A NEW METHOD FOR REMOVING AND INACTIVATING WATER-BORNE PATHOGENS UTILIZING SILANE TREATED MATERIALS

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METHOD OF INACTIVATION AND REMOVAL OF PATHOGENS

INACTIVATION OCCURS THROUGH LYSIS (DISRUPTION) OF CELLULAR WALLS

BACTERIA, VIRUS,Protozoa AND FUNGUS PRESENT ON SURFACE.

SILANE SOLUTION DESTROYS AND ELIMINATES PATHOGENS ON CONTACT

2005 International Symposium on Household Water Management
EVAPORATION OF WATER

ANTISEPTIC SURFACE COATED WITH POLYMERIC FILM; PATHOGENS DESTROYED

ADDITIONAL BACTERIA, VIRUSES, PROTOZOA AND FUNGI CONTACTING COATED SURFACE ARE KILLED.

POST-SILANE SOLUTION TREATMENT
TESTING OF POINT OF USE (POU) DEVICES

SET OF THREE FILTERS PACKED WITH TREATED ZEOLITES - ALL RESULTS ARE SINGLE PASS

EXPERIMENTAL SETUP

Testing was done at Arizona State University, Water Quality Center, Tempe, AZ US
Zeolites supplied by Northern Filter Media, Inc., Muscatine, IA US
BACTERIOPHAGE INACTIVATION/REMOVAL

- 3 Filter Sets Employed
- Bacteriophages tested MS2, PRD1
- Log Inactivation/Removal for MS2 ranged 2.40 (99.60%) to 2.96 (99.89%)
- Average Inactivation/Removal MS2 2.8 log (99.84%)
- Log Inactivation/Removal for PRD1 ranged 1.50 (96.83) to 2.27 (99.46%)
- Average Inactivation/Removal PRD1 2.0 log (99.00%)
BACTERIA INACTIVATION/REMOVAL

- 3 Filter Sets Employed
- Bacteria tested *Klebsiella terriena* and *E. coli*
- Log Inactivation/Removal for *Klebsiella terriena* ranged 2.20 (99.37%) to 2.40 (99.60%)
- Average Inactivation/Removal *Klebsiella terriena* 2.3 log (99.50%)
- Log Inactivation/Removal for *E. coli* ranged 3.50 (99.96) to 4.39 (99.99%)
- Average Inactivation/Removal *E. coli* 3.88 log (99.98%)

![Graph 1](image1)

Klebsiella Removal/Inactivation

![Graph 2](image2)

Removal and Inactivation of E. coli
ALGAE INACTIVATION/REMOVAL

- 3 Filter Sets Employed
- Algae tested *Chorella vulgaris*
- Log Inactivation/Removal for *Chorella vulgaris* ranged 1.90 (98.74%) to 2.05 (99.11%)
- Average Inactivation/Removal *Chorella vulgaris* 1.95 log (98.86%)
3 Filter Sets Employed

*Cryptosporidium parvum* oocysts tested

Log Inactivation/Removal for *C. parvum* oocysts ranged 1.34 (95.40%) to 2.15 (99.30%)

Average Inactivation/Removal *C. parvum* oocysts 1.68 log (97.90%)
## DYNAMIC SHAKE FLASK TEST

- **Inactivation of *Staphylococcus aureus* with treated cotton**

<table>
<thead>
<tr>
<th>Exposure (Min.)</th>
<th># Viable cells/ml Untreated</th>
<th># Viable cells/ml Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.3x10^6</td>
<td>2.8x10^6</td>
</tr>
<tr>
<td>10</td>
<td>2.7x10^6</td>
<td>2.5x10^6</td>
</tr>
<tr>
<td>30</td>
<td>3.9x10^6</td>
<td>1.0x10^6</td>
</tr>
<tr>
<td>120</td>
<td>4.3x10^6</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>
## DYNAMIC SHAKE FLASK TEST

- Inactivation of *Staphylococcus aureus* with treated leather (pigskin)

