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Case Report

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Nickel dust-induced occupational contact dermatitis by welding and grinding work in shipyard workers: a report of nine cases

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ABSTRACT

Background: Occupational skin diseases are skin conditions that occur or worsen in relation to work and known to be the second most common type of occupational disease affecting individuals in the United States. In Korea, epidemiological reports related to occupational skin diseases are rare. But, no cases of occupational contact dermatitis caused by welding and grinding work have been reported previously.
Case presentation: Nine male workers working in the production department for liquefied natural gas (LNG) ships in Ulsan complained of erythematous papules/patches and itching in various areas of the body after welding and grinding work. The work environment monitoring report revealed that the amount of nickel dust exceeded the time weighted average (TWA) and poor local ventilation status. Based on the symptoms and the overall results of surveys, several tests, and work environment monitoring report, the 2 workers who had positive patch-test reactions to nickel were diagnosed with nickel dust-induced allergic contact dermatitis. The other 7 workers were diagnosed that there was a high probability that they had nickel dust-induced irritant contact dermatitis. The 2 workers who had nickel dust-induced allergic contact dermatitis were recommended to switch their jobs.
Conclusions: Nickel is one of the most common cause of allergic contact dermatitis. In this case, the dust was assumed to be created by welding work with a high nickel content new welding rod and subsequent grinding work, and the concentration of this dust exceeded the time weighted average. Thus, it is thought that the nickel dust may have caused contact dermatitis through continuous contact with the workers' exposed skin in a poorly ventilated space. Currently, several domestic shipbuilding companies are manufacturing LNG tankers using a new construction method. Consequently, it is highly likely that similar cases will occur in the future, which makes this case report meaningful.

Keywords: Occupational dermatitis; Nickel; Dust; Welding; Grinding; Heavy industries

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Abbreviations

IgE: immunoglobulin E; LNG: liquefied natural gas; NOSQ-2002/LONG: long version of the Nordic Occupational Skin Questionnaire-2002; OEM: Occupational and Environmental Medicine; TWA: time weighted average.

Competing interests

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Lee H, Yoo C; Data curation: Kim D, Lee H, Yoo C; Formal analysis: Kim D, Kim H, Lee S, Seo B, Suh HS, Sim CS, Yoo C; Investigation: Kim D, Kim H, Lee S, Seo B, Suh HS, Sim CS, Yoo C; Writing - original draft: Kim D; Writing - review & editing: Kim AR, Suh HS, Yoo C.

BACKGROUND

Occupational skin diseases are skin conditions that occur or worsen in relation to work; they are known to be the second most common type of occupational disease affecting individuals in the United States.[1] Contact dermatitis is the most common occupational skin disease and is caused by contact with external substances in the United States (predominantly chemicals).[2] Contact dermatitis can also be classified as irritant contact dermatitis or allergic contact dermatitis. Irritant contact dermatitis is caused by toxic substances that are in contact with the skin of affected individuals. Allergic contact dermatitis is caused by a chemical or antigen that does not usually cause dermatitis in people; the condition occurs in people when they are re-exposed to an antigen after the first phase of sensitization, which occurs at first exposed to the antigen.[3,4]

Occupational skin diseases very commonly affect workers; however, such diseases are often overlooked by many individuals. According to domestic industrial accident statistics published by the Ministry of Employment and Labor of the Republic of Korea, in 2019, of the 14,030 reported cases of occupational diseases, only 26 (0.19%) cases involved occupational skin diseases[5]. There may be several causes behind this underreporting; it could have been caused by people's lack of interest or the fact that symptoms of skin diseases are usually local and mild, and people can work even if they have skin diseases. Additionally, it seems that only a small monetary profit is obtained after going through a complicated compensation procedure for industrial accidents. However, occupational skin diseases can easily become chronic, and symptoms of skin diseases can cause severe discomfort; sometimes, such diseases can cause a decrease in the quality of life of affected workers. With respect to allergic contact dermatitis, the symptoms that workers with this condition complain of do not improve unless exposure to allergens is stopped; therefore, it is important to identify and avoid the cause of the disease and its symptoms.[3]

To the best of our knowledge, in Korea, no cases of occupational skin diseases caused by welding and grinding work have been reported previously. Overseas, cases of occupational skin diseases caused by welding and grinding work in which there was exposure to ultraviolet radiation have been previously reported.[6-8] Herein, we report cases of contact dermatitis in shipyard workers, which we suspect was caused by the use of welding rods containing high concentrations of nickel. These rods were used for the process of building liquefied natural gas (LNG) ships.

CASE PRESENTATION

Since March 26, 2020, about 80 male workers working in the production department for LNG ships (LNG dual-fuel tankers) of a shipbuilding company in Ulsan have carried out welding and grinding work. Among them, 9 male workers complained of erythematous papules/patches and itching in various areas of the body after welding and grinding work; consequently, they visited the outpatient clinic of the Department of Occupational and Environmental Medicine (OEM) and Department of Dermatology at Ulsan University Hospital to check for contact dermatitis (**Fig. 1**). An occupational- and environmental-medicine specialist conducted a work analysis, questionnaire survey, and skin prick tests. The long version of the Nordic Occupational Skin Questionnaire-2002 (NOSQ-2002/LONG), a standardized questionnaire used to analyze work and exposures related to occupational skin diseases, was used to evaluate the workers.[9] The NOSQ-2002 was specifically developed to survey work-related skin recommendations for the prevention, detection, and management of occupational conditions and environmental exposures.

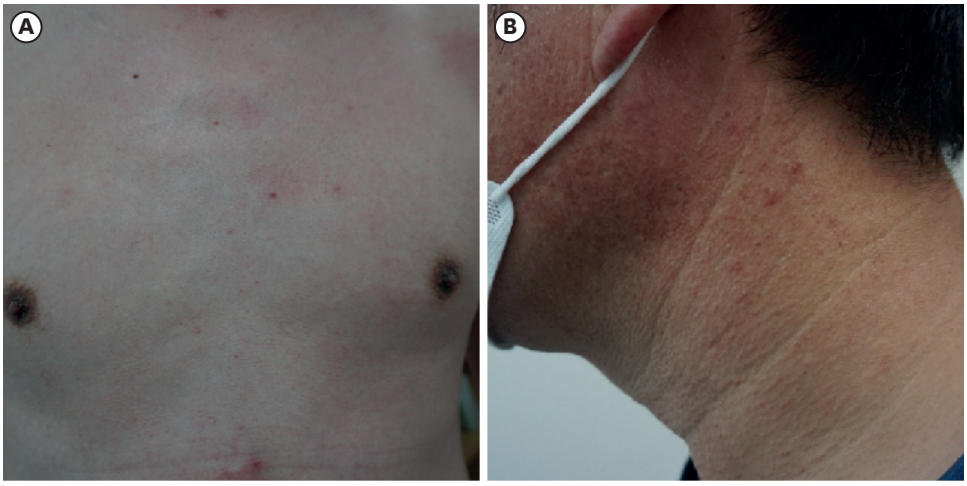

Fig. 1. Photos of workers' first visit to the Department of Occupational and Environmental Medicine. (A) Scattered erythematous papules on the trunk. (B) Localized erythematous telangiectatic patches on the left cheek and neck area.

We wanted to rule out contact urticaria, irritant contact dermatitis, allergic contact dermatitis, and metal fume fever. To rule out other skin diseases, clinical tests, including blood-pressure measurements, spirometry, chest radiography, and blood tests for the evaluation of levels of immunoglobulin E (IgE) were also performed. A dermatologist performed patch tests and dermatological examinations. Work environment monitoring at the workplace of the workers were also conducted.

The work analysis revealed that all of the workers worked for 5 days (40 hours) per week, on weekdays. They worked for 8 hours each day, excluding lunch breaks, and were given a 10-minute break every 2 hours. This job is their first job. They never did a job change. The average period of time for which they had worked in the industry was 12 years. All workers had 2 duties: welding and grinding. They all did the welding before the grinding work. They continued their duties until they visited the outpatient clinic. In terms of the NOSQ-2002/LONG, all of the workers reported that they had no relevant past medical history or history of allergy.

Most of the workers complained of erythematous papules/patches and itching on parts of the body that could be exposed during welding and grinding work, such as the arms, chest, and neck. They stated that the lesions and itching improved on weekends and worsened on weekdays. According to them, the onset time of dermatitis from exposure to nickel-related work was a minimum of 17 days and a maximum of 53 days, and the average duration of onset was about 27.1 days. The workers reported that during the grinding work after welding, all of them worked without protective clothing. The workers' characteristics are summarized in **Table 1**.

For each worker, the results of spirometry-and blood-pressure were normal. With respect to IgE levels (normal levels: < 378 IU/mL), the IgE level in one worker (11.1%) exceeded the upper limit. With respect to the skin prick test, 4 workers (44.4%) had positive test results for mites (*Dermatophagoides farinae* and *Dermatophagoides pteronyssinus*); for other antigens, the results of skin prick tests were negative. With respect to the patch tests, 2 workers (22.2%) had positive patch-test reactions to nickel (**Figs. 2** and **3**). The antigens used for patch testing are listed in **Table 2**. One worker who had a positive patch-test reaction to nickel also had a positive patch-test reaction to cobalt. Six workers also had positive patch-test reactions to

Table 1. Characteristics of the workers with occupational contact dermatitis

No	Sex/Age (years)	Duration of work (years)	Onset time of dermatitis after the exposure (days)	Allergy history/ Past medical history	Hypertension/ Spirometry results/ Immunoglobulin E level[a]	Site of papules/ patches	Skin prick test (positive)	Allergens for which workers had positive patch-test reactions
1	M/47	20	20	Nil[b]/Nil	Nil/Normal/125	Neck	Nil	Nickel (**Fig. 3**)
2	M/45	17	21	Nil/Nil	Nil/Normal/125	Neck, arms	Nil	Thimerosal
3	M/44	17	37	Nil/Nil	Nil/Normal/25	Neck	Nil	Thimerosal, budesonide
4	M/37	9	17	Nil/Nil	Nil/Normal/12.9	Head, back, arms, thighs, calves	Nil	Budesonide, neomycin
5	M/43	9	30	Nil/Nil	Nil/Normal/371	Chest, arms, abdomen, thighs, calves	Dermatophagoides pteronyssinus	Budesonide
6	M/36	8	27	Nil/Nil	Nil/Normal/43	Head, neck, chest	Dermatophagoides pteronyssinus	Nil
7	M/36	5	17	Nil/Nil	Nil/Normal/195	Wrists, thighs, calves	Dermatophagoides farinae	Nickel, cobalt (**Fig. 2**)
8	M/38	9	53	Nil/Nil	Nil/Normal/100	Neck	Nil	Balsam of Peru
9	M/39	14	22	Nil/Nil	Nil/Normal/749	Back, forearms, calves	Dermatophagoides farinae, Dermatophagoides pteronyssinus	Thimerosal

[a]Immunoglobulin E normal levels (quantitative test): < 378 IU/mL; [b]Nil means 'nothing'.

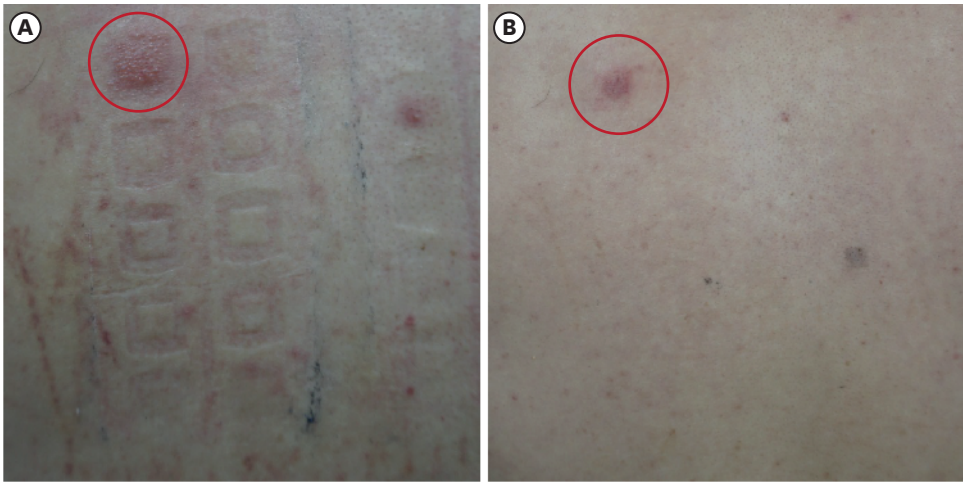

Fig. 2. Patch-test results observed in the 1st case of nickel dust-induced allergic contact dermatitis. (A) Positive patch-test reaction to nickel 2 days after the patch test. (B) Positive patch-test reaction to nickel 4 days after the patch test

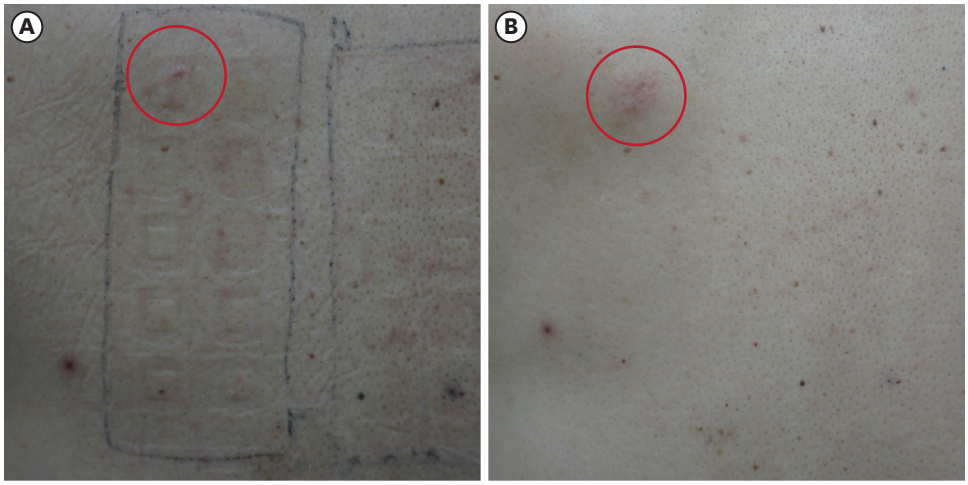

Fig. 3. Patch-test results observed in the 2nd case of nickel dust-induced allergic contact dermatitis. (A) Negative patch-test result for nickel 2 days after the patch test. The circled area is the range that contained nickel in the patch test. (B) Positive patch-test reaction to nickel 4 days after the patch test.

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Table 2. Patch test (Korean Standard Series KOR-1000)

No.	Name of allergen	Concentration (% pet)
1	Nickel (II) sulfate hexahydrate	5.0
2	LANOLIN ALCOHOL	30.0
3	Neomycin sulfate	20.0
4	Potassium dichromate	0.5
5	Mercury (II) amidochloride	1.0
6	Fragrance mix I	8.0
7	COLOPHONIUM	20.0
8	Imidazolidinyl urea	2.0
9	Clioquinol	5.0
10	Balsam of Peru	25.0
11	N-Isopropyl-N-phenyl-4-phenylenediamine (IPPD)	0.1
12	Cobalt (II) chloride hexahydrate	1.0
13	4-tert-Butylphenolformaldehyde resin (PTBP)	1.0
14	Paraben mix	16.0
15	Captan	0.5
16	Budesonide	0.01
17	METHYLISOTHIAZOLINONE + METHYLCHLOROISOTHIAZOLINONE	0.01% aq
18	QUATERNIUM-15	1.0
19	2-Mercaptobenzothiazole (MBT)	2.0
20	p-PHENYLENEDIAMINE (PPD)	1.0
21	FORMALDEHYDE	1.0% aq
22	Mercapto mix	2.0
23	Thimerosal	0.1
24	Thiuram mix	1.0
25	Tixocortol-21-pivalate	0.1

Table 3. Positive patch-test reactions to allergens

Allergen	No. of cases (%)
Budesonide	3 (33.3)
Thimerosal	3 (33.3)
Nickel (II) sulfate hexahydrate	2 (22.2)
Neomycin sulfate	1 (11.1)
Balsam of Peru	1 (11.1)
Cobalt (II) chloride hexahydrate	1 (11.1)

one or more of the following allergens: budesonide, thimerosal, neomycin, and balsam of Peru. The patch-test results for the workers are summarized in **Table 3**.

In case of the work environment monitoring report, up to 14 measurements carried out in the first half of 2020, the value of nickel dust, which is an insoluble compound, and noise level exceeded the time weighted average (TWA). Exposure to other hazardous factors was found to be below TWA. The base material used to manufacture the LNG dual-fuel tankers was 9% nickel steel, and the nickel content in the welding rod used for this purpose was high (up to 75%). From March 26, 2020, all workers didn't be exposed of objects containing nickel, such as jewelry or watches, outside the workplace. The work environment monitoring results are summarized in **Table 4**.

Based on the symptoms of occupational dermatitis, surveys, clinical tests, and work environment monitoring, the 2 workers who had positive patch-test reactions to nickel were diagnosed with nickel dust-induced allergic contact dermatitis. The other 7 workers had negative patch-test results for nickel; however, we judged that there was a high probability of irritant contact dermatitis caused by substances that can cause occupational dermatitis, such as nickel. The 2 workers with nickel dust-induced allergic contact dermatitis were

Table 4. Work environment monitoring results

Hazardous factor	TWA	Number of measurements	Maximum value	Average value	Number of measurements exceeding TWA	Excess rate (%)
Manganese and its inorganic compounds	1 mg/m^2	14	0.34834	0.06124	0	0
Zinc oxide (fumes)	5 mg/m^3	12	0.22411	0.06044	0	0
Zinc oxide (dust)	2 mg/m^3	2	0.61700	0.37844	0	0
Iron oxide dust and fumes	5 mg/m^3	14	0.84961	0.22607	0	0
Nickel (insoluble compound)	0.2 mg/m^3	12	0.34066	0.07918	2	16.67
Nickel (metal)	1 mg/m^3	2	0.13991	0.07175	0	0
Chromium and its inorganic compounds	0.5 mg/m^3	12	0.04725	0.01300	0	0
Titanium dioxide	10 mg/m^3	12	0.18055	0.03062	0	0
Aluminum and its compounds (fumes)	5 mg/m^3	12	0.01945	0.00738	0	0
Magnesium oxide	10 mg/m^3	12	0.01161	0.00575	0	0
Copper (fumes)	0.1 mg/m^3	12	0.00324	0.00080	0	0
Tungsten (metal and insoluble compound)	5 mg/m^3	12	0.00036	0.00006	0	0
Carbon monoxide (CO)	30 ppm	12	4.66	1.03	0	0
Nitrogen dioxide (NO_2)	3 ppm	12	Not detected	0	0	0
Sulfur dioxide (SO_2)	2 PM	12	Not detected	0	0	0
Welding fumes	5 mg/m^3	12	2.47358	0.68662	0	0
Noise	90 db (A)	14	107.0	94.6	11	78.57

TWA: time weighted average.

recommended to switch their jobs and the other 7 workers to thoroughly protect themselves by wearing protective gear and consider switching their jobs. We also recommended that the company should improve the work environment through certain means, such as increasing the use of dust collectors. Other recommendations included for the prevention of dermatitis are as follows; improving workplace ventilation, lowering workplace temperature to reduce sweating and emphasizing the importance of frequent hand washing. All workers were treated with an antihistamine and topical steroid at the outpatient clinic of Department of Dermatology of Ulsan University Hospital, and their symptoms and skin lesions improved after 1 week.

Ethics statement

The present study protocol was reviewed and approved by the Institutional Review Board of Ulsan University Hospital (approval No. 2021-03-021).

DISCUSSION AND CONCLUSION

The 2 workers who had positive patch-test reactions to nickel were diagnosed with nickel dust-induced allergic contact dermatitis. The other 7 workers were diagnosed that there was a high probability that they had nickel dust-induced irritant contact dermatitis.

