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Abstract: Exposure to Lead, Cadmium and Chromium among Spray Painters in Automobile Body Repair Shops: B. Vitayavirasak, *et al.* Faculty of Environmental Management, Prince of Songkhla University- Environmental and biological monitoring of lead, cadmium and chromium levels in spray painters is reported. All of the spray painters worked in automobile body repair shops that had no standard spraying room. They were divided into 2 groups, those who wore an aerosol-removing respirator while spraying (n=20) and those who did not wear the respirator (n=50). Air in the breathing zone of each spray painter was sampled and analysed for lead, cadmium and chromium levels. The painters' blood lead levels and urinary cadmium and chromium levels were also measured along with those of a control group from the general population. The mean environmental and biological levels of these metals between the two groups of painters were not significantly different ($p>0.05$). However, the biological levels of the metals were significantly higher in the painters than in the control group ($p<0.01$). It was concluded that the use of an aerosol-removing respirator alone was not enough for the prevention of toxic metal exposure. Other components, such as the use of an isolated spraying room and good personal hygiene were also essential.

Key words: Lead, Cadmium, Chromium, Occupational exposure, Spray painters, Automobile spray painting

Automobile spray painting is among the jobs which are likely to result in exposure to heavy metals in the workplace. Lead, cadmium and chromium are major toxic metals which are constituted in automobile paints. They are components of paint pigments, such as lead chromate, lead oxide, cadmium yellow, chrome yellow and chrome orange [1-3]. As automobile paints are sprayed, these metal compounds are dispersed and retained in the atmosphere long enough to be inhaled by the paint sprayers. Long term exposure to lead can cause degeneration of the central nervous system (chronic encephalopathy), anemia and renal failure [1]. Chronic exposure to airborne cadmium can cause obstructive lung disease and possibly lung cancer [2]. Long term exposure to cadmium via water and food can lead to renal tubular dysfunction, disturbance of calcium metabolism, osteoporosis and osteomalacia [2]. Chronic inhalation of hexavalent chromium compounds may cause allergic asthmatic reaction, ulceration in the mucus membrane, perforation of the nasal septum and bronchial carcinoma [3].

Automobile body repair shops in Hat Yai City Municipality, Songkhla Province, Southern Thailand are generally small sized, with less than 10 workers. Use of an isolated spraying room is not strictly enforced in the shops, and therefore most automobile spray painters work outside spraying rooms even where they are provided. It has been reported previously that only 30% of them wore an aerosol-removing respirator when spraying paint [4]. However, painters who used a respirator did not wear it while other workers were spraying paint nearby. It was doubtful whether spray painters who wore a respirator under such conditions received enough protection from toxic metal exposure. The objective of this study was to assess the exposure to lead, cadmium and chromium among automobile spray painters who wore a respirator only when spraying compared to exposure of the spray painters who did not wear any respirator at any time.

Materials and Methods

A cross-sectional study was undertaken. Seventy automobile spray painters were recruited to the study. All of them had been working at the job for at least 1 year and had no previous work related to heavy metals. The spray painters were divided into 2 groups: those who wore an aerosol-removing respirator while spraying (n=20) and those who did not wear any respirator at work (n=50). A walk-through survey of each painter's workplace was conducted. A questionaire was used to interview each painter on risk behaviors related to exposure to heavy metals.

Environmental lead, cadmium and chromium exposure was monitored through a personal air sampling pump (pumping 1.5 liters of air per min), attached near the breathing zone of each spray painter during one eight-hour working day (full period single sampling). Mixed cellulose ester filters (37 mm diameter, 0.8 μm pore size) were used to collect respirable dust. After the collection, the filters were digested with concentrated nitric acid (70%) in a laboratory microwave oven (MDS 2000, CEM Corp, USA) . The digested samples were diluted with ultrapurified water and were analysed for lead, cadmium and chromium concentrations in duplicates with a graphite furnace atomic absorption spectrophotometer (GFAAS) (Varian SpectrAA-800 GTA100, Varian, Australia).

Whole blood samples were collected from the spray painters. From each sample, one aliquot (4ml) was kept in an acid cleaned plastic test tube and was analysed for lead content with the GFAAS. The other aliquot was immediately sent to the haematology laboratory for complete blood counts. Spotted urine samples were also collected from the spray painters during a work shift. Each urine sample was divided into 2 portions. One portion was kept in an acid cleaned cup to which a few drops of concentrated nitric acid had been added to reduce the pH of the urine to less than 2. This portion was kept at 4°c until analysed for cadmium and chromium contents with the GFAAS. The other portion was kept in a plastic cup at 4°c and was sent to the clinical chemistry laboratory for measurement of creatinine concentration using a Hitachi 717 Autoanalyser (Boeringer Mannheim, Germany) (Jaffe method) [5]. The same procedure was also performed in a control group which included people from the general population who had never had occupational exposure to heavy metals.

