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ECMC Environmental Chemistry and Materials Centre

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DEVELOPMENT OF NOVEL SUPERABSORBENT CRYOGELS FOR POINT-OF-USE WATER TREATMENT

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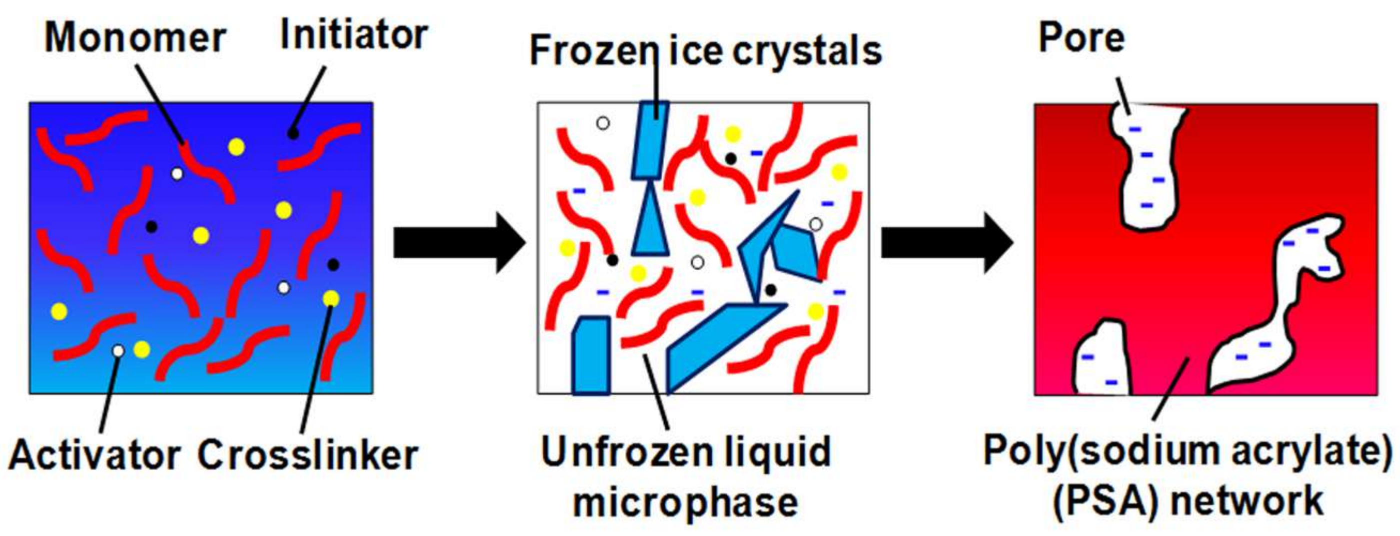
INTRODUCTION

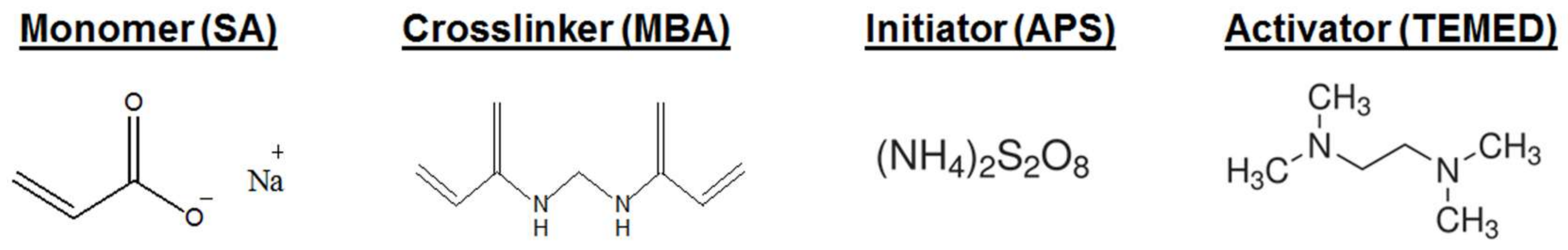
- Providing potable water supply is one of the first priorities in the aftermath of a disaster
- Challenging due to lack of infrastructure and resources

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

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

PRINCIPLES OF CRYOGEL SYNTHESIS





For more information, please refer to the following papers in addition to our project publications:
Lozinsky et al. (2003) Trends in Biotechnology 21: 445-451.
Kirsebom et al. (2011) Polymer Chemistry 2: 1059-1062.

EXPERIMENTAL PROGRESS

SWELLING & MECHANICAL PROPERTIES

The cryogels can rapidly swell to >100 g/g within 15 seconds (Fig. 1a). They are highly robust because they have the elasticity to withstand multiple cycles of swelling/deswelling and compression with no significant deterioration in their microstructure and properties (Fig. 1b-d).

