

# 분사페인트에 의한 이소시아나화물의 노출이 건강에 미치는 영향에 관한 연구

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## A Study of Adverse Health Symptoms of Spray Painters Using Isocyanates(HDI)

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**Abstract :** In the manufacturing industries using HDI(hexamethylene diisocyanate) product hardeners, exposure to HDI is common to spray painters in terms of inhalation and dermal or ocular contact. Due to a lack of information for spray painters in automobile and furniture industries, a questionnaire survey was conducted for the prevalence of adverse health symptoms(33 spray painters and an unexposed group n=91) to assess the importance of personal controls. Despite the small sample size, common health symptoms were reported, such as skin symptoms(dry cracked skin-61% and dermatitis/skin irritation-33%) and respiratory symptoms(phlegm-49%, asthma-21%). In addition, other adverse health symptoms were reported, such as skin rash(12%), cough(39%), shortness of breath with wheezing(30%), chest tightness and difficulty in breathing(30%). No significant eye symptoms were reported. It was founded that the adverse health symptoms reported in this study were related to poor personal work practices and inappropriate PPE use. Therefore, appropriate personal controls like PPE use, work practices, regular training and education are suggested to minimize the risk of health symptoms. In addition, medical examination will also be suggested for individual health effects.

**초 록 :** 이소시아나화물을 경화제로 하는 분사용 페인트를 취급하는 산업현장에서는 HDI에 의해 이소시아나화물 이 호흡이나 피부 및 눈에 노출되는 것이 일반적이다. 이러한 분사페인트를 사용하는 자동차관련 산업이나 가구산업 등에 대한 정보의 부족 때문에 건강에 미치는 증상을 개인관리의 중요성으로 평가하기 위하여 설문조사가 수행되었으며, 분사페인트를 취급하는 근로자 33명과 취급하지 않는 근로자 91명을 대상으로 비교하였다. 그렇게 많지 않은 대상자에 대한 조사에도 불구하고 공통적으로 나타나는 건강에 미치는 영향으로서 피부에 나타나는 증상, 즉 건성피부 손상(61%)과 피부염/피부염증(33%)이 있고 호흡기에 나타나는 증상, 즉 담(49%)과 천식(21%)과 같은 증상이 발견되었다. 그 외에도 건강에 좋지 않은 증상으로는 피부 발진(12%), 기침(39%), 빈번한 호흡으로 인한 새근 거림(30%), 가슴의 답답함과 호흡곤란(30%) 등이 나타났으며, 눈에는 어떤 증상이 나타나지 않았다. 이 연구에서 나타난 건강에 미치는 증후는 근로자들의 좋지 않은 작업형태나 부적절한 보호구에 관련된다는 것을 발견하였다. 따라서 보호구의 사용, 작업형태, 규칙적인 훈련이나 교육 등과 같은 적절한 개인적 관리가 건강의 위험을 최소화 시키는 것이고, 개인적 건강에 미치는 영향을 확인하기 위하여 의학적인 조사도 추가적으로 제시하고자 한다.

**Key Words :** isocyanate, questionnaire, health symptom, spray painter, crash repair shops, furniture industry

### 1. Introduction

The spray painters are at the potentially higher risk of the prevalence of respiratory symptoms than

others. In the case of manufacturing industry using HDI, exposure to HDI is common to spray painters working in an automobile industry and a furniture manufacture in terms of inhalation and dermal or ocular contact<sup>1,2)</sup>. In addition, it may also be from accidental spillage during handling, storage or transports.

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From the exposure to isocyanates, significant adverse health symptoms can be considered<sup>3-6</sup>.

The dose of HDI in the body can effect on various tissues and organs. This effect may be occurred within short time period as acute effects and long time period by repeated exposure as chronic effects<sup>7</sup>. With skin sensitization and eye symptoms<sup>8-10</sup>, HDI biuret and trimer can cause respiratory and immunological reactions which are similar to the HDI monomer in human and animal studies<sup>11</sup> as well as a bronchial reaction<sup>12</sup>.