<table>
<thead>
<tr>
<th>Exposure (Min.)</th>
<th># Viable cells/ml Untreated</th>
<th>#Viable cells/ml Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.4x10^6</td>
<td>5.0x10^6</td>
</tr>
<tr>
<td>10</td>
<td>4.4x10^6</td>
<td>5.6x10^6</td>
</tr>
<tr>
<td>30</td>
<td>4.0x10^6</td>
<td>3.4x10^6</td>
</tr>
<tr>
<td>120</td>
<td>5.0x10^6</td>
<td>1</td>
</tr>
</tbody>
</table>
DYNAMIC SHAKE FLASK TEST

- Inactivation of *Staphylococcus aureus* with rinsed leather

<table>
<thead>
<tr>
<th>Number of 1 second</th>
<th>Time Zero</th>
<th>30 Min. Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Treatments</td>
<td># Viable cells per ml</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1.0x10^6</td>
<td>&lt;1x10^4</td>
</tr>
<tr>
<td>1</td>
<td>2.5x10^6</td>
<td>&lt;1x10^4</td>
</tr>
<tr>
<td>2</td>
<td>1.7x10^6</td>
<td>&lt;1x10^4</td>
</tr>
<tr>
<td>3</td>
<td>8.0x10^6</td>
<td>&lt;1x10^4</td>
</tr>
<tr>
<td>4</td>
<td>1.3x10^6</td>
<td>&lt;1x10^4</td>
</tr>
<tr>
<td>5</td>
<td>1.1x10^6</td>
<td>&lt;1x10^4</td>
</tr>
<tr>
<td>6</td>
<td>1.4x10^5</td>
<td>&lt;1x10^4</td>
</tr>
<tr>
<td>9</td>
<td>4.1x10^5</td>
<td>&lt;1x10^4</td>
</tr>
<tr>
<td>Untreated</td>
<td>1.0x10^7</td>
<td>1.2x10^7</td>
</tr>
</tbody>
</table>
## DYNAMIC SHAKE FLASK TEST

- **Inactivation of Staphylococcus aureus** with polypropylene fabric

<table>
<thead>
<tr>
<th>Exposure (Min.)</th>
<th># Viable cells/ml Untreated</th>
<th># Viable cells/ml Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.6x10^6</td>
<td>3.1x10^6</td>
</tr>
<tr>
<td>10</td>
<td>2.8x10^6</td>
<td>4.0x10^5</td>
</tr>
<tr>
<td>30</td>
<td>3.7x10^6</td>
<td>2.1x10^3</td>
</tr>
<tr>
<td>120</td>
<td>4.0x10^6</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>
Inactivation of Pathogens in Containers

Eight-ounce containers constructed of glass, polyethylene (HDPE), polypropylene (PP) and poly vinyl chloride (PVC) were coated with 1% aqueous solution of silane.

Water containing $10^7$ bacteria/ml introduced Time 0. After 24 hours, bacteria counts measured $<10^3$/ml.

Two-ounce containers constructed of glass, polyethylene (HDPE), polypropylene (PP) and poly vinyl chloride (PVC) were coated with 1% aqueous solution of silane.

Water containing $10^7$ bacteria/ml introduced Time 0. After 8 hours, bacteria counts measured $<10^3$/ml.
BROAD SPECTRUM ACTIVITY

Gram Positive Bacteria

- Bacillus sp. (vegetative cell)
- Micrococcus lutea
- Mycobacterium tuberculosis
- Propionibacterium acnes
- Staphylococcus epidermidis
- Streptococcus mutans
- Streptococcus pyogenes
- Corynebacterium diptheriae
- Micrococcus sp.
- Mycobacterium smegmatis
- Staphylococcus aureus
- Streptococcus faecalis
- Streptococcus pneumonia
BROAD SPECTRUM ACTIVITY

Gram Negative Bacteria

- Acinetobacter calcoaceticus
- Citrobacter deversus
- Enterobacter aerogenes
- Enterobacter cloacae
- Escherichia coli
- Klebsiella pneumoniae
- Legionella pneumophila
- Proteus mirabilis
- Pseudomonas aeruginosa
- Salmonella cholera suis
- Salmonella typhimurium
- Serratia marcescens

