Protocol

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Although porous organic polymer (POP) has been explored as a promising photosensitizer, its powdered form makes it unfavorable for practical applications. Here, we demonstrate a protocol for fabricating imidazoline-based POP composites using fabric and sponge as substrates. This fabrication is limited to POPs with aldehyde containing organic building blocks.

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Protocol for the fabrication of porous organic polymer-based composites for photocatalytic degradation of a sulfur mustard simulant

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SUMMARY
Although porous organic polymer (POP) has been explored as a promising photosensitizer, its powdered form makes it unfavorable for practical applications. Here, we demonstrate a protocol for fabricating imidazoline-based POP composites using fabric and sponge as substrates. This fabrication is limited to POPs with aldehyde containing organic building blocks. For complete details on the use and execution of this protocol, please refer to Kim et al. (2022).

BEFORE YOU BEGIN
Porous organic polymers (POPs) have been recently investigated as prospective candidates for the photocatalytic degradation of sulfur mustard owing to their effective generation of reactive oxygen species (ROS) upon light irradiation. Sulfur mustard, a chemical warfare agent, can penetrate the human skin upon exposure because of its lipophilic property. Protective clothing decorated with catalytically active materials could be a precaution against toxic agents to avoid exposure. It is also crucial to develop a personal decontamination system that promptly decontaminates and detoxifies the agent, especially in unavoidable circumstances. In this sense, POPs with organic building blocks containing functional groups could be promising candidates for composite fabrication with various substrates, including fabrics and sponges. The fabricated composites could detoxify a sulfur mustard simulant owing to the incorporated photosensitizing POP, even under ambient atmosphere and sunlight irradiation.

The protocol below describes the specific steps and characterizations of POP-based composite photocatalysts (KUP-3@OFb and KUP-3@MSp) using fabric and sponge as substrates. Herein, a type of army combat uniform (ACU), cotton and polyester blend fabric, and melamine sponge were utilized. The cellulose hydroxyl groups in the cotton portion can be oxidized into aldehyde groups, thereby serving as anchoring sites to incorporate imidazoline-based POP (KUP-3). In addition, the primary amine groups from the melamine sponge surface can be modified with an aldehyde-containing monomer by means of an imine reaction, which can further incorporate imidazoline-based POP (KUP-3) on the sponge. This protocol can be applied to other porous materials synthesized with aldehyde-containing organic building blocks, aiming at protective gear and decontamination tools against toxic chemicals.
**KEY RESOURCES TABLE**

| REAGENT or RESOURCE | SOURCE | IDENTIFIER |
|---------------------|--------|------------|
| Chemicals, peptides, and recombinant proteins | | |
| Sodium metaperiodate, 98% | Alfa Aesar | CAS: 7790-28-5 |
| Ethanol, 95% | Duksan General Science | CAS: 64-17-5 |
| Methanol, 99.5% | Samchun Pure Chemical | CAS: 67-56-1 |
| Acetone, 99.5% | Samchun Pure Chemical | CAS: 67-64-1 |
| N,N-dimethylformamide, 99.5% | Samchun Pure Chemical | CAS: 68-12-2 |
| 1,3,5-tri(4-formylphenyl)benzene | This was synthesized according to the reported literature with minor modifications (Jiang et al., 2011) | N/A |
| Ammonium chloride, 99% | Yakuri Pure Chemicals Co. Ltd / Samchun Pure Chemical | CAS: 12125-02-9 |
| Acetic Acid, Glacial, 99.0% | Duksan General Science | CAS: 64-19-7 |
| 2-Chloroethyl ethyl sulfide, 97% | Sigma-Aldrich | CAS: 693-07-2 |
| Other | | |
| Fabric (polyester 68% and cotton 32% blended) | Taihan Textile Co., Ltd | N/A |
| Melamine sponge | BASF SE, Germany | N/A |
| Pressure vessel P26, heavy wall*, with side port, 15 mL | FengTecEx Laborglas | Order number: P260001, Commercial supply: https://www.fengtecex-laborglas.de/shop/en/products/pressure-vessel/523/pressure-vessel-p26-heavy-wall-with-side-port |
| Pressure vessel P16, heavy wall*, tube, 35 mL | FengTecEx Laborglas | Order number: P160002TH, Commercial supply: https://www.fengtecex-laborglas.de/shop/en/products/pressure-vessel/306/pressure-vessel-p16-heavy-wall-tube?c=194 |
| Analytic Balance (Capacity- 210 g / Resolution 0.1 mg) | A&D Company, Ltd. | GR-200 |
| Gravity-air Drying Oven | DAIHAN Scientific Group | DH.WON05050 |
| Supersonic washer | Hannam Chemical Co. | Sonic-505, Code: EM-109 |
| Scanning electron microscope (SEM) | JEOL, Ltd | JSM-7001F |
| Thermogravimetric analyzer (TGA) | SCINCO | Thermo Fisher SCIENTIFIC, Catalog No. IQLAADGAAGFAHDMAPC |
| IR spectrometer with an ATR module | Nicolet iS10 FT-IR spectrometer | Thermo Fisher SCIENTIFIC, Catalog No. IQLAADGAAGFAHDMAPC |
| 500 MHz Nuclear Magnetic Resonance (NMR) Spectrometer | Magnet System 500’S4 Ascend | Bruker |

