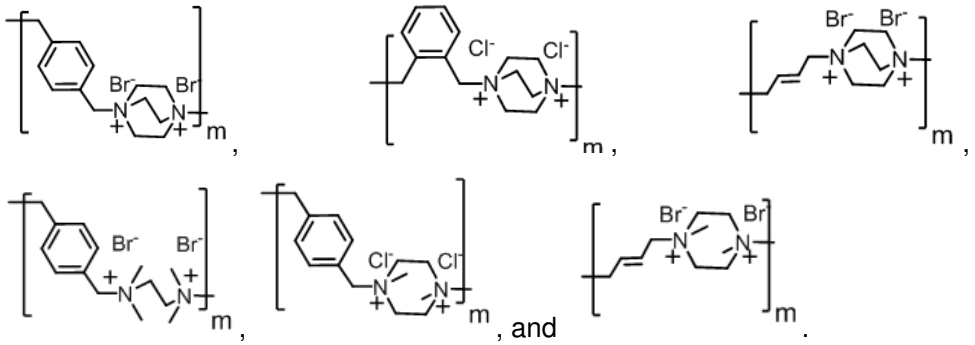
L^4 is selected from optionally substituted alkenyl or optionally substituted aryl; and

L^5 is *ortho*-phenylene.

13. The polymer according to claim 12, wherein L^4 is selected from the group consisting of *ortho*-phenylene group, *para*-phenylene group, *meta*-phenylene group and ethenylene.

14. The polymer according to any one of the preceding claims, wherein X is Cl or Br.

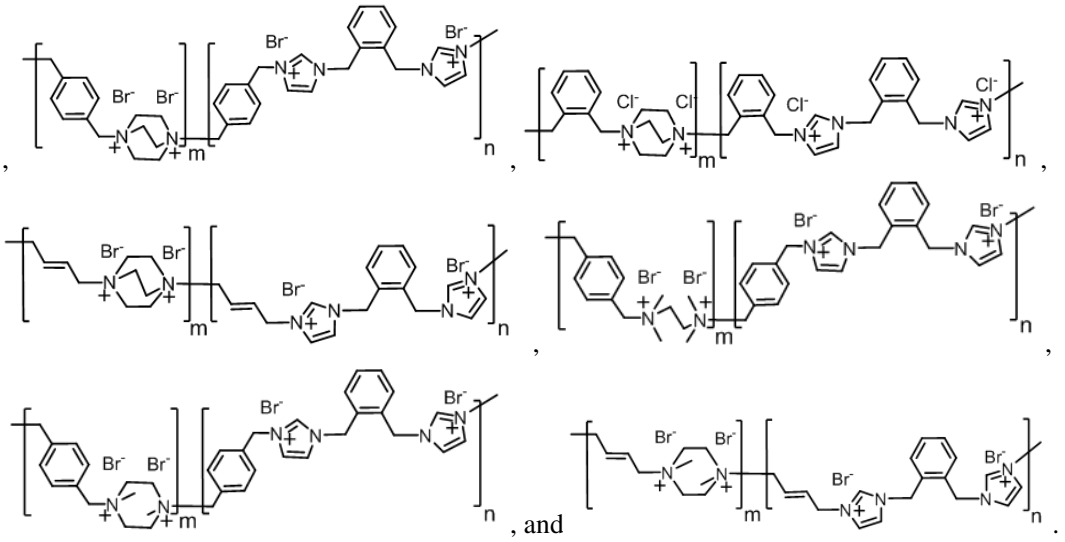
15. The polymer according to any one of claims 12 to 14, wherein the following portion in formula (II):  is selected from the group consisting of the following structures:



16. The polymer according to any one of the preceding claims, wherein p and q are independently an integer between 1 and 5.

17. The polymer according to claim 16, wherein p and q are independently 1.

18. The polymer according to any one of the preceding claims, selected from the group consisting of:



19. A composition comprising the polymer according to any one of the preceding claims, or a salt or hydrate thereof, in association with a carrier.

20. Non-therapeutic use of the polymer according to any one of claims 1 to 18, or the composition according to claim 19, as a non-therapeutic agent for killing or inhibiting the growth of a bacterium, fungus or any mixture thereof.

21. A pharmaceutical composition comprising the polymer according to any one of claims 1 to 18, or a pharmaceutically acceptable salt or hydrate thereof, in association with a pharmaceutically acceptable carrier.

22. A polymer according to any one of claims 1 to 18, or a pharmaceutical composition according to claim 21, for killing or inhibiting the growth of a bacterium, fungus or any mixture thereof.

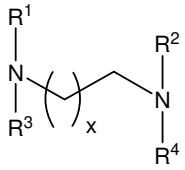
23. Use of the polymer according to any one of claims 1 to 18, or the pharmaceutical composition according to claim 21, in the manufacture of a medicament for killing or inhibiting the growth of a bacterium, fungus or any mixture thereof.

24. A polymer according to any one of claims 1 to 18, or a pharmaceutical composition according to claim 21 for use as an antibiotic.

25. Use of the polymer according to any one of claims 1 to 18, or the pharmaceutical composition according to claim 21, in the manufacture of a medicament for treating an infection by a bacterium, fungus or any mixture thereof.

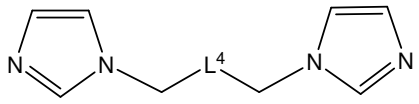
26. A method for preparing the polymer according to any one of claims 12 to 18, comprising the steps of:

contacting a diamine having the following structure:



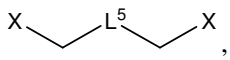
, wherein R^1, R^2, R^3 and R^4 are independently selected from an optionally substituted alkyl, or any two of R^1, R^2, R^3 and R^4 is taken together to form at least one bridging group; and x is an integer of at least 1;

with a di-imidazole having the following structure:



, wherein L^4 is selected from the group consisting of *ortho*-phenylene group, *para*-phenylene group, *meta*-phenylene group and ethenylene;

and a dihalide having the following structure:



, wherein L^5 is *ortho*-phenylene group; and X is a halide;

under reaction conditions.

27. The method according to claim 26, wherein the diamine and di-imidazole are contacted at a molar ratio in the range of 1:5 to 5:1.

28. The method according to claim26, wherein di-imidazole and dihalide are contacted at a molar ratio in the range of 1:6 to 5:6.

29. The method according to any one of claims 26 to28, wherein the reaction is performed in a polar organic solvent, wherein the polar solvent is tetrahydrofuran (THF), dimethylformamide (DMF) or any mixture thereof.

30. The method according to any one of claims 26 to29, wherein the reaction is carried out at a temperature in the range of 60 °C to 100 °C.

31. The method according to any one of claims 26 to30, wherein the reaction is carried out for at least 18 hours.