There are several studies regarding the metabolism<sup>13,14</sup>. However, little information about the toxicokinetics of HDI has been available. No specific information for cardiovascular effects and carcinogenic property are available to humans<sup>9,10</sup>.

Isocyanates used for a variety of applications in many industries can be one of the main causes of occupational asthma(OA)<sup>15-18</sup>, especially concluded OA was a common adverse health symptom among spray painters using isocyanates in automobile and furniture industries. A few cases occurred in South Australia (SA)<sup>19</sup>. Pulmonary irritation and obstruction have been, also, reported by several literatures<sup>20-22</sup>. There are, moreover, supporting literatures about HDI hazardous coming from auto body shops<sup>11,23-27</sup> reported, contaminated working surface and skin exposure to HDI might be able to cause adverse health symptoms and PPE(personal protective equipment) did not protect worker from the exposure.

A survey of isocyanate exposures in crash repair workshops was implemented<sup>28,29</sup>. From the survey, respiratory and skin problems were predominant to polyurethane spray painters in SA. The survey also found the high prevalence of respiratory symptoms to spray painters using isocyanates by a cross-sectional study.

However, no specific study has not been done for spray painters in autobody industry and furniture industry. Under the circumstance, there would be the risk of adverse human symptoms to skin, eye and respiratory system emphasized or those using isocyanates. The effect of HDI was a concern<sup>11</sup> for workers handling hazardous chemicals in workplace or any other places, because there is a lack of actual information.

Therefore, this study was conducted to survey the prevalence of adverse health symptoms with respect to the assessment of personal controls like PPE use, work practices, regular training/education.

## 2. Material and Methods

### 2.1. Study Population

Thirty-three isocyanate(HDI) spray painters were participated, including spray painters using isocyanate-based spray paints.

They were from individual small businesses under the umbrella of the Motor Trade Association(MTA) (n = 29, males) and a large furniture manufacturer(n = 4, males) in SA. The main activities using isocyanate-based paints are surface preparation, paint mixing, compressed air-assisted spraying, rubbing and cleanup. Unfortunately, this study was limited in respect of workers sample size. Workers were introduced by their supervisor. In addition, personal contact was implemented with small crash repair shops and individual mobile sprayers.

Spray painters used HDI based hardeners(3.6-3.8 mg NCO/g liquid hardener in the crash repair shops and the automobile industries, 1.0mg NCO/g liquid hardener in the furniture industry). The main components of the spray paint were resin:hardener(2 : 1) and reducer(5-10% in total). Application time was between 10-20 minutes each time. Workers usually wore overalls, gloves respiratory protection, and in some cases eye protection.

### 2.2. Development and Pilot Investigation

A cross-sectional study was conducted for the isocyanate(HDI) spray painters. The aim of the project was explained to the workers by a member of the research team. An information sheet was supplied to the exposed group, and they were interviewed individually. They were given an opportunity to ask questions and then asked if they wished to participate. If they agreed, a consent form was issued, along with a complaint form.

The questionnaire based on a previous questionnaire<sup>30</sup> for the workers implementing isocyanate(HDI) spray painting. This questionnaire included personal

information(name, date of birth, sex, workplace, job title, work experience and educational status), health information(respiratory symptoms, skin symptoms, ocular symptoms, other symptoms and smoking status) and work practices(chemical usage and PPE usage). The questionnaire for the control group included personal information, health information and chemical usage and work practices.

### 2.3. Administration and Human Ethics

Ethics approval was given by the Human Research Ethics Committee of The University of Adelaide. The author selected volunteer operators who were exclusively using isocyanate(HDI) during the 2-pack spraying painting.

### 2.4. Data Analysis

Data from the questionnaires were kept secure and confidential. Personal information was entered into an Excel spreadsheet, and all information was coded. Data files were kept on a computer requiring password access, or on floppy disks/ CDROMs stored in a locked cupboard. Statistical report was based on Chi-squared two-tailed test of proportions<sup>31)</sup>. Microsoft Excel on a personal computer was used for statistical analysis. Reporting of statistics was in summary form without individuals' identification.