**Note:** All chemicals were utilized without further purification or special treatment.

**Note:** Store 1,3,5-tri(4-formylphenyl)benzene in either a desiccator or a glove box.

⚠️ CRITICAL: 2-Chloroethyl ethyl sulfide has acute toxicity. Make sure to keep the container tightly closed and stored in a refrigerator. Handle in a lab with proper personnel protection gear.

**MATERIALS AND EQUIPMENT**

| Stock solution of dilute acetic acid (storage: 25°C) | | |
| Reagent | Final concentration | Amount |
| Acetic Acid, Glacial (99.0%) | 17.4 M | 0.67 mL |
| Deionized water | N/A | 1.33 mL |
| Total | 6.0 M | 2 mL |
**STEP-BY-STEP METHOD DETAILS**

In this protocol, we describe the synthetic steps for KUP-3 and KUP-3 based composites in detail.

The abbreviation list used in the step-by-step method is as follow:

| Abbreviations | Description |
|---------------|-------------|
| CEES          | 2-chloroethyl ethyl sulfide |
| CEESO         | 2-chloroethyl ethyl sulfoxide |
| DMF           | N,N-dimethylformamide |
| KUP-3         | Korea university porous organic polymer-3 |
| MEES-d3       | 2-methoxymethyl ethyl sulfide |
| MSp           | monomer-modified melamine sponge |
| OFb           | oxidized fabric |

**Synthesis of porous organic polymer (KUP-3)**

**© Timing: 2 days**

Before demonstrating the synthetic schemes of POP-based composites, a synthetic method for photosensitizing POP, termed Korea University Porous Organic Polymer-3 (KUP-3), is described in advance. KUP-3 is synthesized through facile one-pot polymerization of a monomer with aldehyde groups and ammonium chloride without any catalyst (Scheme 1).

1. Prepare pressure vessel P26 with 35 mL capacity (heavy wall).
2. Measure a weight of 2.909 g (7.45 mmol) 1,3,5-tri(4-formylphenyl)benzene (TFPB).
   
   **Note:** TFPB should be stored either a desiccator or a glove box.

3. Measure a weight of 2.391 g (44.7 mmol) ammonium chloride (NH₄Cl).
4. Put them in the pressure vessel.
5. Add 10 mL of N,N-dimethylformamide (DMF) to the vessel.
6. Seal the pressure vessel using a polytetrafluoroethylene (PTFE) bushing.

   **△ CRITICAL:** Make sure to seal the pressure vessel tightly with PTFE bushing to avoid evaporation of DMF solvent during the reaction in the oven at 150°C.

