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**Original Article**

# Skin Irritation to Glass Wool or Continuous Glass Filaments as Observed by a Patch Test among Human Japanese Volunteers

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**Abstract: Glass wool and continuous glass filaments have been used in industry. We examined the irritability of those among Japanese. A patch test was performed on 43 volunteers for the followings: glass wool for non-residential use with and without a urea-modified phenolic resin binder, that for residential use with and without the binder, and continuous glass filaments with diameters of 4, 7, 9, and 13 $\mu$m. Materials were applied to an upper arm of each volunteer for 24 h. The skin was observed at 1 and 24 h after the removal. At 1 h after removal, slight erythema was observed on the skin of a woman after the exposure to glass wool for residential use without the binder. Erythema was observed on the skin of another woman at 1 h after a 24-h exposure to glass wool for non-residential use without the binder. There were no reactions at 24 h after the removal. The low reactions in the patch test suggested that the irritability caused by glass wool, irrespective of a resin component, could be induced mechanically, and that the irritability caused by continuous glass filaments with resin could be slight and either mechanical or chemical.**

**Key words:** Skin irritability, Glass wool, Continuous glass filaments, Patch test, Japanese

## Introduction

Artificial mineral fibers such as glass wool and continuous glass filaments have been used widely in industries as substitutes for asbestos[1]. Glass wool, a fiber consisting of mainly glass, is used as thermal insulation for buildings, houses, boilers, tanks, and pipes. Continuous glass filaments are mainly used as reinforcements in composites for fiber reinforced plastics (FRP) and fiber reinforced thermoplastics (FRTP).

Skin irritation may be induced by these glass materials. Dermatitis is common in workers exposed to glass fibers[2]. In animal experiments, it has been suggested that skin irritation induced by these glass materials is caused by mechanical stimulation and not chemical stimulation[3]. Moreover, negative results for patch tests for these glass materials among human German volunteers also supported this evidence[4]. In another study, an ethnic difference of

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**Table 1. The components of the test samples used in the patch test**

| Test materials | Components |
|---|---|
| Glass wool for non-residential use (coarse fibers) with a binder | Glass: 90% and more (components of glass, $SiO_2$: 55−72%, $Al_2O_3$: 1−7%, CaO: 3−10%, MgO: 2−5%, $B_2O_3$: 0−12%, $Fe_2O_3$: 0−1%, BaO: 0−6%, ZnO: 0−5%, $TiO_3$: 0−1%, $R_2O$ ($N_2O$+$K_2O$: 10−20%)<br>Urea-modified phenolic resin: less than 10% |
| Glass wool for non-residential use (coarse fibers) without a binder | Glass: 100% (components of glass, $SiO_2$: 55−72%, $Al_2O_3$: 1−7%, CaO: 3−10%, MgO: 2−5%, $B_2O_3$: 0−12%, $Fe_2O_3$: 0−1%, BaO: 0−6%, ZnO: 0−5%, $TiO_3$: 0−1%, $R_2O$ ($N_2O$+$K_2O$: 10−20%) |
| Glass wool for residential use (fine fibers) with a binder | Glass: 90% and more (components of glass, $SiO_2$: 55−72%, $Al_2O_3$: 1−7%, CaO: 3−10%, MgO: 2−5%, $B_2O_3$: 0−12%, $Fe_2O_3$: 0−1%, BaO: 0−6%, ZnO: 0−5%, $TiO_3$: 0−1%, $R_2O$ ($N_2O$+$K_2O$: 10−20%)<br>Urea-modified phenolic resin: less than 10% |
| Glass wool for residential use (fine fibers) without a binder | Glass: 100% (components of glass, $SiO_2$: 55−72%, $Al_2O_3$: 1−7%, CaO: 3−10%, MgO: 2−5%, $B_2O_3$: 0−12%, $Fe_2O_3$: 0−1%, BaO: 0−6%, ZnO: 0−5%, $TiO_3$: 0−1%, $R_2O$ ($N_2O$+$K_2O$: 10−20%) |
| Continuous glass filaments with fiber diameters of 4, 7, 9, or 12 µm | Glass: 99% and more (components of glass, $SiO_2$: 52−56%, $Al_2O_3$: 12−16%, CaO: 16−25%, MgO: 0−6%, $B_2O_3$: 5−10%, $R_2O$ ($N_2O$+$K_2O$: 0−2%) |

the Caucasian's high sensitivity to the patch test with glass fibers compared to the Negroid's sensitivity was suggested[5]. There was no mention of the Mongoloid's sensitivity in that study. Additionally, there have been no reports for allergic dermatitis induced by glass materials among the Japanese.