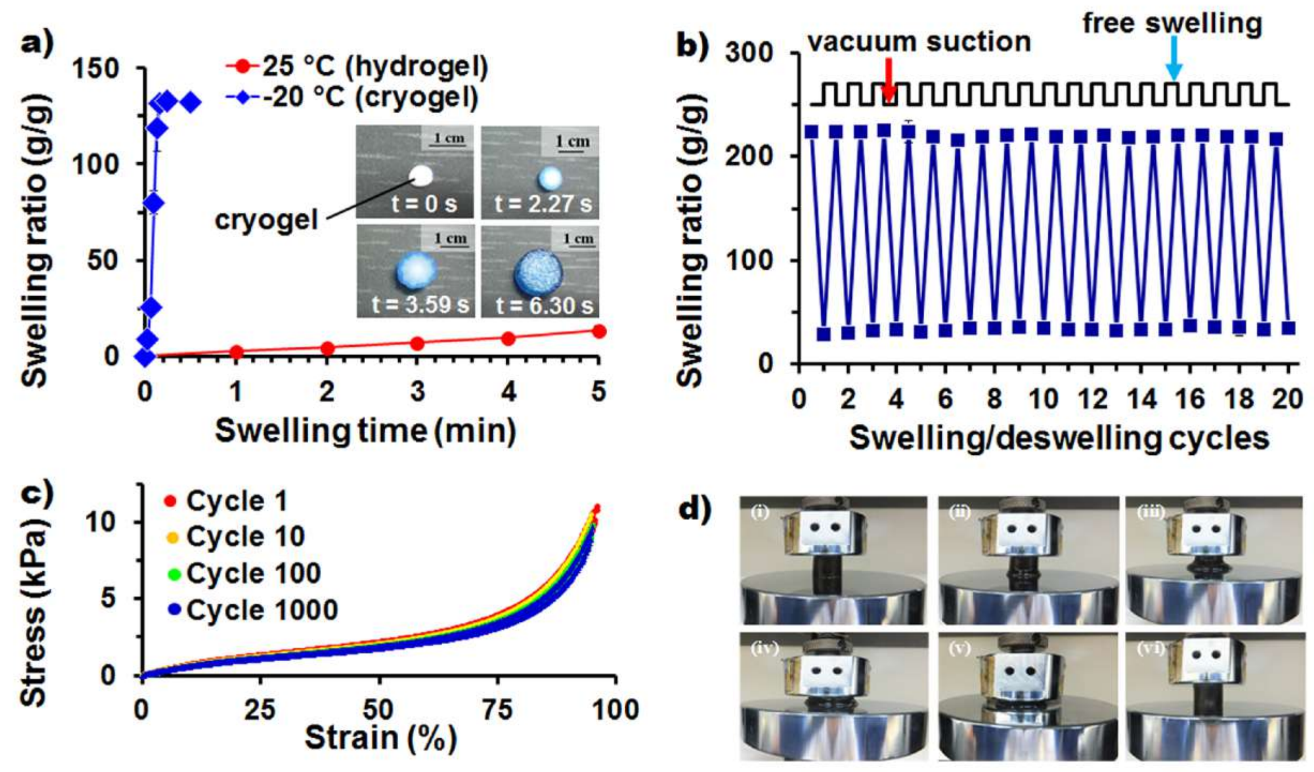


Fig. 1 (a) Dynamic swelling profile of cryogel versus hydrogel. (b) Oscillatory swelling/deswelling behavior of cryogel. (c) Stress-strain curve of cryogel recorded during fatigue test. (d) Photographs of cryogels during compression tests showing their high elasticity.

OUR APPROACH

The cryogels were used in a sponge-like manner for onsite water treatment. The approach involves allowing the cryogels to swell in raw water (Fig. 2a) followed by a simple squeezing step to instantly release the absorbed (and treated) water (Fig. 2b).