## 3. Results

### 3.1. Subjects

Table 1 shows personal baseline data and the prevalence of previous health symptoms from the exposed group and the unexposed group. For the two groups, the average age and smoking prevalence were similar. There were no statistically significant differences for hayfever, asthma, eczma, dermatitis and more severe reactions than others to insect bites.

Information on hardener usage and application among the HDI spray painters is described in Table 2. The average usage of HDI based paint was 0.8L for 2.2 hours per day. During working hours, 46% of spray painters reported that they had sprayed outside a spray booth. Out of hours(hobby) spraying was reported by 24% of workers. From the previous study

Table 1. Baseline Variables for HDI Spray Painters and Controls#

Items	Exposed(n=33)*	Non-exposed(n=91)
Mean Age(STD)(years)	28(12)	38(9)
Current smokers	15(46%)	43(47%)
1-5 per day	1(3%)	7(8%)
6-10 per day	3(9%)	7(8%)
11-15 per day	2(6%)	7(8%)
16-20 per day	3(9%)	12(13%)
> 20 per day	6(18%)	10(11%)
Ex-smokers	5(15%)	12(13%)
Ever had hayfever?	11(33%)	35(39%)
Ever had asthma?	7(21%)	7(8%)
Ever had eczema?	2(6%)	5(6%)
More severe reaction than others to insect bites	2(6%)	7(8%)

# All males, Study Group 3 only

No statistically significant difference in proportions between exposed workers and non-exposed(p < 0.05, two-tailed test,) (Fleiss, 1981)<sup>31)</sup>

Table 2. Chemical Usage and Application Among HDI Spray Painters

Items	Spray painters(n=33, males)
Use amount of chemical(average)	0.8L/day
Application hours(average)	2.2hours/day
Outdoor spraying during working hours?	15(46%)
Spraying outside of regular working hours?	8(24%)

results<sup>1,2)</sup>, airborne exposure levels(AM ± STDEV) were 0.49 ± 0.76mgNCO/m<sup>3</sup>(n = 19, range = < 0.008-15, sampling time = 2 - 20minutes). The maximum contamination levels of neck, forehead and wrist were 1.53 µg NCO, 2.46µgNCO and 3.05µgNCO respectively. Sampling time was between 1-30minutes. The 8-hour time weighted average(TWA) value for all isocyanates(as-NCO) is 0.02mg/m<sup>3</sup>. The 15 minutes STEL is 0.07mg/m<sup>3</sup> according to ACGIH(TLVs and BELs, based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices, 2007). There is no exposure standard for dermal exposure.

### 3.2. Symptom Prevalence

Table 3 gives the symptom prevalence data derived from the questionnaire survey. The main adverse symptoms were skin symptoms(i.e. dry cracked skin, dermatitis and skin irritation), pulmonary symptoms and headaches. Most of the subjects suffered from

Table 3. Work-related Symptom Prevalence Data(HDI Spray Painters)

Symptoms	Exposed(n=33) #		Non-exposed(n=91)#
	Touch-up Sprayers (n=18)	Apprentices (n=15)	
Skin symptoms			
Dry cracked skin*	7(21%)	13(39%)	17(19%)
Skin rash	2(6%)	2(6%)	5(6%)
Dermatitis/skin irritation*	5(15%)	6(18%)	4(4%)
Pulmonary symptoms			
Cough	9(27%)	4(12%)	21(23%)
Morning	4(12%)	2(6%)	13(14%)
Day	4(12%)	2(6%)	3(3%)
Night	1(3%)	0(0%)	5(6%)
Phlegm*	7(21%)	9(27%)	24(26%)
Morning	7(21%)	6(18%)	22(24%)
Day	0(0%)	0(0%)	0(0%)
Night	0(0%)	3(9%)	2(2%)
Increased cough/phlegm	2(6%)	3(9%)	14(15%)
Shortness of breath with wheezing	6(18%)	4(12%)	21(23%)
Chest tight/breathing become difficult	5(15%)	5(15%)	18(20%)
Eye symptoms			
Eye irritation*	0(0%)	3(9%)	24(26%)
Itchy eyes*	2(6%)	2(6%)	26(29%)
Dry eyes	2(6%)	2(6%)	15(17%)
Conjunctivitis	1(3%)	1(3%)	2(2%)
Others	0(0%)	1(3%)	3(3%)
Headaches	7(21%)	9(27%)	36(40%)
Blackouts	1(3%)	0(0%)	0(0%)

