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Microorganism-induced skin disease in workers exposed to metalworking fluids

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Background An outbreak of skin disorders among workers potentially exposed to metalworking fluids prompted the present study. Few studies have described skin disorders associated with microbe-contaminated metalworking fluids.

Methods Samples of materials contaminated with metalworking fluids were obtained from two manufacturing facilities in Ohio. Pathogenic bacteria and yeasts, in concentrations sufficient to cause skin disease, were cultured from 9 of 12 (75%) sampled materials.

Results Allergic patch testing of five affected people produced negative results for standard allergens, augmented by fluids and items from their workplace. This ruled out allergies as the cause of the skin disease. Improper handling and disposal of cotton gloves, inappropriate use of scouring pads and ineffective hand wiping were apparently responsible for the microbiological contamination. The hands and forearms were most commonly affected.

Conclusions Improper handling of soluble, synthetic and semi-synthetic metalworking fluids provides an excellent environment for the growth of a range of microorganisms, including bacteria and fungi. If allowed to grow because of poor occupational hygiene, these microorganisms can cause skin disorders among workers. Soiled protective clothing (gloves, coveralls and work boots) should be cleaned or discarded on a regular basis. When washing up, workers should not use metalworking fluids and items used to clean machinery.

Key words Contaminated clothing; cutting oils; dermatitis; dermatosis; industrial metal workers; metalworking fluids; microbial dermatosis.

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Introduction

Occupational dermatitis is prevalent in all industrialized countries [1]. Many agents are associated with skin lesions in the general population and in occupational settings.

The management of occupational dermatitis involves treatment and investigating opportunities for primary prevention. This involves mitigation of the workplace environment in reference to a skin disease that has already been diagnosed. It also entails protecting other workers who are not affected but are potentially at risk, and minimizing or eliminating the industrial exposure that led to a person's disease. Optimally, this is accomplished with minimal losses of employee time.

Taking a careful history and performing a complete physical examination are essential in diagnosing an occupational skin disease [2]. Further investigations, including patch tests, fungal or bacterial cultures, biopsies and plant visits, may be necessary. Allergic contact dermatitis, when occupationally acquired, is commonly confined to the exposed dorsal aspects of the hand and arms; the palms are often spared [3]. Allergic contact dermatitis should be

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differentiated from an irritant dermatitis. An aid to diagnosis is observing the course of a skin condition when an individual is away from work for >1 day, followed by observation after returning to work.

Soluble, synthetic and semi-synthetic metalworking fluids or coolants provide an excellent environment for the growth of a wide range of microorganisms, including bacteria, molds and yeasts [4,5]. If allowed to grow, these microorganisms can have detrimental effects on the fluids, often reducing their effectiveness as lubricants or coolants [6]. Evidence from available studies has shown that workers may be exposed to microbially contaminated metalworking fluids by skin contact with contaminated items [4,6,7].

We describe a study to investigate an outbreak of dermatitis in workers exposed to metalworking fluids.

Materials and methods

This cross-sectional study was designed to investigate an outbreak of skin problems among employees of two automobile parts manufacturing facilities in the state of Ohio. In both plants, workers who used metalworking fluids containing irritants such as formaldehyde, potassium dichromate, triethanolamine and diisocyanate were studied. A self-administered questionnaire was given to a study group of workers identified as being exposed to metalworking fluids (n = 45) and a group of non-exposed workers, who served as controls (n = 36). The questionnaire gathered data on past or present occupational exposures, hobbies, previously diagnosed skin conditions, skin care, and unusual skin condition or reactions. Non-responders received two written reminders through the mail.

Two inspection visits were made to the plants. These were conducted through appointments with the personnel managers of each facility. During the visits, some potential areas of concern were identified in each plant. Samples of items used by employees and contaminated with metalworking fluid were obtained. A total of 14 samples were obtained from eight different sites in the two plants. These are listed in Table 1. The sampled materials were sealed in self-closing plastic bags before shipment. Two unopened bags were also submitted as controls. These were sent to PathCon Laboratories, Atlanta, GA, for microbiological culture and identification. The sites are described in Table 1.

All employees who were engaged in production work at either facility were examined for the presence of skin lesions. A trained field investigator (with an MD and MSc in occupational health), who was employed by the US HealthWorks, Cleveland, OH, conducted this inspection. Prior to the start of this study, 13 workers identified as having potential skin lesions were patch tested for chemical sensitivity by a board-certified dermatologist from the Dermatology Unit of the Cleveland Clinic Foundation, Cleveland, OH. The same individual administered and evaluated the patch tests.

After the medical reports of the people from University Hospital Cleveland and Department of Dermatology of the Cleveland Clinic Foundation, Cleveland, OH, were reviewed, a cross-sectional analysis was conducted using data from questionnaires, physical examination of the subjects and a walk-through inspection of the subjects' working environment. These were workers who, in the course of their jobs, might have been exposed to metalworking fluids, as assessed using the information from the individual job descriptions and responsibilities. The control subjects had no past or present exposure to metalworking fluids, and were selected from the administrative staff, adjusting for confounding factors such as age, gender and socioeconomic status. Potential subjects were told the purpose of the study and that participation was voluntary. Permission from management and informed consent from potential subjects were obtained before conducting the study. All statistical computations were performed on a personal computer using SPSS 10.0.

Sterile, distilled water was used to extract sample

Table 1. Sources, location and usage of sampled materials sent to the laboratory

Sample number	Source	Location	Material	Usage
1	Plant 1	Metal press	Cotton wiping cloth	Cleaning machinery
2	Plant 1	Metal press	Gloves	Hand protection
3	Plant 1	Plant floor	Disposable tissues	Nasal congestion
4	Plant 1	Metal press top	Cotton wiping cloth	Cleaning machinery
5	Plant 1	Metal press top	Plastic cleaning pad	Cleaning hands and skin
6	Plant 1	Metal press top	Gloves	Hand protection
7	Plant 1	Metal press floor	Plastic cleaning pad	Cleaning hands and skin
8	Plant 1	Plant floor	Disposable hand tissues	Wiping hands
9	Plant 1	Plant floor	Disposable hand tissues	Wiping hands
10	Plant 1	Control	Empty plastic bag	Control
11	Plant 2	Rest room	Plastic cleaning pad	Cleaning hands and skin
12	Plant 2	Sanding booth	Clothing	Protection for workers
13	Plant 2	Tack booth	Gloves	Hand protection
14	Plant 2	Control	Empty plastic bag	Control

materials for growth from the contaminated items collected. Extracted sample materials were inoculated onto malt extract agar to grow fungi and R2Ac agar to grow bacteria. The same sterile solution was added to the control bags, vigorously shaken and then inoculated onto the same growth media.

The material safety data sheets for the metalworking fluids were reviewed for reported evidence of skin disorders as possible health effects of inadvertent exposures. Telephone calls were placed to the manufacturers of the metalworking fluids used at the two facilities. Manufacturers were asked about any reported cases of skin disorders.

Results

Questionnaire

A detailed history questionnaire was given to 81 employees in two plants. A total of 76 questionnaires were returned, giving a return rate of 93%. Of these, five (6%) were discarded because of inadequate information, yielding a usable sample of 71 questionnaires. Twenty-one (26%) employees complained of skin problems. Twelve (57%) of the exposed employees identified an itchy eruption on the hands and/or forearms, while two (14%) complained of problems involving the head, neck or whole body. None of the non-exposed reported such complaints. Most of the exposed workers reported an improvement in or complete cure of their condition during holidays or vacation periods, but experienced a recurrence after returning to work. Nine of the 40 (22%) exposed workers had past medical histories of allergy or skin disease, while one of the 31 (3%) controls had a similar medical history. These results are summarized in Table 2.

Table 2. Analysis of history of skin disease from questionnaire responses of the study population

	Exposed	Non-exposed	Total
Skin complaints	20	1	21
History of allergy	9	1	10
Total	29	2	31

Table 3. Statistical analysis of skin disease in workers exposed to metalworking fluids and controls

Exposure to metalworking fluid	Skin disease	
	No disease	Disease
Control	14	1
Exposed	8	12

Fisher's exact test: $P < 0.002$.

Skin lesions

The exposed and non-exposed groups had essentially similar ages ($t = 1.03$; df = 69; $P > 0.05$). There was no difference between males and females ($\chi^2 = 1.2$; df = 1; $P > 0.05$). People exposed to metalworking fluids were more likely to suffer from allergies than were non-exposed workers ($\chi^2 = 10.4$; df =1; $P < 0.001$). Exposure to metalworking fluids is a significant factor for predicting the presence of skin lesions. These findings are summarized in Table 3. The odds ratio for exposure to metalworking fluids was 11.9 (df =1; $P < 0.001$). Fisher's exact test was performed because the small number of people with skin diseases was significant ($P < 0.002$). Additional details are found in Table 4.

As a job title or occupational class, press operators reported the greatest number of occupational skin disorders (seven cases; 33%). Assemblers had the second greatest number, with four cases (19%). This is most likely due to the need for more frequent contact with metalworking fluids in the course of performing their normal job duties. Complete details are provided in Table 5.

The most common body site for developing a skin lesion was the hand (30%), followed by the forearm (17%). This was not surprising, as the hands are the body parts most likely to have the greatest contact with metalworking fluids. Complete details are provided in Table 6.

Microbiological analysis of environmental samples

Eight of 12 samples (68%) yielded bacteria in sufficient concentrations to cause infection. The bacterial species recovered in relatively large quantities from cultures

Table 4. Prevalence of skin disease in the study population

Subjects	Age (yrs)	Allergy	Gender		Any skin disorder	
			Male	Female	Positive	Negative
Exposed	43.3	9	29	11	20	20
Non-exposed	44.5	1	26	5	1	30
Total		10	55	16	21	50

Odds ratio = 11.9.

Table 5. Number and percentage of cases observed per particular job title

Job title	Cases	Percentage
Press operator	7	33.3
Assembler	4	19.0
Body preparation and paint finishing	2	9.5
Maintenance	2	9.5
Painter	2	9.5
Tooling	1	4.8
Sealer line	1	4.8
Spot welder	1	4.8
Material handler	1	4.8
Total	21	100.0

Table 6. Frequency and distribution of skin diseases as related to body site

Location of dermatitis	Number of cases	Percentage
Hands	16	30.0
Forearm	8	17.0
Back	4	8.5
Collarbone	4	8.5
Neck	4	8.5
Fingers	3	6.4
Lower leg	3	6.4
Whole body	3	6.4
Thigh	2	4.3
Total	47[a]	100.0

[a]Total >21 due to multiple lesions in some individuals.

included Enterobacteriaceae, *Flavimonas*, Gram-positive rods and *Sphigomonas*. One sample yielded yeast.

Of the materials studied, cotton gloves and disposable tissues were the most common sources of the bacterial and fungal infection in this study (8/14 samples, or 57%). Plastic cleaning pads (21%) were the next most common source. Complete details are provided in Table 7.

Table 7. Sources and frequency of microbial contamination of the sample materials

Material	Frequency			
	Bacteria	Fungi	Total	%
Cotton gloves	3	1	4	29
Disposable hand wiping tissues	3	1	4	29
Plastic cleaning pad	3	0	3	21
Cotton wiping cloth	2	0	2	14
Clothing	1	0	1	7
Total	12	2	14	100

Material safety data sheets

The material safety data sheets for a total of eight different metalworking fluids were reviewed. None of the contents indicated that the specific metalworking fluids were known to be able to successfully culture species of pathogenic bacteria.

The following three cases illustrate the affected workers in this study.

Case 1

An assembler gave a 4–5 month history of an itchy rash of the hand and arms. He had 30 years of company service and an occupational history of exposure to various solvents. The rash was essentially unchanged at weekends or after a week of vacation. He wore insulated green rubber gloves and coveralls over the gloves, which were changed every 2 days. He had no evidence of latex allergy symptoms and denied other employment. His past medical history and review of systems were unremarkable.