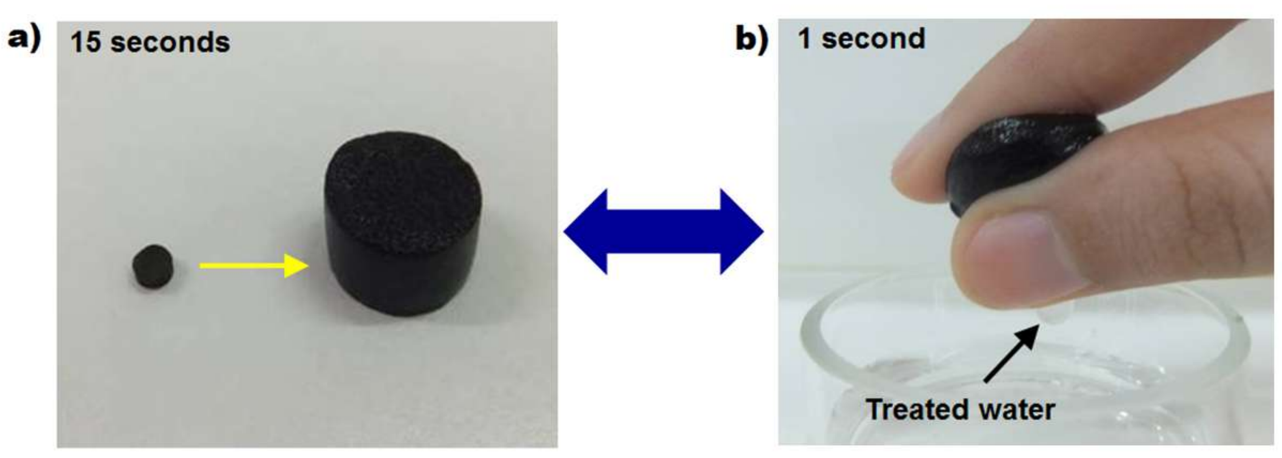


Fig. 2 Our proposed new strategy for emergency water treatment. (a) Comparison of the sizes of dried and fully swollen cryogel. (b) A cryogel being squeezed to release absorbed/treated water.

PARTICULATES REMOVAL

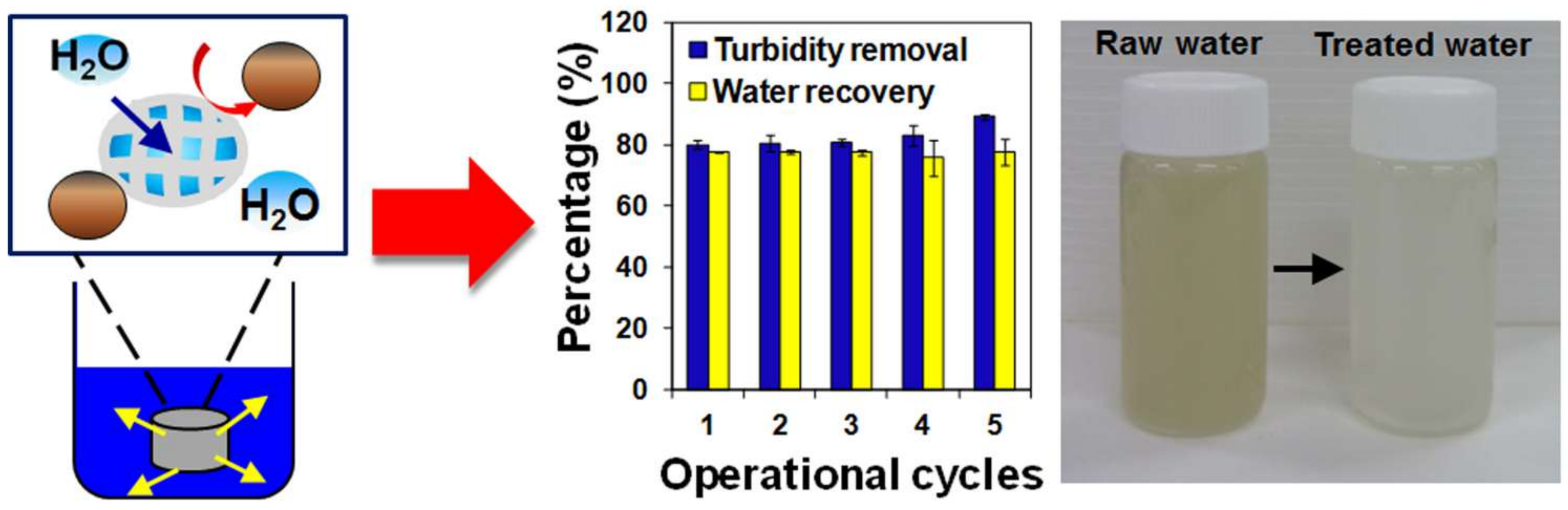


Fig. 3 Selective water absorption by cryogels enables the exclusion of particulates in the absorbed water that substantially improves the water quality visually.

BACTERIAL DISINFECTION

Cryogels functionalized with silver nanoparticles (AgNPs) demonstrate excellent bactericidal properties – more than 5 logs of different types of bacteria can be inactivated with a 5-min contact time (Fig. 4a) by causing irreversible lesions on exposed cells (Fig. 4b).

