

Addition of ferrous sulfate to cement and risk of chromium dermatitis among construction workers

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Lowering the water-soluble chromium content of cement to <2 ppm has been suggested to diminish the risk of allergic hand dermatitis caused by chromium among construction workers. The prevalence of chromium dermatitis was determined for a representative sample of 913 house construction workers and 707 concrete element prefabrication workers, with a questionnaire and clinical examination, before the use of cement with such a low content of water-soluble chromium was started on Finnish construction sites in 1987. The prevalence of allergic contact dermatitis caused by water-soluble chromium, diagnoses confirmed with patch tests among the workers with hand dermatitis, was 9/117 (7.7%), 4 of them were new 4/105 (4%) and 5 had been diagnosed earlier. In 1987, the prevalence of work-related hand dermatitis (allergic and irritant together) was 6.8% among the construction workers and 8.9% among the concrete element prefabrication workers. The Finnish Register of Occupational Diseases was checked for reports of chromium dermatitis and other forms of hand dermatitis from 1978 to 1992. The results indicated that, after 1987, the occurrence of allergic contact dermatitis caused by chromium decreased to less than 1/3 the previous level, whereas the occurrence of irritant contact dermatitis remained stable throughout the observation period. Regardless of some potential confounders, the addition of ferrous sulfate to cement during the production process may have reduced the number of cases of allergic contact dermatitis among construction and concrete element prefabrication workers. Our results agree with the results of Danish studies and Swedish observations.

Key words: construction workers; allergic contact dermatitis; irritant contact dermatitis; chromium allergy; risk of eczema/dermatitis; patch testing; register of occupational diseases; epidemiology.
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In several European countries, the incidence of cement dermatitis was considered to increase between 1960 and 1970 (1). It was the commonest form of dermatitis to cause early retirement among construction workers in Denmark and Sweden during this period (2, 3). In 1979, Fregert et al. (4) suggested that the reduction of hexavalent water-soluble chromium to trivalent insoluble chromium during the production of cement would prevent chromium-induced dermatitis. The 1st method to reduce the amount of water-soluble chromium in cement was patented by Portland A/S Denmark in 1981. Denmark passed legislation requiring the use of cement with lower levels of hexavalent chromium in 1983; Finland followed at the beginning of 1987 and Sweden in 1989.

During the 1980s, Avnstorp (5-7) studied the

prevalence of cement dermatitis and chromium allergy among Danish prefabrication workers, before and after the reduction of hexavalent water-soluble chromium in cement. His conclusion was that both hand dermatitis and chromium allergies decreased significantly from 1981 to 1987. The reduction of dermatitis among construction workers was attributed mainly to the addition of ferrous sulfate to cement.

Later, some dermatologists have doubted the benefit of adding ferrous sulfate to cement, because the incidence of chromium dermatitis also seemed to decrease during the 1980s in Belgium and Germany, where ferrous sulfate had not been added to cement during the production process (8). Improved hygienic conditions and an increase in the use of prefabricated cement elements might,

therefore, explain the decrease in the 1980s. In addition, improved diagnostic procedures, statistics and occupational health services might explain the increase in chromium dermatitis in the 1970s and 1980s. In contrast, a high prevalence of chromium allergy among workers building the tunnel between England and France has recently been published (16).

The objective of this study was to determine whether lowering the amount of water-soluble hexavalent chromium in cement has decreased the risk of chromium-induced dermatitis among construction and prefabrication workers. In addition, we wished to evaluate the effect of the administrative decision to lower the hexavalent chromium content of the cement used in Finland to <2 ppm.

Materials and Methods

This is a retrospective and prospective study based on both clinical and register data.

The 112 participants with current hand dermatitis were referred to the Department of Dermatology of the Tampere University Hospital, and 105 participated in skin tests. The cases of hand dermatitis were classified into defined categories.

In the 1st part of the investigation, in 1986–1987, we determined the prevalence of chromium dermatitis in a representative sample of Finnish construction and prefabrication workers, to establish an accurate account of the occurrence of this disease before the use of ferrous sulfate.

In the 2nd part, the occurrence of allergic contact dermatitis caused by chromium and irritant cement dermatitis was determined from the data contained in the Finnish Register of Occupational Diseases from 1978 to 1991 (9). The preliminary figures for 1992 have been included in Tables 8 and 9 in the Results section but excluded from the statistical analyses. The use of low-chromium-containing cement became mandatory in Finland on 1 January 1987.

Subjects

All of the 913 house construction workers of 15 enterprises and 707 prefabrication workers of the largest prefabricated cement element factory in Finland, located in the southwest part of the country, were selected for study. 7% of the house construction workers and 13% of the prefabrication workers were women. Altogether, 836 construction workers (92%) and 642 (91%) prefabrication workers participated. The main reason for non-participation was sick leave. 7 persons, all construction foremen, refused to participate. No participants were absent due to dermatitis. The age

Table 1. Age distribution^{a)} of the house construction and prefabrication workers

Age (years)	Construction workers		Prefabrication workers	
	n	(%)	n	(%)
15–29	242	29	200	31
30–39	229	28	199	31
40–49	178	21	133	21
50–59	156	19	95	15
60–	22	3	12	2
TOTAL	827	100	639	100

^{a)} The ages of 12 participants are missing.

distribution of the study populations is given in Table 1.

The 1478 workers were interviewed in 1986. Their dermatological status was checked and photographed at their workplace by one of the authors (HS). All of the 112 interviewees who currently had a skin disease or symptoms on their hands were referred to the Department of Dermatology of the Tampere University Hospital, where 96 underwent prick tests and 105 were patch tested in early 1987.

As a separate group within the population of the 1478 examinees, 12 of 16 workers who reported previous chromium allergy were invited for re-testing. The 4 who were not invited had retired or had moved away from the region. The hospital records of the 16 workers were examined, and the Finnish Register of Occupational Diseases, kept by the Finnish Institute of Occupational Health in Helsinki, was checked to determine whether the cases had been reported.

In the 2nd part of the study, in 1992, the original reports of every case of occupational dermatitis among construction and prefabrication workers between 1976 and 1992 were checked from the Register.

Classification of dermatitis

The cases of dermatitis on the hands were classified into the following 4 categories: (a) irritant contact dermatitis: non-atopic, atopic; (b) allergic contact dermatitis; (c) discoid or infectious eczema, other definable dermatitis; (d) undefinable eczema.

Type (a). If the dermatitis was located on the back of the hand, in interdigital areas or on the sides of the fingers, and the patch tests were negative, it was classified as irritant. Subjects who reported a typical history of irritant contact dermatitis, had no eczema at the examination and had negative patch tests, were also classified in the irritant contact dermatitis category. Subjects who had

suffered from atopic dermatitis, allergic rhinitis or asthma, or had positive prick tests for common inhalant allergens, were considered atopic.

Type (b). If the subject had positive patch tests to chromate and the dermatitis was located on the fingers, palms and/or back of the hands and/or volar aspects of the forearm, the dermatitis was considered allergic contact dermatitis from chromium.

Type (c). If the history of the dermatitis revealed no connection with work, the signs indicated infectious or other non-occupational etiology and the patch tests were negative, the case was diagnosed as discoid infectious eczema or non-occupational irritant contact dermatitis. Other definable dermatoses of the hands included psoriasis, lichen ruber and other non-eczema cases, which were not further examined in this study.

Type (d). All unclear eczema cases were classified into the category "undefinable eczema".

For this study, the categories (a) and (b) were the most pertinent.

Interview, exposure and sickness history

All of the participants were interviewed by a specially trained nurse in 1986 at their workplace. The interview was carried out with the help of a questionnaire, providing a detailed work and skin disease history and the length of employment in the current job category. Exposure was calculated as years in occupation. The history of atopic symptoms, both personal and familial, was also recorded. In addition, the subjects were asked about their personal work habits, use of protective gloves and the type of gloves used.

Skin tests

Prick testing was performed with 20 common inhalant allergens (Laboratories Miles, Epernon) on the lower arm with disposable lancets (Laboratories Miles, Epernon). The positive control liquid was 10 mg/l histamine (Allergologisk Laboratorium ALK, Denmark). The tests were carried out and read after 15 min according to EAACI recommendations (10). Altogether, 96 workers were tested. 9 workers were excluded. 2 had been tested within 12 months, and the rest did not participate regardless of 2 consecutive invitations.

The patch tests were carried out with the Finn Chamber method (Epitest Ltd Oy, Helsinki, Finland), using 24 chemicals, including potassium dichromate 0.5% in pet., prepared by Epikon Ltd Oy (Helsinki, Finland) and by Trolab (Hermal Chemie, Germany). Tests were read on the 2nd and 5th days, and the results interpreted according to

ICDRG guidelines (11). Patch tests were carried out for 105 participants.

Separately from the 105 participants, chromate titration was performed with 0.5%, 0.1% and 0.01% potassium dichromate for those 12 workers who had a previous history of chromium allergy. Possible reaction to trivalent chromium was tested with 2% chromium chloride. Both prick and patch tests were carried out by the same nurse and read by the same physician.

Composition of diagnostic groups

The workers whose diagnosis was clinically confirmed in the Dermatological Clinic of the Tampere University Hospital were included in group A and group B. Group A comprised the types of dermatitis diagnosed among the 105 participants tested and examined clinically at the Department of Dermatology in 1987. Group B comprised those participants whose interview information and former hospital records were clear enough to meet the diagnostic criteria used in this study (Table 7).

Analysis of register data

Reports were compiled of all former cases of chromium-induced occupational dermatitis in the Finnish Register of Occupational Diseases between 1976 and 1985. The Register was also checked for the cases found in the interview. For the analysis, basic information was compiled from each case reported to the Finnish Register of Occupational Diseases in 1986 through 1992. The statistical analysis was based on logistic regression models in which the design variables for each categorical explanatory variable were generated by the partial procedure. The fit of the model was measured using the goodness-of-fit χ^2 , for which large p -values indicate a satisfactory model. The significant explanatory variables were interpreted using odds ratios and their 95% confidence intervals, supported by selected cross-tabulations. The computation was carried out with BMDP statistical software (version 1990) on a VAX/VMS computer.

The explanatory variables available were age, sex, year of diagnosis and duration of exposure. The duration of exposure was not available, however, for every case. Therefore, the analysis was carried out in 2 phases, the 1st without the duration and the 2nd with it. The numerical variables were classified for the analysis. Age was divided into 4 groups as follows: <34, 35-47, 48-57, >58 years. The cut-off points were based on the quartiles. The duration of exposure was divided in the same manner, except that we used only 3 classes: <1, 1-2 and >2 years.

Results

Interview and clinical examination

Table 2 presents the length of employment of the participants. Altogether, 460 (55%) of the house construction workers used protective gloves of leather, and 67 (8%) used rubber gloves daily. The corresponding figures for the prefabrication workers were 327 (51%) and 64 (10%). A total of 189 (23%) house construction workers and 145 (23%) prefabrication workers reported atopic symptoms. Some had several symptoms. The types of symptoms are shown in Table 3. During the last 12 months before the interview, 114 house construction workers (14%) and 117 prefabrication workers (19%) reported having dermatitis (Table 4). Furthermore, a total of 345 house construction workers (41%) and 238 prefabrication workers (37%) reported dry skin. Altogether, 112 (7.6%) had current hand dermatitis in the examination, 55 (6.6%) of the house construction workers and 57 (8.9%) of the prefabrication workers. Data on the workers who had symptoms during the last 12 months before the tests, and who were considered

to have work-related irritant or allergic hand dermatitis, are presented in Table 7.