Examination showed dry, scaly, erythematous plaques affecting the web spaces of the fingers on his right hand, with some xerosis and dermatitis of his right forearm. On his left forearm, there was some hypopigmentation and a scar from an old welding burn. He had no prior skin disease, no respiratory symptoms, no other jobs except for his present employment and denied having hobbies.

He was patch tested using a standard screening tray containing alcohols, isocyanates and a number of substances from the workplace, including Lotrisone cream, which he had used. In all, 96 items in the patch test regimen were negative. Conservative management was prescribed.

Case 2

An assembler with 4 years of company service was permanently assigned to cleaning metal surfaces with chemicals. Two weeks later, he complained of a rash on his right forearm. The pigmented patches later involved his trunk, arms and legs. The hands, face, scalp, neck and upper chest were spared. He had no oral or other mucosal blisters. He was diagnosed, by a family physician and subsequently by a dermatologist, to have linear immunoglobulin A disease, based on a compatible clinical picture and his response to dapsone therapy at a dose of 50 mg once a day. His job duties and exposures were reviewed. His dermatitis was controlled as long as he continued dapsone therapy.

His past medical history, exposures at work and systems were reviewed. A potassium hydroxide scraping for fungal hyphae from his abdomen was negative. He denied having a second job and had no history of overt contact dermatitis. His hobbies included woodworking. He was patch tested using a standard screening tray augmented by plastics and glues, alcohols, isocyanates, gloves and sanding paper. Primers, coatings, solvents and hardeners from the plant were also included, to give a total of 95 substances. With the exception of a questionable reaction to isophorone diisocyanate, all patch tests were negative. Since isophorone diisocyanate is not used in the plant, the

specialist described it as false positive. A direct cause-and-effect relationship could not be established. The man was continually managed with dapsone and other conservative treatments.

Case 3

A female press operator complained of a 10 month history of generalized eczematous dermatitis. She had experienced no skin problems prior to working in the company. Her job duties included machining metal parts that were continuously bathed by chemicals. She always wore latex gloves and protective clothing on the job. She also periodically cleaned the surfaces on her press.

During a 2 week leave from work, her skin condition improved. However, the original dermatitis reappeared within 1 week of returning to work. She was managed conservatively with fexofenadine 60 mg twice a day and hydroxyzine 10–20 mg as needed for itching, without improvement.

With the exception of her dermatitis, physical examination was unremarkable. She was patch tested using a standard screening tray augmented by latex and samples of the chemicals used in her work and material from her protective clothing. Personal care products were also included. With the exception of a slight positive reaction to gold, all her patch tests were negative. She had worn a gold ring for years without experiencing any reaction. She had no oral gold and was not using any medications containing gold. A latex radioallergosorbent test was performed to rule out the possibility of latex allergy. Her results were reported as class 0, meaning that there was no evidence of type I latex allergy. The specialist could not establish whether her dermatitis was related to work. A diagnosis of nummular eczema was assigned.

Discussion

The study was undertaken to find the cause of a dermatitis cluster among factory workers exposed to metalworking fluids. In particular, was an occupational exposure to metalworking fluids the cause of recent cases of dermatitis among exposed workers?

This study demonstrated the isolation of bacteria and fungi from the environmental samples subjected to laboratory analysis. The bacteria isolated were *Flavobacterium*, Enterobacteriaceae, Gram-positive rods and *Flavimonas*. Yeast and *Rhizopus* were also isolated. Some, but not all, of these microorganisms have been isolated by others in industrial settings [8,9]. The same organisms were not cultured from the skin of affected workers.

The work supported the findings of many studies and product manufacturers that soluble, synthetic and semi-synthetic metalworking fluids or coolants provide an excellent environment for the growth of a wide range of microorganisms including bacteria, molds and yeasts [4,5,10–12]. If allowed to grow, these microorganisms can have detrimental effects on humans who come into contact with them. Manufacturers of the chemicals studied have not reflected these findings in the material safety data sheets that they issue.

