These materials are secured in a pass-through housing through which water may be flowed for antimicrobial purification.

[0015] U.S. Pat. Pub. No. 2011-0086078 (Gooch et al., Apr. 14, 2011) discloses fibrous antimicrobial materials for uses including water filtration. The materials are prepared from miscibly blended solids of bisguanides such as chlorhexidine with thermoplastic polymers, e.g. polyolefins. The materials are useful as extruded fibers or in the particulate form for preparing nonwoven materials. Methods for formation and use are also taught.

[0016] U.S. Pat. No. 7,427,409 (Gooch et al., Sep. 23, 2008) discloses broad spectrum antimicrobial materials for fluid treatment, where the materials include biguanide hydrates and bases, in particular a hydrate of chlorhexidine, $C_{22}H_{30}$ $C_{12}N_{10}(H_2O)$ for water purification.

[0017] Nevertheless, the use of chlorhexidine poses special problems for filtration because the recovered fluid must be essentially pure. Chlorhexidine base is ~0.08% soluble in water at room temperature, which though it seems low, is still above the EPA's zero-solubility mandate for substances and devices used in water purification. The limit of detection for chlorhexidine in aqueous fluids is commonly in the range of 1 μg/mL (0.0001% by weight, or 0.000002 M), which is about five order of magnitude below the solubility limit. Hence, use of neat chlorhexidine for purification has not been an option for inline aqueous purification in residential and other point-of-use systems.

[0018] In any case, with or without chlorhexidine the pathogen problem has remained real and ongoing. For instance, the U.S. Centers for Disease Control (CDC) reports that the incidence of legionella has grown nine-fold since 2000, and in 2018 about 10,000 patients were diagnosed with it. The CDC suggests that this number is likely low because the disease tends to be underdiagnosed. Moreover, legionella is fatal in about 10% of the cases. However, the pathogenic contamination problem extends far beyond Lp1, as is evident from the current coronavirus pandemic, which is thought to spread in large part through air.

[0019] Thus, there is an ongoing need for systems, methods and devices that can sanitize fluids such as air and water. And there is a further need in the art for systems that can meet the minimum EPA specifications for microbicidal action without leaving significant chemical residues in fluid media.

BRIEF SUMMARY OF THE INVENTION

[0020] The invention provides systems for sanitizing fluids such as water and air. In particular, the invention provides a combination of solid chlorhexidine and a polymer matrix, for which effluents are essentially free of leached chlorhexidine. The systems enable rapid disinfecting of fluids, including in line at the point of use, and can be employed for both high volume applications and disposable single-use applications.

[0021] In particular, the present invention provides a microbicidal filtration system comprising:

- **[0022]** a) a set of solid chlorhexidine (CX) particles having the following characteristics:
  - **[0023]** i) a purity of at least 97.0% chlorhexidine by weight, when any presence of counterions or water molecules is factored out; and
  - **[0024]** ii) no more than 3.0% by weight of chloroaniline impurities, when any presence of counterions or water molecules is factored out;
  - **[0025]** iii) the CX particles are each characterized in having a releasing surface from which molecular chlorhexidine may dissolve into an aqueous medium that passes over them or dissolve into a polymer matrix that is juxtaposed at that surface.
  - **[0026]** iv) a particle phase composition selected from the group consisting of amorphous, crystalline, and mixed amorphous and crystalline, wherein the phase composition of each particle is the same as or independent of the phase composition of a majority of other CX particles in the set;
- **[0027]** b) a porous matrix having the following characteristics:
  - **[0028]** i) when any presence of chlorhexidine and of chloroaniline impurities is factored out, at least 90% of the matrix by dry weight is constituted by one or more polymers that do not dissolve in water;
  - **[0029]** ii) the porous matrix has exposed polymer surfaces that are capable of trapping chlorhexidine from an aqueous fluid in which the chlorhexidine is dissolved; and
  - **[0030]** iii) the matrix has a permeability of at least 100 millidarcies relative to water;
- **[0031]** c) disposal of the CX particles and porous matrix in a relative manner to form a microbicidal filter wherein:
  - **[0032]** i) the chlorhexidine particles are permanently affixed to the porous matrix;
  - **[0033]** ii) the affixed chlorhexidine particles comprise from 0.5% to 95% of the combined weight of the porous matrix and the chlorhexidine particles affixed thereto;
  - **[0034]** iii) when the fluid is aqueous, release of dissolved chlorhexidine from the microbicidal filter into a flow of aqueous fluid is essentially fully counterbalanced by trapping of dissolved chlorhexidine at the exposed polymer surfaces in the porous matrix, such that at a rate of aqueous fluid flow of 0.3 to 1.3 liter/(minute*square inch) through the microbicidal filter:
    - **[0035]** A) effluent from the filtered fluid flow is free of any detectable taste and odor of chlorhexidine;
    - **[0036]** B) dissolved chlorhexidine, if present in the effluent, is present at less than 3.00 milligrams per liter of effluent;
    - **[0037]** C) each of 2-, 3-, or 4-chloroaniline, if present in the effluent, is present at less than 0.100 milligrams per liter of effluent; and
    - **[0038]** D) such full counterbalancing is sustainable for a throughput volume of at least 800 gallons of water at room temperature per cubic inch of foam in a microbicidal filter; and
- **[0039]** d) microbicidal capacity such that, within the sustainable throughput volume at the rate of aqueous flow shown in (c)(iv)(D), the filter kills or otherwise inactivates pathogens from an influent, such that at a minimum the reduction of live cells between influent and effluent occurs to a degree selected from the group consisting of the following: