

ORIGINAL ARTICLE

Persulfate-containing consumer products in the US market

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Abstract

Background: Persulfate compounds are reactive oxidative agents increasingly recognized as contact allergens.

Objectives: The aim of this study was to identify common consumer products containing persulfate compounds in the US market.

Methods: Five publicly accessible online ingredient repositories and searches of two large online retailers were used to identify persulfate-containing consumer products.

Results: We identified persulfates in 23 hair colouring products, 11 denture cleansers, 8 pool/hot-tub products, 3 paints, and 3 cleaning products.

Conclusions: Clinicians assessing contact dermatitis should be aware of three primary categories of consumer products that contain persulfates: denture cleansers, hair colouring products, and nonchlorine hot-tub and pool shock.

KEYWORDS

allergic contact dermatitis, denture cleanser, hair colouring, hot-tub shock, patch test, persulfate salt, pool treatment, potassium peroxymonosulfate, potassium persulfatesodium persulfate

1 | INTRODUCTION

Persulfate salts are highly reactive, low molecular weight oxidative compounds used in the chemical, pharmaceutical, metallurgic, textile, photographic, food, and cosmetic industries.¹ In many commercial products they are present in high concentrations of over 50%.² Persulfate salts are capable of causing sensitization and allergic disease, with both immediate- and delayed-type hypersensitivity reactions previously reported (Table 1).^{2,6,13} To screen for persulfate allergy, patch testing can be performed with ammonium persulfate. Ammonium persulfate was added to the North American Contact Dermatitis Screening series in 2015, but is not included in the 2020 American Contact Dermatitis Society Core Allergen series, the TRUE Test, or the 2019 European Baseline Series.^{4,5,7,14} In a recent series of more than 10 000 patients patch tested with the North American Contact Dermatitis Screening series from 2015 to 2018, 1.8% had a positive reaction to ammonium persulfate, with more than half of the reactions determined to be clinically significant.⁸

Given the diverse use of persulfate compounds in common consumer products and the lack of persulfate compounds on commonly used patch testing series, it is likely that persulfate contact allergy is under-recognized.¹⁵ In this study, we aimed to identify common

household products that contain persulfate compounds to help guide clinician questioning and patch testing choices when a patient presents with an unknown contact allergy.

2 | METHODS

Publicly accessible product ingredient databases were searched for major persulfate salt compounds and their synonyms (Table 2). We searched the Consumer Product Information Database (CPID), a US government-supported repository disclosing chemical ingredients in over 23 000 brands (<https://www.whatsinproducts.com>); the Consumer Product Ingredients Database, an industry-supported repository containing 1641 ingredients from 79 suppliers (<https://www.productingredients.com>); the New Jersey State, Department of Health Right to Know Hazardous Substance List (RTKSL) containing over 2000 hazardous or possible hazardous substances (<https://web.doh.state.nj.us/rthksfs/rthksl.aspx>); the UL Prospector Materials Search Engine (<https://www.ulprospector.com/en/na>); and the Environmental Working Groups (EWG) Skin Deep cosmetic database containing over 70 000 cosmetic products and 9000 ingredients (<https://www.ewg.org/skin-deep>).

TABLE 1 Common uses of persulfate compounds and known allergy associations

Compound name	Commercial uses	Allergy associations
Sodium persulfate	Hot-tub shock, hair bleaching products	Allergic contact dermatitis ³
Ammonium persulfate	Hair bleach, hair colouring agents, denture cleaner, flour maturing agent (E922)	Allergic contact dermatitis, ^{4,5} severe systemic reactions including anaphylaxis, ^{4,6} asthma, ⁷⁻⁹ angular cheilitis ¹⁰
Potassium peroxydisulfate	Cleaning solutions, pool and hot-tub shock	Allergic contact dermatitis ^{11,12}
Potassium persulfate	Hair bleach, hair colouring agents, pool and hot-tub shock, flour maturing agent (E923)	Allergic contact dermatitis, ^{4,5} severe systemic reactions including anaphylaxis, ^{4,6} asthma ⁷⁻⁹