This study further demonstrated that poor personal hygiene, improper handling and incorrect disposal of materials contaminated with metalworking fluids contribute to the microbiological contamination of these objects. For example, the plastic cleaning pad used in the lavatory for cleaning workers' hands during breaktime or at the close of work was the most likely source of infection for nine (43%) of the 21 workers identified with a skin infection.

Plastic cleaning pads were not designed to be used on skin. When used inappropriately on skin, they can cause significant dermal abrasion. This use also transfers any microbiological contamination to newly created breaks in the skin, initiating a skin infection. Protective clothing was the likely source of contamination for two (10%) of the workers with skin problems. One of these workers stated that he wore specially prescribed gloves for an entire week before discarding them. Yet another source of contamination was soiled cotton wiping cloths, used to clean surfaces of metalworking tools. These cloths are soaked with cleaning fluids and may be reused for days or weeks before being discarded. Ten (48%) of the cases of skin diseases studied were attributed to exposure to such contaminated materials.

Several cutaneous disorders have been associated with the use of metalworking fluids. These include irritant contact dermatitis [13,14], allergic contact dermatitis [15,16], folliculitis [17,18], oil acne [19], oil keratosis [20], squamous cell carcinoma [21], and pigmentary changes such as melanoderma and leukoderma [22].

The attempts to recover organisms from skin sample material failed. Others who have attempted to culture organisms from similar skin conditions have also failed to recover pathogens [4]. The reason offered for this finding is that the skin lesions are due to endotoxins produced by the organisms [7]. This is also the explanation given for the generalization of symptoms [5].

Few studies have described skin disorders associated with microbially contaminated metalworking fluids. This study demonstrated that improper use of personal protective equipment, such as gloves, aprons and clothing, as well as the mishandling of metalworking fluids, improper usage of cleaning products (plastic cleaning pads) and inadequate workplace cleanliness (not promptly discarding soiled cleaning pads), are all possible causes of skin disorders among workers exposed to metalworking fluids.

The outcomes of the interventions implemented after this study include a decrease in the incidence of skin diseases related to exposure to metalworking fluids. Costs

for disposable materials have increased slightly. However, these costs have been more than offset by savings due to decreased lost work time and decreased utilization of health care benefits.

Recommendations and conclusions

The results of this study clearly demonstrate that soluble, synthetic and semi-synthetic metalworking fluids provide an excellent environment for the growth of a range of microorganisms, including bacteria, fungi and yeasts. If allowed to grow because of poor occupational hygiene, these microorganisms can have detrimental effects on workers.

Professionals providing environmental health and safety support for operations that use metalworking fluids should initiate or ensure safe handling practices that meet or exceed National Institute for Occupational Safety and Health (NIOSH) recommendations. This may involve establishing a multi-disciplinary team, including an outside chemical salesperson and personnel from engineering, production and safety functions, to review and offer recommendations on issues relating to metalworking fluids. Priorities for such a team include developing written procedures for acquiring, using, maintaining and disposing of metalworking fluids; implementing a verification system to ensure that procedures are followed; providing procedures and controls to maintain metalworking fluids near ideal conditions; installing, maintaining and monitoring the performance of engineering controls; and ensuring that employees use personal protective equipment and follow good personal hygiene practices as appropriate [23].

Because workers with metalworking fluid dermatitis have a poor prognosis for full recovery [24], prevention of skin disorders is important. Limiting the dermal exposure to metalworking fluids is the crux of preventive measures.