The health condition of the spray painters was evaluated through physical examination and use of a questionnaire to establish their medical history. Their brain functions were assessed using the Thai mental state examination (TMSE) which is a test adapted from the minimental state examination (MMSE) [6]. TMSE has a total score of 30, including 6 scores for orientation, 3 scores for registration, 3 scores for attention, 3 scores for calculation, 10 scores for language and 3 scores for recall.

Validation of the Analyses

Field blank samples and laboratory blank samples were used in all of the analyses as a quality control. A blood lead control, containing 9.99 μg/dl lead, was used as a reference material. The control was supplied by the Ministry of Public Health Department of Medical Science for quality assurance of the blood lead analysis. The coefficience of variation (CV), accuracy and detection limit of the blood lead analysis were 1.01 %, 98.81$\pm$2.93 % and 0.22 μg/dl, respectively.

Urine metals controls (Bio-Rad Laboratories Limited, Germany) were used as reference materials for the urine analyses. The CV, accuracy and detection limit of the measurement of urinary cadmium levels were 1.10 %, 87.03 $\pm$ 2.12 % and 0.11 μg/l, respectively. The CV, accuracy and detection limit of the measurement of urinary chromium levels were 6.22 %, 95.96 $\pm$ 12.97 % and 0.38 μg/l, respectively.

Statistical Analyses

Differences of the mean levels of lead, cadmium and chromium among the 3 groups were tested with the Kruskall-Wallis test. Differences of the mean levels of the metals between the groups were tested with Mann-Whitney U test.

Results

Physical examination and medical histories of the automobile spray painters established that all of them had normal health conditions, except for three painters who experienced asthma and one painter who had numbness of the extremities. The painters stated that the most frequently occurring symptoms which they had experienced over the previous year were oronasal symptoms, nervous symptoms and musculoskeletal symptoms (Table 1). The occurrence of these symptoms was in the range 25.7 - 54.3 % of all painters. No further detailed examination was conducted on these spray painters. All of the painters passed the TMSE. Their scores ranged from 23 to 30 (Table 2). The score for passing the test is 23 or more.

Table 3 shows the levels of atmospheric lead in the working areas and the blood lead levels of the two groups of the spray painters and the control group. There was no significant difference in the mean environmental lead levels and blood lead levels between the two groups of spray painters ($P > 0.05$). The mean blood lead levels of the two groups were significantly higher than the control group ($p < 0.01$), but were nevertheless below the regulatory limit (40 μg/dl) set by the 1993 US Occupational Safety and Health Administration (OSHA) [1].

The mean urinary cadmium levels of the two groups of the spray painters were also significantly higher than that of the control group ($p < 0.01$) (Table 4), but were still less than the regulatory limit set by OSHA (3 μg/g creatinine) [2]. The mean environmental and urinary cadmium levels between the two groups of the spray painters were not significantly different ($p > 0.05$) although one value of the environmental cadmium levels from the non-protected group exceeded the time weighted average permissible exposure limit (5 $\mu g/m^3$) [7].

The mean environmental and urinary chromium levels of the two groups of the spray painters were less than the standard allowances (100 $\mu g/m^3$ and 10 μg/g creatinine, respectively) [7, 8]. However, the urinary chromium levels of the two groups were significantly higher than those of the control group ($p < 0.05$) (Table 5).

Discussion

Many chemicals used by automobile spray painters, especially those in organic solvents, can elicit respiratory injuries by acting as nonspecific irritants or by stimulating immune-mediated mechanisms [9]. The clinical symptoms reported in this study were predominately related to exposure to organic solvents and certain organic chemicals rather than to heavy metal exposure (Table 1). For example, some of the spray painters had asthma, of which the most common cause is a group of chemicals, isocyanates, found in organic solvents [9]. Symptoms reported which might be partly related to heavy metal exposure were abdominal pain, muscle weakness and nervous symptoms [10].

The Thai mental state examination (TMSE) used to test the automobile spray painters was originally designed for evaluation of elderly psychiatric patients' brain function [11]. It seemed that the TMSE was not sensitive enough to be used with the spray painters since none of them failed the test (Table 2). However, the rather low scores on orientation, calculation and recall capabilities suggested that the spray painters' central nervous system might be impaired.