The irritable effects of glass wool may be different depending on whether or not it includes a binder. Epoxy resins, which are sometimes used in man-made vitreous fibers, have been shown to cause allergic and irritant contact dermatitis[6, 7]. Recently, urea-modified phenolic resins are commonly used as binders. Therefore, the effects of a urea-modified phenolic resin binder to cause irritability to the skin should be examined. The fiber diameters of glass wool and continuous glass filaments may also attribute to their irritability-producing effects. Eun *et al.* suggested that the different diameters of fibers affect the patch test responses[8]. Therefore, the chemical irritability of artificial mineral fibers should be examined with consideration to the binders and the fiber diameters. It is important for occupational management to confirm whether or not glass wool and continuous glass filaments with various diameters with or without a binder of urea-modified phenolic resin, which is commonly used, causes chemical irritability.

Among the different types of glass wool, there are coarse fibers that are used for non-residential use and fine fibers used for residential use. There have been no reports for chemical irritability, allergic contact dermatitis among people exposed to these fibers either because of their occupations or from their dwellings, in case of fibers used for residential use. However, it would be better to examine both kinds of fibers.

Therefore, in the present study with healthy human Japanese volunteers, we examined the chemical irritability of glass wool for non-residential use (coarse fibers) with and without a urea-modified phenolic resin binder (Mag-Isover, Tokyo, Japan), and the same for residential use (fine fibers) with or without the binder, and continuous glass filaments with different fiber diameters.

## Materials and Methods

The patch test was performed on 43 healthy, Japanese volunteers aged 22 to 61 yr old (14 men and 29 women) for the following standard samples of 8 fibrous materials: glass wool for non-residential use (coarse fibers) with and without a binder of urea-modified phenolic resin and the same for residential use (fine fibers) with and without a binder of urea-modified phenolic resin and continuous glass filaments with fiber diameters of 4, 7, 9, or 12 $\mu$m (Japan Glass Fiber Association[9], Tokyo, Japan). Japan Glass Fiber Association asked their member companies to produce these standard samples. The components of the 8 fibrous materials are given in Table 1. The volunteers' health statuses including without having serious past medical histories or dermal diseases were confirmed prior to performing the patch test.

Written informed consent was obtained from each volunteer before the patch test by the Japan Hair Science Association[10]. As a control material, petrolatum was applied. Each sample of fibers was attached to Finn chamber tape

**Table 2. The Japanese standard for determination of the patch test**

| Determination | Reactions |
|---|---|
| − | No reaction |
| ± | Slight erythema |
| + | Erythema |
| ++ | Erythema + edema + papules |
| +++ | Erythema + edema + papules + vesicles (small blisters) |
| ++++ | Large blisters |

with an area of 10 × 10 mm. The test materials were then affixed occlusively to an upper arm of each volunteer for 24 h then removed. The skin conditions were subsequently observed at 1 and 24 h after the removal. A dermatologist verified the conditions according to Japanese patch test standards[11](Table 2).

This study was approved by the ethical committee of the Japan Hair Science Association and performed following its guidelines.

## Results

Table 3 shows the results of the patch test at 1 h after the removal of the glass wool for non-residential or residential use without a binder of urea-modified phenolic resin. Erythema was observed on the skin of a 31-yr-old woman after the exposure to glass wool for non-residential use without a binder. At the 1 h after the removal, slight erythema was observed on the skin of a 39-yr-old woman after the exposure to glass wool for residential use without a binder. There were no reactions for glass wool for non-residential or residential use with a binder of urea-modified phenolic resin (data not shown). There were no reactions caused by any continuous glass filaments of different diameters in any of the volunteers at 1 h after the patch removal. And at 24 h after the removal, there were no reactions to any of the materials.

## Discussion

Glass fibers are essential materials in industries. They are used as components in FRP and FRTP. Unfortunately, dermatitis is a common disease among workers exposed to glass fibers. Bjornberg stated that because glass is chemically inert, the reaction must be due to physical injury[2]. In the present study, using the patch test, we examined human irritability to glass wool for non-residential use (coarse fibers) with and without a urea-modified phenolic resin binder and the same for residential use (fine fibers) with or without the binder, and continuous glass filaments with different diameters with healthy, Japanese volunteers as subjects. If we could get the basic data to confirm that these materials stimulate the skin mechanically, and not chemically, proper management of these materials could be done simply by avoiding physical contact with them. We used the Japanese standard for the patch test, because we examined Japanese people, and the results were judged by a Japanese dermatologist.