Skin tests

Table 5 shows the distribution of the diagnoses. 5 of the 105 subjects tested had dermatitis on their face and no symptoms on their hands. All of the 38 cases of irritant contact dermatitis among the house construction workers were work-related. 4 of the 29 cases of irritant contact dermatitis diagnosed among the prefabrication workers were not work-related. 6 of the irritant contact dermatitis patients among the house construction workers and 5 among the prefabrication workers had a positive (+++ or +++) reaction to animal epithelia or hay or tree pollen in the prick tests. 4 new cases of allergic contact dermatitis were diagnosed among the 105 workers who were patch tested. Thus, the prevalence of chromium allergy was 4%. 1 new case of chromium dermatitis was diagnosed among the house construction workers, and 3 cases were found among the prefabrication workers. 1 of the 4 cases had chromium allergy only; 3 had chromium and other contact allergies. Furthermore, 1 case was allergic to epoxy resin. More detailed information on the workers who had allergic contact dermatitis is given in Table 6.

Table 2. Length of employment of house construction and prefabrication workers, as reported at interview in 1986

Length of time in current job (years)	House construction workers		Prefabrication workers	
	n	(%)	n	(%)
<3	188	22	148	23
3-10	273	33	205	32
11-20	185	22	182	28
>20	190	23	107	17
total	836	100	642	100

Table 3. Occurrence of atopic symptoms before 1986

Symptom	House construction workers		Prefabrication workers	
	n	(%)	n	(%)
atopic dermatitis	84	10	67	11
allergic rhinitis	136	16	120	19
asthma	21	3	27	4

Table 4. Occurrence of hand dermatitis during the last 12 months, reported at interview in 1986

Occurrence	House construction workers		Prefabrication workers	
	n	(%)	n	(%)
constantly	23	3	36	6
sporadically	64	8	58	9
seldom	27	3	23	4
total	114	14	117	19

Group with earlier diagnosed chromate allergy

Out of the 16 persons who reported previous chromium allergy in the questionnaire, 12 were re-tested in 1987. 5 (all prefabrication workers) had a positive patch test reaction to 0.5% and 0.1% potassium dichromate. 4 of the 5 workers with chromium allergy had a history of occupational hand dermatitis. All 5 had also had symptoms during the last 12 months before the investigation. The

Table 5. Distribution of dermatitis diagnosed on the hands of the house construction and prefabrication workers according to the type of dermatitis in 1987

Type of dermatitis	House construction workers n	Prefabrication workers n
type 1		
irritant contact dermatitis		
non-atopic	23	15
atopic	15	14
type 2		
allergic contact dermatitis	1	3
types 3 and 4 combined, and undefinable eczemas	10	11
total	49	43

Table 6. New allergic contact dermatitis in 1987

Diagnosed allergy	Gender	Occupation	Age group (years)	Length of employment (years)
house construction chromium, cobalt		carpenter	15-24	1-2
prefabrication work chromium, cobalt	male	carpenter	15-24	3-5
epoxy resin, chromium, mercapto mix	male	concrete worker	55-59	11-20
chromium	male	concrete worker	>60	>20

Table 7. Prevalence of work-related hand dermatitis among the house construction and prefabrication workers in 1986-1987 (before the possible effect of ferrous sulfate)

Type of dermatitis	House construction workers (N=836)		Prefabrication workers (N=642)	
	group A	group B	group A	group B
Irritant				
non-atopic	23	9	13	9
atopic	15	4	12	9
Allergic	1	3	4	7
chromium			3	
total	39	16	32	24

Group A: types of dermatitis diagnosed among the 105 participants tested and examined at the Department of Dermatology in 1987. Group B: participants whose interview information and former hospital documents were clear enough for diagnosis.

other 7 workers who reported previous chromium allergy were negative in the patch testing. They were house construction workers. 4 of them had chromium allergy diagnosed in the late 1960s. 5 reported symptoms of hand dermatitis during the last 12 months. 2 house construction workers and 1 prefabrication worker who did not participate in the skin tests had their chromium allergy diagnosed earlier in the Department of Dermatology of the Tampere University Hospital. The 4th non-participant had been diagnosed in another outpatient clinic. He was the only non-participant who reported no symptoms of dermatosis during the preceding 12 months.