TABLE 2 Persulfate salt compounds and their synonyms

Compound name	Synonyms	Chemical formula	Chemical abstracts service number
Sodium persulfate	Sodium peroxydisulfate, peroxydisulfuric acid disodium salt, disodium peroxodisulfate	Na ₂ S ₂ O ₈	7775-27-1
Ammonium persulfate	Ammonium peroxydisulfate, E923	(NH ₄) ₂ S ₂ O ₈	7727-54-0
Potassium peroxydisulfate	Potassium monopersulfate, MPS, KMPS, potassium caroate, peroxydisulfuric acid, potassium salt, brand names: Caroate, Oxone	KHSO ₅	0058-23-8
Potassium persulfate	Potassium peroxydisulfate, KPS, dipotassium peroxodisulfate, E922	K ₂ S ₂ O ₈	7727-21-1

ewg.org/skindeep/). All databases referenced product brands commonly found in the United States. Additional products were identified through internet searches of the two largest retailers in the United States: Walmart and Amazon.¹⁶ All database and internet searches were performed in June 2021. Brand, product name, use category, and the percent of active persulfate ingredients were collected from safety data sheets (SDSs) or packaging materials.

3 | RESULTS

Our search identified 48 consumer products containing persulfate compounds: 23 (48%) were hair colouring products, 11 (23%) denture cleansers, 8 (17%) pool/hot-tub products, 3 (6%) paints, and 3 (6%) cleaning products (Supplemental Table S1). The CPID database listed 21 persulfate-containing products and the EWG database listed 9. Although the RTKSL identified 108 SDSs listing persulfate compounds as ingredients, SDS listings could not be linked to products directly available to consumers. Publicly accessible versions of the Consumer Product Ingredients Database and the UL Prospector Materials Search engine did not contain persulfate-containing products. Our additional product search identified 7 and 15 persulfate-containing products at Amazon and Walmart, respectively.

4 | DISCUSSION

In this study, we identified five categories of consumer products (hair colouring products, denture cleansers, pool/hot-tub treatments, paints, and

cleaning products) that contained persulfate compounds. Many of these compounds contained combinations of two or three persulfate compounds, with concentrations varying from 0.1% to 70%. We believe these results emphasize the diversity of persulfate-containing consumer products, potential sources of contact allergy which clinicians should be aware of.

While completing our search, we found that publicly available consumer product ingredient databases were not comprehensive, with our searches of large internet retailers identifying several additional consumer products. We also noted that persulfate compound concentrations were consistently listed on the front of pool and hot-tub treatment packaging, but often not clearly listed on the front of hair colouring products or denture cleansers, despite these products containing high concentrations of persulfate compounds. SDSs had to be referenced for persulfate compound concentration information for these products, for example, using Walmart's SDS database (msds.walmartstores.com). In addition, we noted that SDSs and package ingredient lists sometimes used alternative persulfate compound names, such as "potassium caroate" as opposed to "potassium monopersulfate" (Table 2). The use of persulfate compound synonyms may complicate persulfate compound identification when patients bring in products to their office visits and patient avoidance of products after patch testing has confirmed a persulfate contact allergy.

4.1 | Cosmetic, hair colouring, and bleaching products

Nearly half of the products we identified in our search (48%) were hair colouring and bleaching products. Many products contained more

than one persulfate compound, and many products did not list the precise concentration of persulfate products present in the product (Supplemental Table SS1). Hair lightening and colouring products use persulfate compounds to boost their colouring effects. Persulfate-containing hair products were first associated with allergic reactions in 1967, with a wide variety in the severity of reactions, from irritation to anaphylaxis, reported in the time since.^{2,6,9,11} A 2018 report by the US-based Cosmetic Ingredient Expert Review Panel (CIR) determined that persulfates are safe when used as oxidizing agents in hair colourants and hair lighteners if used briefly, discontinuously, and followed by thorough rinsing, but may not be safe in leave-on make-up products, tonics, dressings, and other hair grooming supplies.¹⁷ Per the European Commission database for information on cosmetic substances and ingredients (CosIng), there is no current cosmetic regulation provision for sodium persulfate, ammonium persulfate, potassium caroate, potassium monopersulfate, or potassium persulfate, nor an opinion on any of these substances from the Scientific Committee for Consumer Safety (https://ec.europa.eu/growth/sectors/cosmetics/cosing_en). We did not identify any leave-on or leave-in cosmetic products containing persulfates in our search. It is unclear if this is due to a true lack of availability or secondary to the limited numbers of products indexed in public ingredient databases and inadequate cosmetic package labelling.