References

1. Alomar A, Conde-Salazar L, Romaguera C. Occupational dermatoses from cutting oils. *Contact Dermatitis* 1985;**12:** 128–138.
2. Mathias CGT. Occupational dermatoses. In: Zenz C, ed. *Occupational Medicine*, 2nd edn. Chicago, IL: Yearbook, 1988; 132–165.
3. Bernstein DI. Allergic reactions to workplace allergens. *J Am Med Assoc* 1997;**278:**1907–1913.
4. Jaksic S, Uhitil S, Zivkovic J. Bacteria pollution of cutting fluids: a risk factor for occupational diseases. *Arh Hig Rada Toksikol* 1998;**49:**239–244.
5. Laitinen S, Linnainmaa M, Laitinen J, Kiviranta H, Reiman M, Liesivuori J. Endotoxins and IgG antibodies as indicators of occupational exposure to microbial contaminants of metal-working fluids. *Int Arch Occup Environ Health* 1999;**72:**443–450.
6. NIOSH. *Proposed National Strategies for the Prevention of Leading Work-related Diseases and Injuries, Part 2*. Cincinnati, OH: US Department of Health and Human Services, Public Health Services, Centers for Disease Control, National Institute for Occupational Safety and Health and the Association of Schools of Public Health, 1988.
7. Liesivouri J, Kotimaa M, Laitinen S, *et al*. Airborne endotoxin concentrations in different work conditions. *Am J Ind Med* 1994;**25:**123–124.
8. Albert RE. Allergic contact sensitizing chemicals as environmental carcinogens. *Environ Health Perspect* 1997;**105:**940–948.
9. Rosenkranz HS, Klopman G, Zhang YP, Graham C, Karol MH. Relationship between allergic contact dermatitis and electrophilicity. *Environ Health Perspect* 1999;**107:**129–132.
10. Chazal PM. Pollution of modern metalworking fluids containing biocides by pathogenic bacteria in France. Reexamination of chemical treatments accuracy. *Eur J Epidemiol* 1995;**11:**1–7.
11. Sherburn RE. Amine borate catabolism by bacteria isolated from contaminated metalworking fluids. *J Appl Microbiol* 1999;**87:**668–675.
12. Mattsby-Baltzer I, Sandin M, Ahlstrom B, *et al*. Microbial growth and accumulation in industrial metalworking fluids. *Appl Environ Microbiol* 1989;**55:**2681–2689.
13. Fisher AA. Dermatitis due to cutting oils, solvents, petroleum and coal tar products. In: Fisher AA, ed., *Contact Dermatitis*, 3rd edn. Philadelphia, PA: Lea & Febiger, 1986; 531–545.
14. de Boer EM, Van Ketel WG, Bruynzeel DP. Dermatoses in metal workers. II. Allergic contact dermatitis. *Contact Dermatitis* 1989;**20:**280–286.
15. Sprince NL, Palmer JA, Popendorf W, *et al*. Dermatitis among automobile production machine operators exposed to metal-working fluids. *Am J Ind Med* 1996;**30:**421–429.
16. Alomar A. Occupational skin disease from cutting fluids. *Dermatol Clin* 1994;**12:**537–546.
17. Suvorov AP, Orkin VF. Diagnosis of oil-induced folliculitis. *Gig Tr Prof Zabol* 1989;**33:**16–18.
18. Khachatrian LA, Airapetian MA. Oil folliculitis in adolescents working at the metallurgical plants of the Armenian SSR. *Gig Tr Prof Zabol* 1974;**18:**46–47.
19. Das M, Misra MP. Acne and folliculitis due to diesel oil. *Contact Dermatitis* 1988;**18:**120–121.
20. Ramos H. Occupational health case report. 5. Cutting oil mists. *J Occup Med* 1974;**16:**273–275.
21. Tsuji T, Otake N, Kobayashi T, Miwa N. Multiple keratoses and squamous cell carcinoma from cutting oil. *J Am Acad Dermatol* 1992;**27:**767–768.
22. Tsyrkunov LP. Skin pathology from exposure to the lubricating coolant fluid MR-7. *Gig Tr Prof Zabol* 1992;**36:** 38–40.
23. NIOSH. *Criteria for a Recommended Standard: Occupational Exposure to Metalworking Fluids*. DHHS Publication No. 98-102. Cincinnati, OH: NIOSH, January 1998.
24. Pryce DW, Irvine D, English JSC, Rycroft RJG. Soluble oil dermatitis: a follow up study. *Contact Dermatitis* 1989;**21:** 128–135.