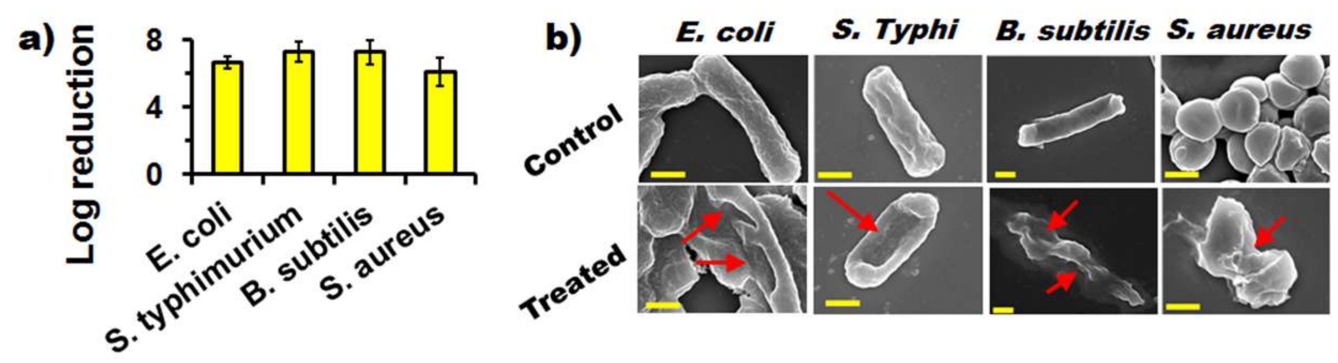


Fig. 4 (a) Disinfection efficacy of cryogels against various types of bacteria. (b) FESEM images showing the morphological changes of exposed bacterial cells. All scale bars represent 0.5 μm while the red arrows point to lesions.

We attribute the fast disinfection to the rapid water imbibition by cryogels that drives the bacterial cells to approach the AgNPs in a timely manner (Fig. 5a). The intimate contact between the bacterial cell and AgNP allows a targeted delivery of Ag+ into the cell that subsequently causes severe lesions to the cells (Fig. 5b).

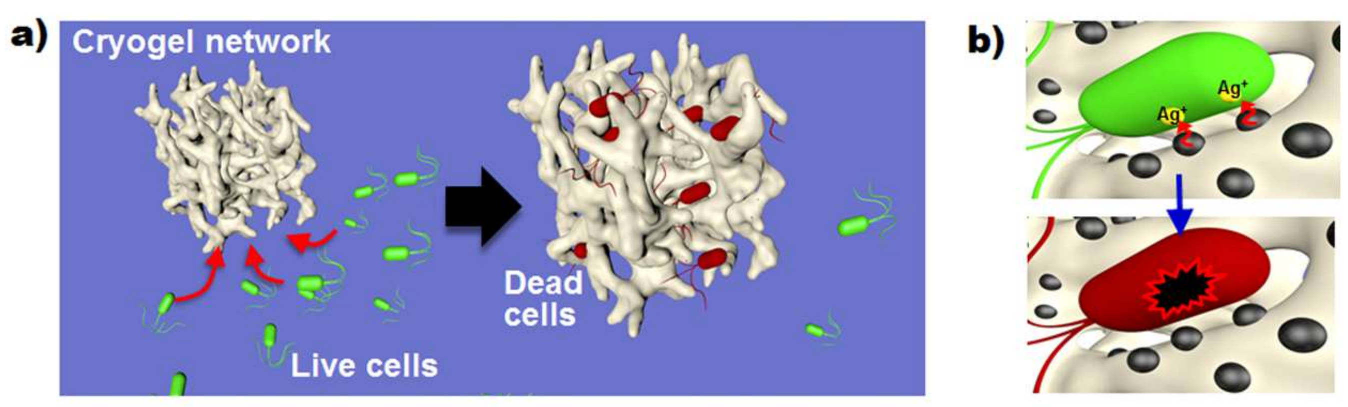


Fig. 5 Illustration summarizing our hypothesis for the fast disinfection ability of cryogels. (a) Rapid water absorption for timely exposure of bacterial cells to AgNPs. (b) Targeted delivery of toxic Ag+ into cell that initiates a cascade of events leading to irrevocable cell lesions.

PUBLICATIONS

1. Bactericidal Mechanisms Revealed for Rapid Water Disinfection by Superabsorbent Cryogels Decorated with Silver Nanoparticles, ENVIRONMENTAL SCIENCE & TECHNOLOGY, 49(4): 2310-2318, 2015
2. Superabsorbent cryogels decorated with silver nanoparticles as a novel water technology for point-of-use disinfection, ENVIRONMENTAL SCIENCE & TECHNOLOGY, 47(16): 9363-9371, 2013
3. Design and synthesis of ice-templated PSA cryogels for water purification: towards tailored morphology and properties, SOFT MATTER, 9(1): 224-234. 2013
4. Emergency water supply: A review of potential technology and selected criteria, WATER RESEARCH, 46(10) 3125-3151, 2012

IP LIST

1. PCT patent application
2. Singapore patent application
3. US patent application