7. Sonicate the mixture to dissolve TFPB for 5 min.

   **Note:** TFPB is clearly soluble in DMF during sonication, while NH₄Cl is insoluble in DMF at 25°C.

8. Place the pressure vessel in the oven at 150°C for 2 days.
9. After the reaction, take the vessel out and then cool down at 25°C.
10. Filter and wash the pale-yellow powder with the following solvents: each 100 mL of DMF, H₂O, MeOH, and acetone, thoroughly.
11. Dry the resultant product, KUP-3, at 100°C under vacuum for 12 h.

**Preparation of oxidized fabric (OFb) via periodate oxidation**

**© Timing: ~1 day**

The cotton part of the fabric, which was made by blending 68% polyester and 32% cotton is subjected to oxidation using sodium periodate (Scheme 2A). The hydroxyl groups from the cellulose
cotton fibers are oxidized into aldehyde groups, which serve as anchoring sites for incorporating POP.

12. Immerse a size of 8 × 8 cm\(^2\) fabric in a 250 mL beaker containing excess amount of EtOH for 30 min to remove impurities.
   a. After a while, take out the fabric and wash several times with fresh EtOH.
   b. Dry the washed fabric in the oven at 80°C for 3 h.

13. Cut the fabric with a size of 2 × 2 cm\(^2\) square as an example (Figure 1A).

   **Optional:** The fabric can be cut with any sizes and shapes in accordance with certain utility.

14. Measure a weight of 1 g of sodium metaperiodate (NaIO\(_4\)) (Figure 1B) in a 70 mL vial by using precision balance (Figure 1C).

15. Add 20 mL of deionized water to the vial and a magnetic stirrer bar (Figure 1D).

16. Put the washed fabric into the vial and then wrap the vial up with aluminum foil to block light (Figure 1E).

**Scheme 1.** Synthetic scheme of photosensitizing KUP-3, featuring type I and II ROS generation

**Scheme 2.** Schematic representation of OFb and KUP@OFb
(A) Synthetic scheme for oxidized fabric (OFb).
(B) Synthetic scheme for KUP-3@OFb.
17. Stir the mixture in the vial with 300 rpm for 12 h using a water bath and hotplate at 60°C (Figure 1F).

△ CRITICAL: The vial should be wrapped with aluminum foil to prevent photo-induced degradation of NaIO₄ (Sirvio et al., 2011).

18. After the completion of the reaction, filter and wash the oxidized fabric (OFb) with the excess of deionized water and EtOH.
19. Dry OFb at 25°C under vacuum for 3 h.

Note: OFb should be stored either a desiccator or a glove box to avoid further oxidation of aldehyde groups under atmospheric conditions.

Fabrication of porous organic polymer-based fabric (KUP-3@OFb)

© Timing: ~2 days

POP (KUP-3) can be evenly synthesized on the surface of OFb using aldehyde-anchoring sites. The incorporation of KUP-3 on the surface of OFb proceeds via the following steps (Scheme 2B).

20. Prepare pressure vessel P26 with 15 mL capacity (heavy wall with side port) (Figure 2A).
Optional: Pressure vessel without side pore is also available.

21. Measure the weights of 0.0291 g (0.0746 mmol) TFPB and 0.0239 g (0.447 mmol) NH₄Cl, and then put them in a 15 mL pressure vessel (Figures 2B and 2C).

22. Add 8 mL of DMF in the pressure vessel and sonicate the mixture for 5 min (Figure 2D).
CRITICAL: While TFPB is soluble in DMF during sonication, NH₄Cl is insoluble in DMF at 25°C.

23. Put a piece of OFb into the pressure vessel, and seal the vessel using a PTFE bushing and a stopcock plug (Figure 2E).

CRITICAL: Make sure to seal the screw glass tightly with PTFE bushing and stopcock plug to avoid evaporation of DMF solvent during the reaction in the oven at 150°C.

