An Outbreak of Chromium Ulcer in a Manufacturing Plant*

Joe-Fang Deng, Veterans General Hospital, Taipei, Taiwan

and

Alan K Fleeger, Thomas Sinks, NIOSH, Cincinnati, Ohio, USA

ABSTRACT. On May 23, 1989, managers of a manufacturing plant requested an investigation of an outbreak of hand ulceration and skin discoloration among workers. The plant has manufactured kitchen ranges for 30 years and employs approximately 633 hourly workers. The affected employees worked in the enamel department, where metallic range tops are coated with a "ground coat" or sprayed with an enamel coloring, and then baked in ovens at 1200F. Our evaluation included physical examinations, environmental sampling, and a questionnaire eliciting information concerning skin ulceration job history, demographics, and use of protective practices. We identified 10 enamel department workers (13.5%) who developed chromium ulcers between January 1st and June 30th, 1988. Ulcers were found on hands, forearms, periumbilical area and/or axillae. Within the enamel department, workers who handled conveyer hooks used to suspend range tops as they passed through the oven were at greatest risk (rate ratio (RR) = 12.44, 95% confidence interval (CI) = 2.90-53.35). Workers who wore gloves were protected from developing ulcers (RR = 0.08, 95% CI = 0.01-0.60). Normally, trivalent chromium (Cr^{+3}) does not cause skin ulcers unless it is oxidized to hezavalent chromium Cr^{+6}). The enamel used contained only Cr^{+3}, not Cr^{+6}, but analysis of hooks that had passed through the oven revealed Cr^{+6} on their surface. A mechanical failure of the oven reuslted in the formation of sharp edges of the parts and consequently causing the abrasion of exposed skin. We believe Cr^{+3} was converted to Cr^{+6} during the baking process which associated with the mechnical failure of the oven causing this outbreak.

Chromium was discovered in 1797 and first used in chemical production early in the 19th century. In recent industry, several of the principal and most important uses of chromium are for plating, alloying, and various chromium contained chemicals manufacturing. The chief industrial exposure to hazardous chromium substance was believed to be an acid-soluble, water-insoluble chromate-chromite mixute produced in the preparation of chromate (3). Workers involved in the manufacturing processes or operations of chromite ore/smelter, chromium plating, chromium allow welding a are potentially exposed (11). In 1974, NIOSH estimated that 104 occupations with approximately 175,000 workers were exposed to chromium (8).

Although chromium was discovered almost 200 years ago, the health effects related to the chromium exposure had never been reported until 1827, when "Chrome sores" was used to describe the skin effect in 2 dyers who immersed their hands in potassium bicarbonate solutions (1). The well-known principal hazardous health effects associated with chromium exposure are inflammation or ulceration of the skin and the mucosa of upper respiratory tract and bronchogenic carcinoma of the lung. We report an outbreak of chromium ulceration found among workers involved in the enamel coating process of a consumer ranges manufacturing facility, which has never been mentioned in the literature. The data of our investigation determined that a health hazard existed among the hook handling workers in the enamel department due th the potential for skin contact with sharp surfaces contaminated with chromium VI. The skin abrasions facilitated the penetration of chromium VI compounds beneath the skin. Repair of the curing oven resolved the skin problems. Recommendations for oven maintenance and worker protection are discussed.

HISTORY

On May 23, 1988 we received a request for a health hazard evaluation from the management of a manufacturing facility. This facility manufacturers consumer gas and electric ranges. We were asked to evaluate the source of skin problems at the Enamel Department. According to the management, the first reported case occurred around the middle of March 1988. The symptoms and signs described were discoloration and ulceration associated with drying and chafing of the skin over the hands. The hook handlers were the only workers who reported the skin problems.

MATERIALS AND METHODS

This evaluation consisted of an initial site visit and a follow-up survey. The initial site visit was conducted on June 29, 1988, which included a walk-through of the facility, environmental sampling, and a brief physical examination on selected workers with skin problems. During the initial site visit, bulk samples were collected in the Enamel Department for chromium VI and trace metals analysis.

