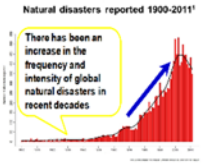
Development of Novel Superabsorbent Cryogels for Emergency Potable-Water Production

Siew-Leng Loo[1,2], Anthony G. Fane[1,2], Teik-Thye Lim[1,2], William B. Krantz[1,3], Xiao Hu[1,4]

[1]Singapore Membrane Technology Centre; [2]School of Civil and Environmental Engineering, Nanyang Technological University, Singapore; [3]Department of Chemical *and* Biological Engineering, University of Colorado, Boulder, USA; [4]School of Materials Science and Engineering, Nanyang Technological University, Singapore.

1. Motivation

- Providing potable water supply is one of the first priorities in the aftermath of a disaster
- Challenging due to lack of infrastructure and resources



There is interest to develop novel emergency water technologies having the following properties[2]:

- ❖ Compact and easy to deploy
- ❖ Easy to use
- ❖ Able to produce potable water of good quantity and quality
- ❖ Operable without access to power supply

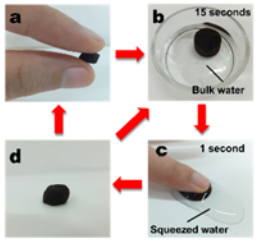
2. Inspiration

Sea squirts – a living water pistol[3,4]

- Sea squirts are filter feeders capable of separating particulates and water
- They look like blobs of jelly when removed from water
- They have the ability to take in water but expel them when squeezed

3. Objectives

A new approach for emergency water treatment



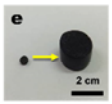


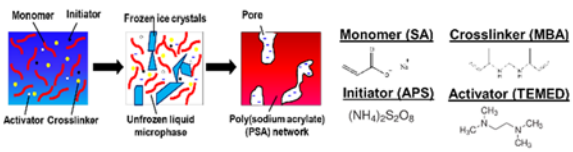
Fig. 1 (a) Dried PSA/Ag cryogel. (b) Swelling of PSA/Ag cryogel in contaminated water. (c) Recovery of treated water via hand compression. (d) Deswollen PSA/Ag cryogel. (e) Comparison of the size of dried and swollen PSA/Ag cryogels.

The objectives of this study were:

- To prepare PSA/Ag cryogels having:
  - ❖ Fast and substantial swelling;
  - ❖ High elasticity against compression
  - ❖ Good water recovery
  - ❖ Excellent antibacterial properties
  - ❖ Ability to maintain performance through multiple swelling/deswelling cycles
- To demonstrate the potential of using PSA/Ag cryogels for point-of-use water disinfection in a new approach (Fig. 1)

4. Materials synthesis

Principles of cryogel synthesis



Note: Please see refs. 5 and 6 for more information about cryogels.

Synthesis route of PSA/Ag cryogels

Note: Please see refs. 7 and 8 for details on PSA/Ag cryogel synthesis.

5. Results & discussion

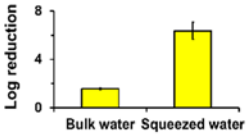


Fig. 2 Comparison between the extent of disinfection of bulk and squeezed waters.

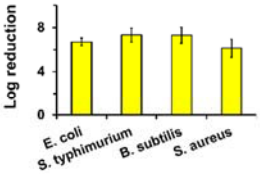


Fig. 3 Disinfection efficacies of PSA/Ag cryogels against various types of bacteria.

PSA/Ag cryogels were used as a sorbent to disinfect water because they showed a significantly higher disinfection efficacy for the squeezed water (i.e., absorbed water) than for the bulk water (i.e., excess water outside the gel) (Figs. 1 and 2).

The PSA/Ag cryogels are effective against various types of bacteria (Fig. 3). Bacterial cells exposed to the cryogels showed severe damage of their outer membrane (Fig. 4). This is thought to be one of the key events that leads to cell death.

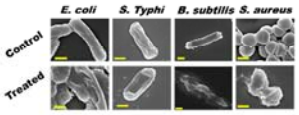


Fig. 4 Morphological changes in bacterial cells after exposure to PSA/Ag cyrogles. Scale bar = 0.5 µm.

We found that close to 3 logs of *E. coli* cells were immediately inactivated during the 15-s contact time (Fig. 5). Up to 6 logs of bacteria were inactivated when the contact time was increased to 5 min. These results are corroborated by *in situ* fluorescence imaging of exposed cells stained with nucleic acid dyes (Fig. 6).

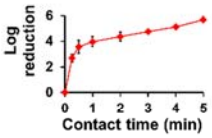


Fig. 5 Rate of *E. coli* disinfection using PSA/Ag cryogels.

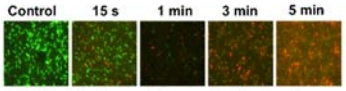


Fig. 6 Live/dead assay of exposed cells at various contact times. Note: Green cells = viable cells and red cells = dead cells (with damaged membranes).

The rapid disinfection ability of cryogels can be attributed to the good dispersion of fine silver nanoparticles (AgNPs) combined with the highly interconnected porous network of the PSA cryogels that expose a high surface area of bioactive Ag to bacteria (Fig. 7).

Also, the fast disinfection is due to the ability of cryogels to imbibe water that brings the bacteria into close contact with the AgNPs in a timely manner.

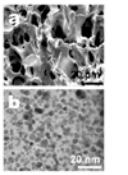


Fig. 7 (a) SEM image of PSA/Ag cryogel. (b) TEM image of AgNPs decorated on cryogel.

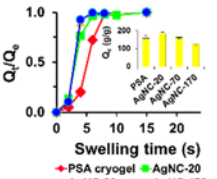


Fig. 8 Swelling behavior of the cryogels. Note: Q_t and Q_e are the swelling ratios at time t and equilibrium, respectively.

The PSA/Ag cryogels are also highly reusable as they did not show any deterioration in disinfection efficacy and mechanical properties after repeated usage (Figs. 9 and 10).

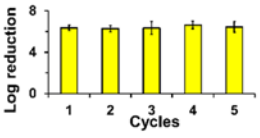


Fig. 9 Disinfection efficacies of PSA/Ag cryogels after repeated usage.

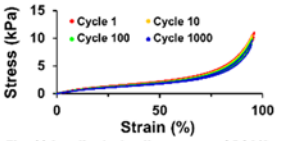


Fig. 10 Loading/unloading curves of PSA/Ag cryogel during fatigue test.

6. Conclusions

- ✓ The remarkable swelling-deswelling and mechanical properties of PSA/Ag cryogels allow their use in a sea-squirt-inspired approach that resulted in enhanced disinfection efficacies
- ✓ The cryogels could inactivate 3 logs of bacteria after a 15-second contact time
- ✓ The PSA/Ag cryogels were highly reusable allowing repeated usage
- ✓ Dissolved Ag concentration is below WHO limit (< 100 µg/L)
- ✓ The cryogels prepared in this study offer a new and simple approach for potable-water disinfection that can be easily deployed for applications in acute emergencies.

SMTC website: http://smtc.ntu.edu.sg

References

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