4.2 | Denture cleansers

Nearly 23% of identified products were denture cleansers, which contained persulfate compounds in concentrations from 10% to 75%. Denture cleansers are products used to clean and preserve dentures when they are not being worn, with persulfate compound-

containing solutions especially effective for denture wearers who smoke.¹⁸ In 1999, a case of recurrent allergic contact cheilitis secondary to persulfate-containing denture cleanser solutions was confirmed by patch testing.¹⁹ The safety of persulfates in leave-on denture cleansers came to more widespread public attention in 2008, when the US Food and Drug Administration issued updated labelling requirements after 73 reports of possible persulfate-related reactions, including one death.²⁰ In 2018, the CIR reported that there were insufficient data to make any safety recommendation on persulfate-containing denture cleansers.¹⁷ We note that some denture cleansers clearly advertise being "persulfate free" on their packaging, for example, DentaSOAK (Great Lakes Denture Technologies, Tonawanda, New York) and dentibrite (Dentibrite, Los Gatos, California), given the consumer awareness of possible reactions to these compounds.

4.3 | Chlorine-free hot-tub and pool shock treatments

In our product search, we identified eight pool and hot-tub shock treatments containing persulfate compounds ranging from 28% to 70% in concentration. All products identified the persulfate compound and percentage clearly on the front of the package. Pool and hot-tub shock treatments are used to remove contaminants and bromine/chlorine degradation products from sterilized water in pools and hot tubs.¹⁵ Chlorine and bromine-free preparations often use persulfate compounds, such as potassium peroxydisulfate (PPMS) and sodium persulfate, as the oxidative agents to accomplish this.

PPMS is a known cause of hot-tub- and pool-associated allergic contact dermatitis with 15 previous reports in the literature: 14 on

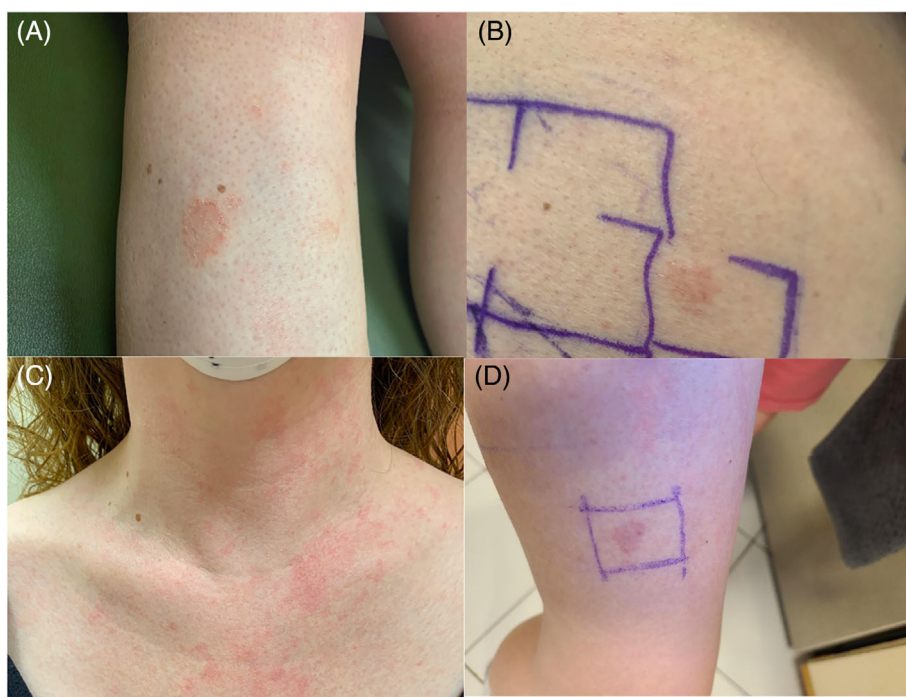


FIGURE 1 Case #1's (A) PPMS-associated dermatitis on the left upper extremity and (B) 2+ patch testing reaction to ammonium persulfate. Case #2's (C) PPMS-associated dermatitis on the trunk and parasternal area and (D) 2+ reaction to ammonium persulfate

adult men and one on a 11-year-old boy.^{15,21–25} Two additional cases of PPMS-associated hot-tub shock dermatitis were also identified in the authors' clinic in 2021 (Figure 1), further emphasizing how common these cases may be. The first was a 33-year-old female nurse without atopic history, who presented with a few months of pruritus and associated dermatitis on the bilateral extremities and trunk noted to flare after hot-tub use (Figure 1A). The rash started after the addition of the hot-tub nonchlorine shock Leslie's Fresh and Clear (Leslie's, North Hollywood, California), a 38% PPMS solution, to her hot-tub chemical regimen. Patch testing showed a 2+ reaction to 2.5% ammonium persulfate (Figure 1B). Symptoms were managed with triamcinolone 0.1% and removal of persulfate hot-tub chemicals. The second case was a 46-year-old female social worker with a history of environmental allergies, eczema, and coeliac disease who presented with several months of itch and dermatitis on the hands, arms, and shoulders worsened by hot-tub use (Figure 1C). History revealed the use of a non-oxidative hot-tub shock containing PPMS. Patch testing revealed a 2+ reaction to 2.5% ammonium persulfate (Figure 1D). Symptoms were managed with betamethasone dipropionate ointment, 0.1% tacrolimus ointment, and removal of persulfate hot-tub chemicals.