A follow-up survey was conducted on September 26-27, 1988, following repair

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of the curing oven coils. This included the collection of bulk and air (personal breathing zone and area) samples for chromium VI and trace metal analysis, and a cross sectional study. In cross sectional study, the questionnaire asked information regarding skin ulceration, job history, protective workpractice, and demographics. We examined the workers who reported to have skin ulcerations, or hyperpigmentation or scar formations resulting from a previous ulcer over the upper extremities, armpits and periumbilicus. Data were analysed by Chi-square analysis. The associations between the disease of interest and the continuous variables, such as age, seniority, and frequency of handwashing, were examined by student t-test. Further evaluation was done after dichotomizing each variable into two categories of equal numbers of workers and using Chi-square analyses. Stratified analysis was used to control for confounding variables.

RESULTS

Operation Procedure at Enamel Department

This manufacturing facility employs approximately 750 employees, of whom 78 work in the Enamel Department. The Enamel Departmentis primarily responsible for painting the individual range parts prior to their final construction. Porcelain enamel paints are applied to the range parts by either a dipping of flow coat process. The porcelain enamels are trivalent chromium based. Oxidizers are added to the enamels, causing the potential for the trivalent chromium to change to a hexavalent state. Following the application of the paint, the parts enter a drying oven (approximately 400F) and a reinforcing ground coat is applied. The parts are then hung on small hooks and enter the curing oven (approximately 1500 F).

The ground coat line workers, responsible for hanging the parts on small hooks prior to entering the curing oven, originally reported the skin problems. The first reported case occurred around January 1988. Most of the ground coat line workers do not wear protective gloves when handling the hooks; the gloves reportedly reduce dexterity. The workers are paid on an incentive basis, causing them to handle a large quantity of hooks during the shift.

Management reported that prior to March 1988 there were no reported skin problems in the Enamel Department. They also stated that there were no changes made in the process when the skin problems began to occur. However, in March 1988 open flames were detected in the curing oven, causing a greater number of product defects. When the flames contacted the enameled surface, they burned off small patches of enamel from the parts. In addition, it was reported that the flames caused sharp edges to form on the hooks, cutting the employees hands.

Environmental

The 3 bulk samples collected on June 29, 1988 had chromium VI levels that ranged from 0.1 to 2.4 ug/mg of sample. The highest chromium VI level was found from the bulk sample collected in number 1 coupler in the curing oven. The two samples out of four collected on September 27, 1988, revealed the concentration of 2.6 and 4.4 ug/mg of chromium CI. The highest chromium VI level was in a bulk sample of scrapings from the 2 hooks collected on the floor of the ground coat line (Table 1). Nonsignificant levels of trace metals were detected in some of the bulk samples collected on both site visits.

Five air (personal breathing zone and area) samples collected on the ground coat line, September 27, 1988, were all reported below the analytical LOQ for chromium VI. Five air samples collected on the ground coat line for trace metal analysis on September 27, 1988, were all reported below the analytical LOQ for chromium VI. Five air samples collected on the ground coat line for trace metal analysis on September 27, 1988 were nondetected for 29 of the 30 tested analytes.

Medical

Employee interviews and physical examinations on June 29, 1988 revealed 7 workers with a yellowish discoloration of the hands, accompanied by a burning sensation and punched-out ulcerations, and chafing on the hands and forarms. One of the 7 workers also had multiple ulcerations and scarring with increased pigmentation over the left subaxillary region. The ulcerations were compatible with those seen in workers exposed to hexavalent chromium.

On September 26-27, 1988 78 workers were employed in the Enamel Department. Seventy-four of the workers completed the questionnaire, giving a participation rate of 95%. The 4 workers who did not participate in the study were either on vacation or medical leave unrelated to skin problems.