24. Place the vessel in the oven at 150°C for 48 h (Figures 2F and 2G).

25. After polymerization, take the vessel out and then cool down at 25°C.

26. Filter and wash the composite, KUP-3@OFb, with DMF, H₂O, MeOH, and acetone, thoroughly to remove unreacted reactants.

27. Dry the resultant composite at 100°C under vacuum for 12 h and store it in the desiccator.

Preparation of monomer-modified melamine sponge (MSp)

Timing: ~1 day

Primary amine groups from a melamine sponge surface can be covalently modified with monomers containing aldehyde groups through an imine reaction in the following steps (Scheme 3A). Surface modification with aldehyde-containing monomers results in a monomer-modified melamine sponge (MSp) that serves as an aldehyde-anchoring site.

28. Immerse a piece of melamine sponge (3.8 × 3.8 × 2.8 cm³) in a 250 mL beaker including 100 mL 1 M HCl aqueous solution for 30 min to remove impurities (Figures 3A and 3B).
   a. Decant 1 M HCl aqueous solution and pour several times with the excess of water until the washed water became pH 7.
   b. Squeeze out the water from the washed melamine sponge.
c. Dry the washed melamine sponge in the oven at 90°C for 12 h.

29. Cut the sponge with a size of 1 × 1 × 1 cm³ cube as an example (Figure 3C).

Optional: The sponge can be cut to any size and shape in accordance with certain utility.

30. Measure a weight of 0.02 g of TFPB in 100 mL round bottom flask (RBF) by using precision balance (Figure 3D).
31. Add 20 mL of 1,4-dioxane to the flask.
32. Add 2 mL of 6 M acetic acid aqueous solution, which catalyzes the imine reaction (Figure 3E).

Note: 6 M acetic acid aqueous solution can be stored at 25°C.

33. Sonicate the mixture in the flask for 5 min.
34. Put MSp into the flask and then seal with a rubber septum.
35. Sonicate the mixture with MSp in the flask at 50°C for 12 h (Figure 3F).
36. After the reaction, filter and wash MSp using 1,4-dioxane and acetone.
37. Dry MSp at 25°C under vacuum for 3 h.

Note: MSp should be stored either a desiccator or a glove box to prevent cleavage of imine bonds under atmospheric conditions.
Fabrication of porous organic polymer-based sponge (KUP-3@MSp)

© Timing: 2 days

POP (KUP-3) can be uniformly polymerized with the aldehyde-anchoring sites on the surface of MSp via the following steps (Scheme 3B).

38. Prepare pressure vessel P26 with 35 mL capacity (heavy wall) (Figure 4A).
39. Measure the weights of 0.0582 g (0.149 mmol) TFPB and 0.0479 g (0.894 mmol) NH₄Cl, and then put them in a 35 mL pressure vessel (Figures 4B and 4C).
40. Add 10 mL of DMF in the vessel and sonicate the mixture for 5 min (Figure 4D).

△ CRITICAL: While TFPB is soluble in DMF during sonication, NH₄Cl is insoluble in DMF at 25°C.

41. Put a piece of MSp into the vessel, and seal the vessel using a PTFE bushing (Figure 4E).

△ CRITICAL: Make sure to seal the screw glass tightly with PTFE bushing to avoid evaporation of DMF solvent during the reaction in the oven at 150°C.

42. Place the vessel in the oven at 150°C for 48 h (Figure 4F).
43. After polymerization, take the vessel out and then cool down at 25°C (Figure 4G).
44. Filter and wash the composite, KUP-3@MSp, with DMF, H₂O, MeOH, and acetone, thoroughly, to remove unreacted reactants (Figure 4H).
45. Dry KUP-3@MSp under vacuum for 1 h (Figure 4I).
46. Put the dried KUP-3@MSp in a 20 mL vial and add 10 mL hexane (Figure 5A).
47. Sonicate the mixture for 5 min to remove physically incorporated KUP-3 particles (Figure 5B).
48. After that, take out KUP-3@MSp (Figure 5C).
49. Dry the resultant composite at 100°C under vacuum for 12 h and store in the desiccator (Figure 5D).