Analysis of register data

The total material analysed from the Finnish Register of Occupational Diseases is presented in Table 8. During 1978-1992, altogether 273 cases of allergic contact dermatitis and 174 cases of irritant contact dermatitis were reported for the construction and prefabrication workers. In the 1st analysis, the only statistically significant independent variable needed in the model was the year of diagnosis, which had a risk-decreasing effect on chromium contact dermatitis, with an odds ratio of

0.381 (95% CI 0.202-0.716). The respective cross-tabulation is shown in Table 9. In the 2nd analysis, in which the duration of exposure was also used, the statistically significant independent variables were the year of diagnosis and the duration of exposure. The odds ratio for the year of diagnosis was almost identical to that of the previous analysis, namely, 0.248 (95% CI 0.102-0.604), and the duration of exposure had a risk-increasing effect, the odds ratios being 7.02 (95% CI 2.29-21.50) and 9.11 (95% CI 3.98-20.90), when a comparison was made with the class of duration of exposure of one year or less. In both analyses, we also studied the existence of possible interactions between independent variables, but they were not significant.

Discussion

In the present study, among workers before the addition of ferrous sulfate, we found a 4.0% prevalence of chromium allergy among the 105 workers with hand dermatitis. 16 workers reported previously-diagnosed chromium-induced dermatitis. On the other hand, when we retested the 12 workers with a previous history of occupational chromium allergy, only 5 were confirmed to have this condition. A few other cases of chromium allergy might have been detected if all of the participants could have been patch tested.

5 workers with a previous history of chromate allergy had confirmed re-tested chromium allergy. The prevalence of chromium allergy in the total study population cannot be determined on the basis of the present study, because the skin tests were performed only on the workers with symptoms or reported former chromium allergy. The results of the register data indicate that the occurrence of occupational dermatitis associated with chromium allergy in the house construction and prefabrication occupations has clearly diminished since 1987, whereas the number of reported cases of irritant contact dermatitis was stable from 1978 to 1992.

There are, however, several possible sources of

Table 8. Occupational dermatitis reported to the Finnish Register of Occupational Diseases between 1978 and 1992 for construction workers

Year	Allergic contact dermatitis from chromium ^{a)} (n)	Irritant contact dermatitis from cement, alkalis ^{b)} included (n)	Other (n)
1978	21	9	55
1979	20	3	68
1980	28	12	58
1981	20	15	63
1982	25	10	62
1983	25	14	52
1984	23	12	71
1985	21	12	82
1986	27	17	61
1987	21	7	74
1988	6	11	73
1989	13	8	87
1990	8	15	71
1991	11	13	55
1992	4	16	36
total	273	174	968

^{a)} Allergic contact dermatitis, with allergy to chromium as the reported cause.

^{b)} Alkalis are a reported cause of irritant contact dermatitis associated with wet cement.

Table 9. Irritant and chromium-induced dermatitis according to time of occurrence

	Cause		
	chromium (n)	cement/ alkalis ^{a)} (n)	total (n)
1978-1987	231 (68%)	111 (32%)	342
1988-1992	42 (40%)	63 (60%)	105
total	273	174	447

^{a)} alkalis are a reported cause of irritant contact dermatitis mainly associated with wet cement.

bias that could also explain the diminishing amount of hand dermatitis associated with chromium allergy. For example, variations in the reporting system, differing diagnostic procedures, and changing numbers of exposed persons. The prevalence of chromium allergy in a given population is difficult to assess exactly, due to the fact that some of the patch test results that had been interpreted earlier as allergic had probably been irritant reactions. In agreement with this possibility, re-testing seems to give clearly fewer positive results (11). In the present study, we could not confirm the previously-diagnosed chromium allergy in 7 of the 12 re-tested workers. Thus previous false-positives could possibly explain at least part of the observed decrease in hand dermatitis. The prevalence figure does not reveal the prevalence of chromium allergy but only clinically observable cases. From the viewpoint of occupational health, chromium allergy without any clinical signs associated with work is of minor interest.