Analysis of the questionnaire revealed the following information: The majority of the workers were male (82%) and white (97%); The mean age of the workers was 40-year-old, ranging in age from 22-63; The average number of employment years at this facility was 14 years, ranging from 2 to 35 years; 18 of the 74 workers were either hookers or hangers; Only 43 of the 74 workers in the Enamel Department reported wearing

TABLE 1
The Concentrations* of Chromium VI Detected From The Bulk Samples Collected During The Site Visits

Sample:	No. 1 Coupler Curing Oven	No. 2 Coupler Curing Oven	Hook 1	Hook 2
June 29	2.4	1.3	0.1	
September 27	2.6	NA	0.3	4.4

NA = Not analyzed. *(ug/mg of sample)

protective gloves (among the 18 hookers and hangers, only 7 reported wearing gloves); The mean frequency of hand washing during the work shift was 6 times, ranging from 1 to 50 times; and Only 4 workers reported using barrier creams to protect their skin.

Workers who reported a chromium ulcer on the upper extremities, armpits, or abdomen after January 1, 1988 were considered cases. By this defination, 10 cases were identified during the period of January 1 to September 27, 1988. The overall attack rate was 14% (10/74). Among the 10 cases, 8 were hangers or hookers (hook handler). Hangers and Hookers (combined) were at a greater risk for developing ulcerations (Rate Ratio, RR= 12.44, 95%; Confidence Interval, CI=2.90-53.35) than workers with other job classifications. The association between chromium ulceration and gender, glove use, age, frequency of handwashing, and job classification can be found in Table 2. The association between gender, glove use, age, frequency of handwashing and chromium ulceration only among hook handlers is given in Table 3.

Workers who developed an ulcer were on the average 7 years younger than those who did not. The mean age for the cases was 34.4 (standard deviation, sd=4.8) while the mean age for controls was 41.2 (sd=9.5). This difference was stastically significant ($p<0.05$). Age was then categorized into those < 38 years and those 38 years or older. The relative risk of being a case for the younger workers was 3.79 (95% CI=0.86-16.66). However, when categorized in this manner the association was no longer statistically significant. Younger workers were at excess risk if they worked as hooker handlers as shown in Table 2 (RR=4.45, 95% CI=0.69-28.87).

Workers who developed an ulcer washed their hands on the average of 4 times (sd= 1.1) each day. The mean frequency of handwashing for workers without ulcers was 6.5 times (sd=8.8) each day. This difference was statistically significant ($p<0.05$). Frequency of handwashing was then categorized into < 4 times/day and those 4 times or more. The relative risk of being a case for workers who washed 4 or more times a day was 0.77 (95% CI=0.24-2.47), and this association was not statistically significant. Among hooker handlers, those with ulceration washed their hands less frequently than those who did not (RR=1.33, 95% CI= 0.45-3.96).

Among the 10 workers with an ulcer, 4 were female and 6 male. In general, woman were 3 times more likely to develop an ulcer than man. Proportionately, woman were more likely to work as hooker handlers than men. Among hooker handlers, men and women were equally likely to develop ulceration (RR=0.94, 95% CI=0.32-2.76).

Among the 45 workers who reported wearing gloves, only 1 developed an ulcer. Nine of the 31 workers who did not wear gloves developed ulcers. Overall, those who wore

TABLE 2

The Association Between Chromium Ulceration And Gender, Glove Use, Age, Frequency Of Handwashing, And Job Classification.

	Case	Noncase	RR*	95% CI+
Gender				
Female	4	9		
Male	6	55	3.1	1.0-9.5
Glove				
Use	1	42		
Nonuse	9	22	0.1	0.0-0.6
Age				
LT 38 yr	8	30		
GE 38 yr	2	34	3.8	0.9-16.7
Handwashing Frequency				
GE 4/day	6	43		
LT 4/day	4	21	0.8	0.2-2.5
Job Classification				
Hook handler	8	10		
Other jobs	2	54	12.4	2.9-53.4

RR* = Relative risk.
CI+ = Confidence interval.

gloves were protected from developing an ulcer (RR=0.08, 95% CI=0.01-0.60). The protective effect of glove wearing was also seen among hook handlers (Table 3).