EXPECTED OUTCOMES

This protocol demonstrates the fabrication strategies of POP-based composite materials using fabrics and sponges. This protocol aims to incorporate substances onto the substrate, thereby employing composite materials for practical utility, such as protective clothing and decontamination tools. The expected outcomes are consistent with our earlier work on Cell Reports Physical Science (Kim et al., 2022). Characterization and application are as follows.

Expected porosity of KUP-3

We measured N₂ isotherms at 77 K to evaluate the porosity of KUP-3 (Figure 6). The adsorption isotherm showed Type II behavior, which is common in nonporous materials. This could be attributed to well-packed networks formed by strong hydrogen bonding. As a result, the Brunauer–Emmett–Teller (BET) surface area corresponded to 24 m² g⁻¹ for KUP-3.

Expected XPS analysis data for the oxidized fabric

After the oxidation process of the fabric, the increased aldehyde groups can be confirmed through XPS analysis by deconvoluting C1s and O1s peaks for the oxidized fabric (Figure 7). The relative intensities of the C=O/O–C–O peak (288.78 eV) for C1s and the C=O peak (533.28 eV) for O1s were stronger than those of unmodified fabric, thus confirming the generation of aldehyde groups after oxidation process.

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**Expected optical and microscopic images**
The selected fabric (polyester 68% and cotton 32% blended) is interwoven with numerous fibers (Figures 8A and 8D). After the oxidization of hydroxyl groups into aldehyde groups in the cotton
portion of the fibers, there are no dramatic changes in the optical and SEM images (Figures 8B and 8E). After polymerization, the color of the oxidized fabric changes from khaki to dark yellow, implying that KUP-3 particles cover the surface of OFb (Figures 8C and 8F). In addition, SEM imaging confirm the uniform distribution of KUP-3 particles onto the fiber surface.

The skeletons of the pristine melamine sponge are smooth, and the color of the pristine sponge is white (Figures 9A and 9D). The SEM images confirm no dramatic changes in surface morphology after modification with the TFPB monomer (Figures 9B and 9E). The composite material turned yellow, indicating the successful polymerization of KUP-3 particles onto the surface (Figures 9C and 9F).

**Expected KUP-3 loading amounts for the composites**

The amount of KUP-3 incorporated into each substrate (OFb or MSp) is quantified by thermogravimetric analysis (TGA) (Figure 10). The substrate (OFb or MSp), composite (KUP-3@OFb or KUP-3@MSp), and KUP-3 are analyzed for comparison. In addition, each sample (substrate and composite) is assessed thrice for clarity. Considering the fact that KUP-3 starts to decompose at around 400 °C, the loading weight percentage for each composite is calculated from the point after loss of the residual solvent or water to the point that KUP-3 starts to decompose. The KUP-3 loading for each composite is approximately 8.5% and 15% for KUP-3@OFb and KUP-3@MSp, respectively.

**Expected photocatalytic degradation performance of a sulfur mustard simulant, catalyzed by the composites**

To evaluate the photocatalytic degradation performance, a sulfur mustard simulant, 2-chloroethyl ethyl sulfide (CEES), is used instead of sulfur mustard for safety. Toxic CEES can be converted into nontoxic 2-chloroethyl ethyl sulfoxide (CEESO) and a methanolysis product, 2-methoxyethyl ethyl sulfide (MEES-d3) catalyzed by KUP-3@OFb and KUP-3@MSp. To confirm the potential for practical use, photocatalytic degradation experiments are carried out under realistic conditions,
including an ambient atmosphere (~21% O₂ concentration) and sunlight irradiation. As shown in Figure 11, the CEES conversion ratios into CEESO reached 93% and 92% for KUP-3@OFb and KUP-3@MSp within 3 h, respectively. For clarity of the performance, photocatalytic degradation experiment was conducted three times, thereby showing error bars. The results prove the potential for functioning as a protective clothing and decontamination/degradation tool because of the outstanding degradation capability of sulfur mustard simulant even under realistic condition.