In an animal experiment with albino rabbits, Sato *et al.* examined skin irritation caused by contact with 3 different kinds of rock wools, 3 different kinds of glass wool with a binder, and a rock wool without a binder by pathological observation and a patch test[3]. There were no positive results in the patch test for any of the kinds of rock wool examined, nor did the histological observation by light microscopy of the rabbits' skin reveal any reactions.

For humans, Jolanski *et al.* analyzed the data on occupational irritant and allergic contact dermatitis caused by man-made vitreous fibers including glass wool, rock wool, slag wool, and other synthetic fibers from 1990 to 1999 in Finland, according to the Finnish Register of Occupational Diseases[12]. They reported a total of 63 cases of occupational dermatoses caused by exposure to synthetic mineral fibers, of which 56 cases were diagnosed as irritant contact dermatitis, and only 2 cases were diagnosed as allergic contact dermatitis. This supported the growing evidence that allergic contact dermatitis caused by man-made vitreous fibers is rare. In Japan, Minamoto *et al.* surveyed the skin problems of the entire manual workers from FRP factories located in Kyushu district between October 1997 and September 1998[13]. The workers were exposed to unsaturated polyester resin, hardeners and glass fibers. Although 58.8% of workers reported having skin problems such as itching and dermatitis, the authors noted that the skin problems tend to be minor. There was no mention about chemically induced dermatitis by glass fibers in the study. Minami *et al.* reported a case of fiberglass dermatitis, and stated that fiberglass dermatitis is due to mechanical irritation[14].

The epidemiological observation for skin irritability of glass wool by Jolanski *et al.*[12] was confirmed by their experiment with human volunteers. The allergic skin irritations of 6 mineral wool materials were examined using the patch test with German volunteers[4]. The tested materials included stone wool and glass wool, both coarse and fine fibers for each, with and without a binder. Sheep wool was used as a negative control, and 20% sodium dodecyl sulphate was used as a positive control. The test materials

**Table 3. The patch test results for glass wool for non-residential and residential use without a binder at 1 h after a 24-h exposure**

| Sex | Age | Non-residential | Residential | Sex | Age | Non-residential | Residential |
|---|---|---|---|---|---|---|---|
| M | 32 | − | − | F | 37 | − | − |
| M | 45 | − | − | F | 39 | − | − |
| M | 48 | − | − | F | 31 | − | − |
| F | 28 | − | − | M | 57 | − | − |
| M | 35 | − | − | M | 35 | − | − |
| F | 25 | − | − | F | 22 | − | − |
| F | 37 | − | − | F | 30 | − | − |
| F | 35 | − | − | M | 36 | − | − |
| F | 29 | − | − | F | 37 | − | − |
| M | 61 | − | − | F | 43 | − | − |
| F | 33 | − | − | F | 27 | − | − |
| M | 41 | − | − | F | 23 | − | − |
| M | 32 | − | − | F | 39 | − | ± |
| F | 34 | − | − | F | 38 | − | − |
| M | 53 | − | − | F | 33 | − | − |
| F | 40 | − | − | M | 41 | − | − |
| F | 57 | − | − | F | 32 | − | − |
| F | 41 | − | − | F | 46 | − | − |
| F | 31 | − | − | F | 28 | − | − |
| F | 30 | − | − | F | 38 | − | − |
| M | 51 | − | − | F | 31 | + | − |
| M | 37 | − | − | | | | |

were applied occlusively via a patch affixed to an upper arm of 32 volunteers for 4 h. The results were then assessed visually first at 15 min, and then again at 24, 48, and 72 h after removal. In the conclusion of that study, the irritation potential of all mineral wool test materials was significantly lower than that with the positive control[4].

It remained questionable whether or not the very low chemical irritability of glass wool thus revealed among Germans would also be observed among Japanese. Although as far as we know, there were no reports of chemical irritability of glass wool among Japanese. There may be a possible difference regarding chemical irritability among ethnicities. Bjornberg *et al.* reported that among the workers at a glass wool factory who were patch tested with glass fibers, a tendency towards increased reactivity to the patch test with the glass fibers was found in persons with fair skin and blue eyes[5].