Occupational contact dermatitis very commonly affects areas exposed to allergens, mainly the hands. The probability of it occurring on the hands, among other areas of the body, of affected individuals is high (approximately 80%–90%).[10]

Hazardous factors that cause occupational skin diseases are irritants, allergens, physical factors, and biological factors. Irritants include water, acids, alkalis, detergents, organic solvents, oils, and oxidizing agents. They cause irritant contact dermatitis through skin irritation and can occur in most workers, depending on exposure. Allergens include metals such as nickel, chromium, and cobalt; rubber additives, such as carbamates, adhesives, and resins; disinfectants, such as formaldehyde; and cosmetic additives, pharmaceuticals, and plants. These substances cause allergic contact dermatitis in sensitized workers.[3,4]

Nickel is the one of most common causes of allergic contact dermatitis that occurs due to skin exposure in occupational settings and among general populations. Nickel is an occupational allergen for workers who carry out work associated with welding, engineering, and plating. Moreover, it is known that occupational dermatitis caused by nickel is mainly related to the hand and wrist.[11,13] The workers we examined developed dermatological symptoms on the arms, chest, and neck; these affected regions correspond to the areas in which occupational dermatitis caused by nickel exposure occurred in previously reported cases. In this case, the work survey revealed that after 2 to 3 hours of working on the welding, the workers participated in the grinding for approximately 5 to 6 hours without completely covering themselves with upper protective clothing. They downplay wearing all protective clothing because they are so skilled at grinding. Therefore, it is highly probable that their skin, which was not covered by protective clothing for lengthy periods of time, was exposed to nickel dust causing occupational dermatitis. Regarding the basis for relevance of the cases, a case of airborne nickel dermatitis on the face and neck of a woman who worked as a seamstress in Germany and was exposed to nickel-containing dust has been reported previously.[14] Additionally, a case in which a woman, who worked in a factory where grinding tools were made, developed dermatitis on her face and forearm due to exposure to isocyanates and epoxy resin has been previously reported.[15] Mann et al.[16] showed that nickel sensitization was more likely to occur in people who inhaled airborne nickel. Therefore, exposure to low concentrations of nickel in ambient air may be sufficient to induce sensitization. We can provide an explanation for why 2 workers with no history of nickel induced allergic contact dermatitis with this article.

Patch test is important diagnostic tool for identifying the causes of contact dermatitis. In patch test, skin reactions are checked 48 hours after the application of appropriate concentrations of various allergens to the skin of individuals. Korean standard series, the most used patch test in Korea, is associated with high reproducibility and is easy to use; it involves the use of 25 major antigens that account for 80% of all causes of allergic contact dermatitis.[17] However, even if an individual has a positive patch-test reaction, if the reaction does not match the individual's medical history and clinical course, the patient cannot be diagnosed with allergic contact dermatitis. For example, in our case, budesonide, thimerosal, neomycin, and balsam of Peru—the allergens for which certain workers had positive patch-test reactions—were substances that the workers were not likely to be overexposed to during welding and grinding work. Furthermore, an individual can be diagnosed with irritant contact dermatitis, the most common occupational skin disease, only if the individual has a negative patch-test result for a causative agent.[3,4,10] Also, irritant contact dermatitis can be diagnosed by exclusion of allergic contact dermatitis.[18] All workers underwent testing to rule out type I and type IV hypersensitivity. Seven workers got negative results from both type I and type IV hypersensitivity. So, we suggested 7 workers as 'high probability of nickel dust-induced irritant contact dermatitis'.

In 1989, Toby Mathias proposed 7 criteria to assess the relationship between contact dermatitis and occupation. It is noted that the Mathias criteria show a high validity and diagnostic yield, making them useful for establishing occupational causation of contact dermatitis. **Table 5** shows the 7 items considered in the Mathias criteria that are used to establish occupational causation of contact dermatitis; it can be concluded that occupational exposure and dermatitis are related only when at least 4 criteria are satisfied.