Pause point: 2-Chloroethyl ethyl sulfide has acute toxicity. Make sure to examine the Material and Safety Data Sheet (MSDS) and carefully handle in a lab with proper personnel protection gear.

LIMITATIONS

The type of substrate is important for fabricating a composite. The surface of the substrate could contain certain functional groups or be modified to incorporate substance (e.g., POP). Although we tried to incorporate POP onto the surface of the substrate, physically attached POP particles
are inevitably formed on the substrate. This probably results in the discharge of POP particles as the frequency of usage increased. Moreover, the photocatalytic degradation experiment under sunlight irradiation might result in the inconsistent performance due to the different amount of sunshine and atmospheric environment. According to the reusability test, both of the composite materials maintained their photocatalytic performance over four cycles. However, each performance is influenced by the amount of sunshine, as shown in 3rd cycle (Figure 12).

TROUBLESHOOTING

Problem 1
When preparing OFb through periodate oxidation, the amount of periodate, time, and temperature are important factors, owing to the low reactivity of cellulose in water ("step-by-step method details" in preparation of oxidized fabric (OFb) via periodate oxidation).

Potential solution
It is recommended that the periodate oxidation process is performed using a large amount of periodate. In addition, long oxidation times and elevated temperatures are recommended to enhance

Figure 9. SEM and optical images of substrate and composite
(A–F) (A and D) unmodified melamine sponge, (B and E) MSp, and (C and F) KUP-3@MSp (Magnification, A–C: ×1,000 and D–F: ×5,000). Reprinted from Cell Reports Physical Science, Volume 3, Kim et al., Photocatalytic detoxification of a sulfur mustard simulant under realistic conditions by imidazoline-based porous organic polymer composites with permission from Elsevier.

Figure 10. TGA decomposition data for measuring POP loading amounts for the composites
(A) Data for OFb, KUP-3@OFb, and KUP-3.
(B) Data for MSp, KUP-3@MSp, and KUP-3. Reprinted from Cell Reports Physical Science, Volume 3, Kim et al., Photocatalytic detoxification of a sulfur mustard simulant under realistic conditions by imidazoline-based porous organic polymer composites with permission from Elsevier.
the effectiveness of periodate oxidation, probably leading to a high content of aldehyde groups (Calvini et al., 2006). Among several factors, temperature and reaction time would have a major effect on oxidation into aldehydes. Periodate oxidation process was carried out using 1 g of NaIO₄ at 25°C and 60°C for 12 h. As shown in Figure 13A, the broad bands related to hydrogen bonding of hydroxyl groups were almost suppressed when the oxidation reaction was performed at 60°C, implying that the oxidation occurred more effectively at elevated temperature. Moreover, this oxidation process should be maintained for at least 3 h to achieve a high aldehyde content, as shown in Figure 13B.

**Problem 2**

In the case of the oxidized fabric (OFb), some of hydroxyl groups were oxidized into aldehyde groups, which might suffer from further oxidation when exposed to atmospheric conditions. In addition, the melamine sponge was modified with an aldehyde-containing monomer, TFPB, via imine condensation. The imine bond can be cleaved when exposed to atmospheric conditions, resulting in the loss of monomers on the surface of MSp (“step-by-step method details” in preparation of oxidized fabric (OFb) via periodate oxidation and “step-by-step method details” in preparation of monomer-modified melamine sponge (MSp)).

**Potential solution**

OFb and MSp are recommended to be stored in either a desiccator or a glove box to prevent further oxidation of aldehyde groups and cleavage of imine bonds under atmospheric conditions. Moreover, the aldehyde-containing monomer, TFPB, should be stored in a desiccator, refrigerator, or glove box to avoid oxidation of the aldehyde group.

**Problem 3**

Controlling the amount of KUP-3 incorporated on the substrate may be difficult. In other words, physically attached KUP-3 was inevitably included in the composite, particularly in the case of KUP-3@MSp. This can be attributed to the inherent macro-porosity of the sponge. This might cause KUP-3 particles to fall off the composite when repeatedly used as a decontamination/degradation
tool (Figure 5; “step-by-step method details” in fabrication of porous organic polymer-based sponge (KUP-3@MSp)).