Our prevalence rates of occupational hand dermatitis are similar to the results of earlier studies carried out among Scandinavian construction workers. In a Swedish population of construction workers, the prevalence of hand eczema has been reported to be 9.2% (12), and in a Norwegian population, it was 7.8% (1).

From the rosters of the construction workers' union, we checked the number of workers in the most-exposed groups (i.e., construction laborers, carpenters, bricklayers and concrete workers) from the year 1980 to 1992. About 90% of construction workers are unionized in Finland. The membership register is reliable because of the social benefits received through membership. Our enquiry revealed that the distribution of different occupations and the number of workers was very stable throughout the entire period of study. For example, in 1980, there had been 4798 bricklayers, and this number had increased only slightly, up to 5266, in 1991. During the intervening period, the annual numbers varied between these 2 figures. Since the same trend was observable for the other occupations, it seems that the number of workers exposed to cement in construction and prefabrication has remained practically the same before and after the year 1987. Moreover, there is no evidence indicating that the reporting of new cases of occupational diseases has become less accurate since 1987. On the contrary, it can be assumed that the reporting system has improved, because the number of specialists in occupational health has tripled since 1980.

Our clinical investigation in 1986-1987 revealed

16 cases of hand dermatitis that met the criteria for work-related dermatitis and that should have been reported to the Register of Occupational Diseases before 1987. We found only 5 of these cases actually listed in the Register. In other words, only 1/3 of the earlier cases of occupational dermatitis had been reported to the Register. Thus, the observed decrease in the prevalence of chromium contact dermatitis could have been even more evident if no under-reporting had occurred in the late 1970s and early 1980s.

Since the latter part of 1987 up to 1993, all of the cement used in Finland has had a water-soluble chromium content of less than 2 ppm. Improved use of personal protective equipment is not likely to explain the decrease in chromium-induced dermatitis, because the rate of reported irritant contact dermatitis has not changed correspondingly. Probably the strongest epidemiological evidence in favor of a decreased risk of dermatitis induced by water-soluble chromium is the stable occurrence of irritant hand dermatitis throughout the whole follow-up period. We have no evidence indicating that the reporting system for occupational dermatoses would have been selective between the 2 types of hand dermatitis.

Observations from the Swedish occupational health service network for construction workers, Bygghälsan, indicate that the prevalence of allergic contact dermatitis caused by chromates has decreased among construction workers since the beginning of the 1980s (2, 13). However, it is possible that the decrease had already begun before the low-chromate-containing cement was mandatory in Sweden in 1989. Therefore, the addition of ferrous sulfate to cement explains only part of the decrease (14). It can partly be explained by the fact that the largest Swedish cement producer, Cementa AB, began to add ferrous sulfate as early as 1983. In contrast, despite the legislative requirements in Scandinavia, high concentrations of chromates have still been observed in cement (15). It is probable that this cement has been stored for longer than 6 months or in humid circumstances, both of which destroy the reductive effect of ferrous sulfate.

The best confirmation for the decrease of chromium allergy would have been repeating the skin tests in 1992. However, repetition of the tests was not possible because the deep economic recession in the construction trade had put more than 1/3 of the construction workers out of work in the last half of 1992. As a result, the original study population became dispersed.

Our study cannot prove that the addition of ferrous sulfate to cement decreases the development of chromium allergy. However, both the infor-

mation available for our study and the statistical analysis performed as part of the study indicate that adding ferrous sulfate to cement may decrease the risk of chromium-induced dermatitis among construction workers.

Experience in Finnish companies producing construction materials and in Finnish construction companies has not revealed any serious health, technical or economic problems with the use of cement containing low amounts of hexavalent chromium. Thus far, the only difficulty has been the storage of the cement, since storage for longer than 6 months can decrease the ability of ferrous sulfate to reduce hexavalent chromium to trivalent chromium. We recommend that occupational health and safety administrators support the production of cement with a low content of hexavalent chromium. Our recommendation is shared in a recent report from England (16).

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