On the average, workers who developed an ulcer had worked at this facility for about 11 years (sd=5). Workers without ulcers had been in this facility for about 14 years (sd=9). This difference was not statistically significant. Among the 10 cases, only 1 reported using barrier creams. In fact, only 4 of the 74 enamel department employees used these creams.

After controlling for age, sex, and frequency of handwashing, the hangers or hookers remained 7 times more likely of developing ulcers than the other workers in the enamel department.

DISCUSSION AND CONCLUSION

The principal toxicological reaction sites from industrial exposures to chromium are the skin, larynx, lung, and upper respiratory tract. The harmful effects of chromium include carcinogenicity, skin sensiti-

TABLE 3

The Association Between Chromium Ulceration And Gender, Glove Use, Age, Frequency Of Handwashing, Among The Hook Handlers

	Case	Noncase	RR*	95% CI+
Gender				
Female	3	4		
Male	5	6	0.94	0.32-2.76
Glove				
Use	1	6		
Nonuse	7	4	0.22	0.01-1.45
Age				
LT 38 yr	7	4		
GE 38 yr	1	6	4.45	0.69-28.87
Handwashing Frequency				
GE 4/day	5	5		
LT 4/day	3	1		

RR* = Relative risk.
CI+ = Confidence interval.

zation, and skin and mucosal ulcerations. The harmful effects are heavily dependent on the valence state of the chromium. Divalent chromium is of minor importance in industrial exposures bacause it readily oxidizes to the tribalent state. The tetravalent and pentavalent forms are essentially unstable and are used as intermediates in chemical production. Trivalent and hexavalent chromium are the only compounds known to be significantly associated with human disease. With specific regard for skin ulcerations, tribalent chromium is poorly absorbed through the skin. Normally, trivalent chromium does not cause skin ulcers unless it is oxidized to a hexavalent state, which can easily penetrate the skin (6). Hexavalent chromium can have a corrosive, necrotizing effect on living tissue, forming ulcerations known as chromium holes.

Chromium-induced skin ulcerations and perforations of the nasal septum have been well documented since the 1930's (2,11,12). Ulcerations generally occur on exposed areas of the body, chiefly the hands, forarms, and feet. They may develop more readily if there is a break in the skin, such as at the site of an insect bite or other injury. The ulcerations are round and deeply penetrating, with a clean-cut central crater, 2 to 5 mm in diameter, whose base is covered with exucate or a tenacious crust. Once developed the ulcer is slow to heal, and if exposure continues it may persist for many months. The healing process usually leads to scar formation.

Based on the observations made during the initial site visit (June 29, 1988) we determined that the ground coat line workers developed chromium ulcers as a result of their employment. The observed symptoms were the result of a direct skin contact phenomenon and were diagnosed to be chromium VI induced. No new cases were reported after the initial visit. These findings left the following 2 questions unanswered: Why were no new cases found after June 29, 1989? What originally caused the ulcerations to develop in March, 1988? To address the question as to why no new cases occurred after June 29, 1989, a comparison was made between the concentration of chromium VI in the bulk samples. The analytical results from the initial (0.09 to 2.4 ug/mg) and follow-up (0.3 to 4.4) ug/mg) evaluations, revealed that the chromium VI levels were slightly higher during the follow-up investigation. Prior to the follow-up investigation, it was assumed that the chromium VI levels would be higher during the initial site visit when the skin problems existed, but this was not the case.

The discrepancy between the analytical results and the lack of active skin disorders during the follow-up evaluation was attributed to the possibility of laboratory error, the change of the enamel formula, and/or the work practice during that period. However, after careful evaluation, none of these 3 factors existed.