Sodium persulfate, another hot-tub shock compound closely related to PPMS, has also been associated with contact dermatitis in a 61-year-old male.²² Alternative pool and hot-tub shock products typically utilize chlorine, bromine, or hydrogen peroxide as their active ingredient.

4.4 | Chemical disinfectants

Our database search identified Virkon brand products (LANXESS, Cologne, Germany; <https://virkon.us>) as containing persulfates. Virkon is a multipurpose disinfectant utilized in hospital and agricultural environments that utilizes potassium peroxyphosphate as its primary oxidative agent. It does not appear that contact dermatitis from persulfate disinfectant use is frequently reported in the literature: we found one previous report of potassium peroxyphosphate associated with disinfectant contact allergy in a sheep farmer.²¹

4.5 | Paint

Our database search identified three exterior paints that contain persulfate compounds in concentrations of less than 1%. Persulfate compounds are used to prepare the latex polymers in latex-based paint products.²⁶ We could not find any cases of persulfate allergy associated with paint exposure.

4.6 | Flour

Although we did not find any food products containing persulfate compounds in our search, we wanted to note that the very first report of persulfate contact dermatitis was in a series of European

bakers exposed to persulfate-based flour additives in the 1940s and 1950s.⁹ The prevalence of persulfate flour allergy was high enough in bakers in those times that the use of persulfates as flour additives was banned by the European Union in 1957. More recently, occupational hand dermatitis has also been reported in pizza makers in Naples with contact to food additives containing ammonium persulfate.²⁷ Potassium and ammonium persulfate compounds are still approved as food additives at very low concentrations by the US Food and Drug Administration, but it is unclear how frequently they are currently used as food additives.⁹ The use of persulfates as food additives is likely rare in the United States as we could not find an example product with local production after an extensive internet search, although we did find one brand of flour (Prima Unbleached Bread Flour, Prima Limited, Singapore) that contained potassium persulfate as a listed ingredient.

4.7 | Limitations

Although we accessed several publicly available ingredient databases containing tens of thousands of products on aggregate, relatively few persulfate-containing products were identified. Therefore, the primary limitation of this study is that given the limited indexing of persulfate-containing consumer products in public databases, our list is likely not comprehensive and may be missing many products, and possibly even categories of products, that contain persulfate compounds. Confirming this limitation is that our simple searches on large retailer websites identified additional products that we had expected would have been present in the ingredient databases. We hope that the public indexing of product ingredients will improve in the future, allowing for the easier study and reporting of potential allergenic consumer ingredients.

5 | CONCLUSIONS

Clinicians should be aware of three general consumer product categories containing persulfates: hair colouring products, hot-tub/pool shock, and denture cleansers. Publicly accessible ingredient databases (CPID, EWG, RTKSL, Consumer Products Ingredients Database, UL Prospector materials engine) are not currently comprehensive for persulfate-containing products. Consumer product package labelling of persulfate compounds is not always clear, especially given the many persulfate compound synonym names. If a clinician reasonably suspects a persulfate allergy, patch testing including ammonium persulfate should be performed.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

Owen R Dean: Conceptualization (equal); data curation (lead); formal analysis (lead); investigation (lead); methodology (lead); visualization (equal); writing – original draft (lead); writing – review and editing (equal).

Kathryn E Somers: Conceptualization (equal); data curation (supporting);

formal analysis (supporting); investigation (supporting); methodology (supporting); project administration (lead); supervision (lead); writing – original draft (supporting); writing – review and editing (equal).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study were derived from the following resources available in the public domain: <https://www.whatsinproducts.com>, <https://www.productingredients.com>, <https://web.doh.state.nj.us/rtkhsfs/rtkhs.aspx>, <https://www.ulprospector.com/en/na>, <https://www.ewg.org/skindeep/>, <https://www.amazon.com>, <https://www.walmart.com>, <https://msds.walmartstores.com>

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Dean OR, Somers KE.

Persulfate-containing consumer products in the US market. *Contact Dermatitis*. 2022;86(4):295-299. doi:10.1111/cod.14028