Moreover, there are several factors which affect human irritability to glass fibers. One of which is the type of binder used. Several cases of allergic contact dermatitis due to synthetic mineral fiber products have been reported. The pathogenesis is mainly caused by the contact with epoxy resins used in finishing work with glass fibers. Holness and Nethercott reported that the workers handling glass fibers coated with epoxy resins, which were used as a binder, developed allergic contact dermatitis of their hands, forearms, head, and neck[6]. The patch test results, in their study, showed that all the subjects exhibited positive responses to epoxy resin at either 2 or 7 d after the application[6]. Jolanski *et al.* also reported that 6 patients with occupational allergic contact dermatitis were sensitive to epoxy resin compounds in a ski factory[7]. Therefore, in the present study, we examined fibers both with and without the most common urea-modified phenolic resin binder.

Another factor that affects human irritability to glass fibers is their diameters. Eun *et al.* performed patch tests among Koreans for two types of rock wool that had different mean diameters[8]. The reactions were different from those of the control after a 48-h exposure. Although not significantly different, the authors stated that the rock wool with a mean diameter of 4.20 $\mu$m induced more intense reactions compared with that with a mean diameter of 3.20 $\mu$m. This finding suggested the possibility that the difference in the diameters of the fibers affects the contact allergic reactions of humans to glass wool. Therefore, in the present study, fibers with different diameters were examined to determine their caustic properties for allergic reactions and/or irritability.

Our study revealed only two cases of positive results in the patch test. At 1 h after removal of the patch, slight erythema was observed in a woman after the exposure to glass wool for residential use without the urea-modified resin binder, and in another woman, erythema was observed after the exposure to glass wool for non-residential use without the binder. There were no reactions to any of the other materials. These results showed that there were similarly low reactions in the patch test to glass fibers observed among the Japanese subjects as well as among the Germans[4]. The positive cases in the present study were women who were exposed to glass fibers without the binder suggesting that the binder of the glass fibers used in this study, a urea-modified phenolic resin, is not irritable to human skin. This was, however, different from the chemical irritability to epoxy resins[6, 7]. Moreover, because the patch tests for all of the continuous glass filaments with different fiber diameters were negative, the differences in diameters of continuous glass filaments did not cause chemical irritability. Therefore, these results suggest that the irritability caused by glass fibers was not chemical. Bjornberg *et al.* reported that there were no differences in the intensity of the skin reactions as revealed by the patch test results with glass fibers before starting work and after at least 4 wk of exposure to glass fibers[15]. This observation also supports the evidence that the dermal reactions to glass fibers are due to mechanical stimulus and not chemical.

We did not perform the patch test for the binder, the urea-modified phenolic resin. We considered that if the fibers with the binders showed positive results and those without the binders did not, it would be clear that the skin irritation was caused by the binder. However, lack of the data for the binder might be a limitation of this study even if, to our knowledge, there have been no reports of allergic dermatitis induced by urea-modified phenolic resin.

Another limitation of this study is the observation time for the patch test. Because we asked healthy volunteers to take the patch test, we considered that the observation time of 48 h was too long, so we decided to do it for 24 h instead. It may be long enough, since there were no positive reactions in the patch test for 24 h. However, still there is a possibility that the observation time of 48 h results in more positive reactions. Furthermore, in this study, a dermatologist judged the results without double checking. This may also be one of the limitations to this study.

As the first step, we used healthy volunteers. If patients with atopic dermatitis or workers who come into contact with glass materials that induce mechanical irritability took the patch test with an observation time of 48 h, there might have been more positive results.

Although there are several limitations to this study, we could consider the results and the fact that to our knowledge, there are no reports of the chemical irritability of glass wool among Japanese. Therefore, in conclusion, because only very slight changes were observed after the exposure to glass wool and continuous glass filaments among Japanese, the irritability caused by these materials observed previously was probably induced mechanically and not chemically. From the very low reactions in the patch test for irritability, the irritability caused by glass wool, irrespective of its resin component, may or may not be induced mechanically, and that the irritability by continuous glass filaments bound by the resin might be slight and either mechanical or chemical. With an adequate choice of a binder, allergic chemical dermatitis will probably not be induced by contact with glass fibers of different fiber diameters.

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