- Aeromonas hydrophilia
- Citrobacter freundii
- Enterobacter agglomerans
- Enterococcus
- Klebsiella oxytoca
- Klebsiella terriena
- Morganella morganii
- Proteus vulgaris
- Pseudomonas fluorescens
- Salmonella typhi
- Serratia liquifaciens
- Xanthomonas campestris
## Viruses

<table>
<thead>
<tr>
<th>Adenovirus Type II &amp; IV</th>
<th>Bovine Adenovirus Type I &amp; IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feline pneumonitis</td>
<td>Herpes Simplex Type I</td>
</tr>
<tr>
<td>Herpes Simplex Type II</td>
<td>HIV-1 (AIDS)</td>
</tr>
<tr>
<td>Influenza A2 (Aichi)</td>
<td>Influenza A2 (Asian)</td>
</tr>
<tr>
<td>Influenza B</td>
<td>Mumps</td>
</tr>
<tr>
<td>Parainfluenza (Sendai)</td>
<td>Rous Sarcoma</td>
</tr>
<tr>
<td>Reovirus Type I</td>
<td>Simian Virus 40</td>
</tr>
<tr>
<td>Vaccinia</td>
<td>MS2</td>
</tr>
<tr>
<td>PRD1</td>
<td></td>
</tr>
</tbody>
</table>
Fungi, Algae, Mold, Yeast, Spores

Alterania alternata  
Aspergillus flavus  
Aspergillus sydowi  
Aspergillus versicolor  
Aureobasidium pullans  
Candida albicans  
Candida pseudotropolcalis  
Cladosporium cladosporioides  
Dreschslera australiensis  
Gliomastix cerealis  
Gloeoophyllum trabeum  
Microsporum sp.  
Monilia grisea  
Penicillium chrysogenum  
Penicillium funiculosum  
Penicillium variable  
Pithomyces chartarum  
Porri placenta  
Scenedesmus  
Saccharonyces cerevisiae  
Saccharomyces cerevisiae  
Trichoderma viride  
Trichophyton interdigitale  
Trichophyton mentogrophytes

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BROAD SPECTRUM ACTIVITY

Protozoa Parasites

Cryptosporidium parvum (oocysts)
DURABILITY

- Testing results on treated sand utilizing the British Abrasion Test indicate retention of antimicrobial activity for 5-7 years.
Testing of the treated zeolites used in the POU challenge studies above by NSF, Ann Arbor, MI to the rigorous Standard 42 protocol for drinking water found no extractable materials from the antimicrobial silane coating. NSF Standard 50 and Standard 61 tests produced identical results of a non-leaching coating.
Before/After Pond

BEFORE
Before/After Pond
Before/After Pool

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Household Water Management
Before/After Pool

After
CONCLUSION

The foregoing tests indicate inactivation and removal of pathogens through use of treated surfaces, including sand, zeolites and plastics is possible. The new process for inactivation/removal demonstrates:

- Antimicrobial activity against a wide variety of pathogens including bacteria, fungi, viruses and protozoa.
- No disinfection byproducts. Carcinogenic, halogen-containing byproducts (chloroform, methylene chloride, etc.) are not formed in the inactivation process.
- Durable, long-lasting antimicrobial activity through chemical bonding of the coating to the treated material. Estimated average media life 5 years.
- Non-additive process. No chemicals, oxidizers or energy are required to be added to the water to inactivate and eliminate pathogens.
- Non-leaching process. Treated phase does not leach, dissolve or migrate into contacting water.
CONCLUSION

- Inactivation of pathogens occurs through cellular membrane disruption. Process is rapid and efficient.
- No pathogen mutagenicity or increasing pathogen resistance on continued exposure to the treated material.
- Treated materials will not harm humans, fish and aquatic plants.
- Effective inactivation and elimination of up to 99.9% for waterborne viruses, bacteria, algae and protozoa on single pass exposure.
- Effective inactivation of *cryptosporidium parvum* oocysts.
- Cost effective water purification process.
- Reusable media. Backwashing regenerates media.
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Patents Pending