At this point in the evaluation, efforts were focused on the time frame of when the symptoms began to occur. It was determined that the skin problems began to occur in March 1988, when the hook handling employees noticed a yellowish discoloration on the hooks, which rubbed off onto their hands. About this time, the company noticed a greater number of part defects exiting the curing oven. As a result of the increased number of defects, an inspection of the curing oven. As a result of the increased number of defects, an inspection of the curing oven was conducted. This inspection detected open flames present in the oven, resulting from tiny holes in the heating coils. As a result, the flames were causing "burn-off" on the parts which came into contact with the flames. Several employees also mentioned that the hooks used to hang the parts were developing very sharp edges and were cutting their hands. Further investigation revealed that the hooks were being used to hang smaller parts on the conveyor prior to receiving the ground coat application. Therefore, the hooks were also receiving a direct application of the ground coat and developed an excess layer of enamel.

To reduce the increased number of part defects, the company repaired the tiny holes in the oven coils during the last weekend of June. Following the repair of the oven, the employees noticed that the hooks were no longer discolored. Also, the part defect ratio was reduced drastically. Finally, the employees reported that the hooks no longer had sharp edges and that their skin problems began to clear.

Based on the prior information, it is evident that the repair of the oven coils not only reduced the part defect ratio, but also resolved the skin problems on the ground coat line. We conclude that the open flames were causing an improper curing of the paint, thus making the chromium VI more readily available on the hooks. In addition, the sharp edges that developed on the hooks in combination with the normal mechanical friction that existed when the employees placed a great number of hooks in their hands, resulted in skin abrasions that allowed the chromium VI a direct source of entry beneath the skin to cause ulcerations.

RECOMMENDATIONS

Based upon these findings, the following recommendations are made: Quarterly maintainance should be conducted to inspect the curing oven coils for leaks; A mechanism should be developed to clean the hooks after they exit the curing oven; The workers should wear protective gloves to minimize the potential for skin exposure; Should the problems occur again (ie discoloration of the hooks) we recommend 10% ascorbic solution or ointment which has been shown efeective in preventing as well as treating the chromium ulcers until the oven can be repaired.(4,5,9,10,13).

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An Analysis of the Types of Papers Presented at the Annual Toxicology Meetings*

Jeffrey Brent MD, PhD, Ken Kulig MD, FACEP and Barry Rumack MD

Rocky Mountain Poison and Drug Center, University of Colorado Health Sciences Center, Denver General Hospital, 645 Bannock St, Denver, CO

One major purpose of the annual AACT/AAPCC/ABMT/CAPCC meeting is to disseminate scientific informatiion related to poisoning. This data is traditionally derived from a variety of sources, including individual experience with a single or multiple cases, prospective collections of clinical experience, surveys, experimental studies of various kinds, and controlled prospective clinical trials. Inferences drawn from these studies have varying degrees of weight depending on many factors such as ambiguities in the data and the experimental design. There is also an implicit diversity in the nature of the data presented, ranging from case reports to the controlled prospective clinical trial. The latter type of study is generally considered to be the most definitive form of proof or disproof of a hypothesis.

The present study was undertaken because of our perception that much of the data available to the clinical toxicologist is in the form of case reports and case series, with a relative scarcity of controlled prospective clinical trials. This hypothesis was tested by examining the types of abstracts presented over a 6-year period at the annual AACT/AAPCC/ABMT/CAPCC meetings and comparing them with those from a similar scholarly assembly.

MATERIALS AND METHODS

All abstracts from the AACT/AAPCC/ABMT/CAPCC meetings between 1984 and 1989 were evaluated, as were those of the University Association for Emergency Medicine (UAEM), now the Society of Academic Emergency Medicine (SAEM), during the same time period. Abstracts were classified into case reports, clinical series, program descriptions, experimental studies, prospective controlled

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