Table 5. The Mathias criteria for establishing occupational causation of contact dermatitis

Mathias criteria
1. Is the clinical appearance consistent with contact dermatitis?
2. Are there workplace exposures to potential cutaneous irritants or allergens?
3. Is the anatomic distribution of dermatitis consistent with cutaneous exposure in relation to the job task?
4. Is the temporal relationship between exposure and onset consistent with contact dermatitis?
5. Are nonoccupational exposures excluded as probable causes?
6. Does dermatitis improve away from work exposure to the suspected irritant or allergen?
7. Do patch or prick tests implicate a specific workplace exposure?

Based on the patch tests and Mathias criteria, contact dermatitis were considered to have developed due to local nickel exposure. The workers were exposed to high concentrations of nickel during work, and dermatitis occurred on areas of the hands and wrists, chest, and neck where the skin was exposed during work. The workers had no dermatitis before exposure to nickel but complained of dermatitis symptoms after March 26, 2020. Symptoms of dermatitis improved on weekends when they did not work and worsened on the weekdays. With respect to the patch tests, 2 workers had positive patch-test reactions to nickel; of the remaining 7 workers, 6 workers had positive patch-test reactions to one or more allergens (except nickel), and one worker had negative patch-test results for all allergens. Therefore, according to the Mathias criteria, our diagnosis of occupational contact dermatitis is reasonable.

The work environment monitoring report result showed that the value of nickel insoluble compounds exceeded the TWA. Nickel insoluble compounds include dust and fumes. If it is assumed that nickel fume caused dermatitis, fume would affect respiratory irritation symptoms in workers, decreased lung function, X-ray abnormalities, or metal fume fever. However, the workers did not show these conditions and only showed symptoms of dermatitis. In addition, the values of all other fumes were below the reference. Therefore, we inferred that nickel dust rather than nickel fume caused dermatitis.

In the workplace, we found that the work for the production of LNG dual-fuel tankers included welding and grinding, and there was no quality control of the work. During welding and grinding, the base material used is 9% nickel steel, and it has been used for a long time for purposes such as the production of LNG tankers because of its excellent impact toughness at cryogenic temperatures. It has a higher nickel content than 2.5% nickel steel and 3.5% nickel steel, which are used for building other ships. Inconel- and Hastelloy-based welding rods that contain large amounts of nickel (nickel constitutes approximately 60%–75% of such rods) are used as the welding material, which can ensure the same toughness and strength as that of base material in the welding.

In addition, only one large fan was used in the factory to ventilate the entire plant, and 24 mobile dust collectors were used. Some workers moved during the welding and grinding, which resulted in insufficient use of portable dust collector. We believe the workplace where LNG ships are made had higher values of nickel than the that of workplaces where other ships are made. Considering the work environment monitoring report and poor ventilation, it can be presumed that the nickel content of the workplace air was fairly high. Therefore, due to high nickel concentrations in welding fumes or nickel dust in the air, inhalation of welding fumes and dust or dermal exposure to nickel lead to nickel sensitization, which lead to occupational dermatitis.

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The limitation of our study was that the association between nickel concentration and dermatitis could not be quantitatively evaluated because the workers' urine nickel concentration could not be measured.[11] Furthermore, according to Chaudhry et al.[19] and Davis et al.,[20] in cases involving metals and certain antibiotics, there is a possibility of the delayed reactions, even 4 days after the application of patch tests. It is regrettable that due to difficulties associated with time and testing conditions, it was not possible to confirm whether any of the 7 workers diagnosed with irritant contact dermatitis had delayed positive patch-test reactions to nickel.

Nevertheless, these cases are meaningful because to the best of our knowledge, they are the first reported cases of nickel dust-induced occupational dermatitis caused by welding and grinding in Korea. One case of nickel dust-induced allergic contact dermatitis caused by a grinding has been reported previously overseas; however, since then, there have not been any such reports.[21] Considering the several cases of contact dermatitis and regarding the working environment monitoring report, therefore, exposure to nickel dust in welding and grinding is more likely to cause occupational contact dermatitis compared to exposure to nickel fumes. Many domestic shipbuilding companies are planning to build new LNG tankers using a new method; therefore, it is highly likely that dermatitis will similarly affect other workers in the future.

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