Though the average biological levels of lead, cadmium and chromium were lower in the spray painters who wore a respirator than those who did not, there were no significant differences in any of these levels between the two groups ($p > 0.05$). Close observation of the spray painters' activities at work revealed that most of them did not use spray paint in an isolated room, and those who wore a respirator did so only when they were spraying paint. They did not wear a respirator while other workers were spraying paint nearby. In addition, some of the spray painters showed poor personal hygiene habits, such as eating food or smoking cigarettes in the workplace without washing their hands first, returning home after work without taking a bath or changing into clean clothes, or living at their workplace. Such behavior increased their risk of exposure to the heavy metals and negated the protective effect of a respirator. In conclusion, the use of an aerosol-removing respirator alone is not adequate for the prevention of toxic metal exposure among spray painters. Other components, such as the use of an isolated spraying room and good personal hygiene, are also required.

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Table 1 Most frequently occurring symptoms among the automobile spray painters

Symptoms	Frequency (%)
Digestive System	
Dry mouth	54.3
Sore throat	54.3
Constipation	30.0
Abdominal pain	24.3
Respiratory System	
Nasal congestion	44.3
Sneezing	38.6
Phlegm discharge	34.3
Nasal irritation	32.9
Cough	30.0
Musculoskeletal System	
Muscle weakness	48.6
Muscle pain	44.3
Joint pain	34.3
Muscle cramp	30.0
Tremor	30.0
Nervous System	
Irritability	41.4
Headache	41.4
Drunk-like	35.7
Lightheaded	34.3
Numbness of extremities	32.9
Change in mood	31.4
Insomnia	30.0
Confusion	25.7

Table 2 Scores of the Thai Mental State Examination (TMSE) obtained by the automobile spray painters (n = 68). Values are shown as mean ± standard deviation.

Test	Full Score	Earned Score
Orientation	6	5.7 ± 0.6
Registration	3	3.0 ± 0.0
Attention	5	5.0 ± 0.0
Calculation	3	2.5 ± 0.6
Language	10	10.0 ± 0.0
Recall	3	2.6 ± 0.5
Total	**30**	**28.8 ± 1.6**

Table 3 Working atmospheric and blood lead levels of two groups of automobile spray painters and a control group. Values are shown as mean ± standard deviation with range values in parenthesis.

Group	n	Working Atmospheric Lead ($\mu g/m^3$)	Blood Lead ($\mu g/dl$)
Painters wearing a respirator	20	0.97 ± 1.73 (0.08-5.75)	8.62 ± 2.72* (3.54-14.10)
Painters not wearing a respirator	50	0.62 ± 1.30 (0.05-5.60)	10.42 ± 4.07* (5.27-26.00)
Control	30	N/A	4.24 ± 1.25 (2.33-6.50)

*Significantly different from the control group ($p < 0.01$)
N/A = not applicable

Table 4 Working atmospheric and urinary cadmium levels of the two groups of the automobile spray painters and a control group. Values are shown as mean ± standard deviation with range values in parenthesis.

Group	n	Working Atmospheric Cadmium (μg/m³)	Urinary Cadmium (μg/g creatinine)
Painters wearing a respirator	20	0.01 ± 0.01 (nd-0.02)	0.57 ± 0.26* (0.15-1.05)
Painters not wearing a respirator	50	0.30 ± 1.28 (nd-5.74)	0.76 ± 0.54* (0.29-3.42)
Control	30	N/A	0.12 ± 0.09 (nd-0.30)

*Significantly different from the control group ($p < 0.01$)
nd = not detectable
N/A = not applicable

Table 5 Working atmospheric and urinary chromium levels of two groups of the automobile spray painters and a control group. Values are shown as mean ± standard deviation with range values in parenthesis.

Group	n	Working Atmospheric Chromium ($\mu g/m^3$)	Urinary Chromium ($\mu g/g$ creatinine)
Painters wearing a respirator	20	0.73 ± 0.83 (0.31-3.07)	0.87 ± 0.54* (0.19-2.44)
Painters not wearing a respirator	50	0.64 ± 0.50 (0.25-2.55)	1.25 ± 0.88* (0.11-3.90)
Control	30	N/A	0.17 ± 0.16 (nd-0.67)

*Significantly different from the control group ($p < 0.01$)
nd = not detectable
N/A = not applicable