Potential solution
To remove physically attached KUP-3 particles, KUP-3@MSp was subjected to sonication process in 10 mL of hexane for 5 min (steps 20–23 in fabrication of porous organic polymer-based sponge (KUP-3@MSp)). Therefore, whenever a composite is prepared, a similar amount of KUP-3 incorporation into the sponge substrate can be achieved through the removal process (Figure 14).

Problem 4
When used in real applications, the sponge-based composite (KUP-3@MSp) can suffer from light penetration issue. KUP-3@MSp may have difficulties with light penetration in degradation applications, considering the size of KUP-3@MSp ($1 \times 1 \times 1 \text{ cm}^3$).

Potential solution
As shown in Figure 15, light entered into the inner space of the sponge. The melamine sponge has macro-porosity inside, probably capable of light penetration into the inner space to some extent. Although the light did not penetrate through the thick sponge ($1 \times 1 \times 1 \text{ cm}^3$), it could enter the inner space, which can serve as a photosensitizer (Figure 15A). Instead, the light could penetrate through the thin sponge ($1 \times 1 \times 0.3 \text{ cm}^3$), as confirmed by a light trace on the ground (Figure 15B). It is also expected to decontaminate as well as detoxify toxic chemicals in real applications.

Figure 12. Conversion ratio photocatalyzed by KUP-3@OFb and KUP-3@MSp for 4 h over four cycles
(A) Conversion ratio catalyzed by KUP-3@OFb.
(B) Conversion ratio catalyzed by KUP-3@MSp.

Potential solution

Figure 13. IR spectra of fabric and OFb depending on the reaction conditions
(A) Periodate oxidation results depending on the temperature.
(B) Periodate oxidation results depending on the time.
Problem 5
Photocatalytic degradation performance under sunlight irradiation could have relatively high margin of error due to the inconstant sunshine, derived from atmospheric influence, as shown in Figure 11 (Figure 11; “Expected outcomes” in Expected photocatalytic degradation performance of a sulfur mustard simulant, catalyzed by the composites).

Potential solution
Since it is impossible to receive constant sunshine at every moment, it is recommended to conduct the experiment at daytime from 12 pm to 5 pm, which are generally peak hours of sunshine.

RESOURCE AVAILABILITY
Lead contact
Further information and requests for resources and reagents should be directed to and will be fulfilled by the lead contact, Chang Seop Hong (cshong@korea.ac.kr).

Figure 14. Optical images of untreated KUP-3@M3p and treated KUP-3@M3p
(A) KUP-3@M3p before removal of physically attached KUP-3 particles.
(B) KUP-3@M3p after removal of physically attached KUP-3 particles.

Figure 15. Light penetration experiment using a 405 nm laser (450 mW cm⁻²)
(A) Photo of light entering into the inner space of melamine sponge (1 × 1 × 1 cm³).
(B) Photo of light penetrating through melamine sponge (1 × 1 × 0.3 cm³). Reprinted from Cell Reports Physical Science, Volume 3, Kim et al., Photocatalytic detoxification of a sulfur mustard simulant under realistic conditions by imidazoline-based porous organic polymer composites with permission from Elsevier.
Materials availability
This study did not generate new unique reagents.

Data and code availability
This study did not generate datasets and code.

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AUTHOR CONTRIBUTIONS
Conceptualization, H.K.; validation, H.K., J.H.C., and M.K.; methodology, H.K., D.W.K., and H.Y.; investigation, H.K.; writing – original draft, H.K.; writing – review & editing, H.K. and C.S.H.; funding acquisition, C.S.H.; supervision, C.S.H.

DECLARATION OF INTERESTS
H.K. and C.S.H. filed patent application KR 10-2021-0154029 for composite fabrication of porous organic polymers with fabrics and sponges.

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