\* Statistically different proportions from controls(p < 0.05, two-tailed test,) were indicated(Fleiss, 1981)

# All males

cough or phlegm had more symptoms in the morning or daytime. Among the exposed group, pulmonary symptoms were often attributed to smoking, asthma, hayfever and chemical mists and vapors from spraying.

Eye symptoms, except for conjunctivitis(6% vs 2%), were relatively uncommon among spray painters. Only four of the exposed group reported itchy eyes.

A little high prevalence of headaches was reported from the exposed group(49%), compared with the unexposed group(40%). There was no reason given for the causes of the headaches for the exposed group, although it is possible solvent or thinner exposure

may have been a factor. Of the exposed group, when both the touch-up spray painters and the apprentices were compared each other, there was no significantly different symptom prevalence.

The question on “Blackouts” was used to check on over-reporting of symptoms by the interviewee. As in the pesticide study, over-reporting of symptoms did not appear to be an issue.

### 3.3. Accidental Exposures

Table 4 gives the accidents caused by chemical use, and it can be seen that 42% had an experience of a major spill(>500mL). Eighty five percent had experienced a splash on the body, due to chemical liquid leakage from spray guns, chemical spillage from mixing, chemical splash from washing/cleaning equipment etc.

### 3.4. Use of Personal Protective Equipment

Table 5 gives information on PPE usage. The main PPE used were full-face airline respirators, half face-airline respirators, hood or helmet-airline respirators, half face cartridge respirators, overalls, disposable coveralls, safety glasses including prescription lenses, safety goggles and protective gloves.

Of the protective gloves, disposable latex examination gloves were mostly used for spray painting in the crash repair shops. Neoprene gloves were used for cleaning spray guns after spraying painting. In the case of disposable gloves, the gloves were replaced every time within 20 minutes as maximum. Several workers used more than one type of glove for different purposes on the same day, such as spraying painting and cleaning or washing equipment.

For foot protection, of the exposed group, 21% used sports shoes and 76% used safety boots during working hours. However, since they were provided

Table 4. Accidents from Chemical Use Among HDI Spray Painters

Items	Spray painters(n=33, males)
Major spill(>500mL)	14(42%)
A splash in eyes	14(42%)
Splashing any other part of the body	28(85%)
Accident free from spill and splash	2(6%)

Table 5. Use of Personal Protective Equipment Among HDI Spray Painters

Items	Spray painters(n=33, males), % prevalence
<b>PPE usage</b>	
Full face-airline respirator	11(33%)
Half face-airline respirator	6(18%)
Hood or helmet-airline respirator	6(18%)
Air purifying cartridge respirator	24(73%)
Overalls	22(67%)
Disposable coveralls	16(49%)
Glasses(prescription lenses)	4(12%)
Goggles	3(9%)
Face shield	0(0%)
Protective gloves	15(46%)
<b>Protective Gloves #)</b>	
<b>Type of gloves</b>	
Cotton	0(0%)
Disposable latex examination	9(27%)
Disposable rubber	0(0%)
Disposable nitrile	3(9%)
Disposable vinyl	3(9%)
Leather	0(0%)
Neoprene	18(55%)
Nitrile	0(0%)
Nitrosolve	0(0%)
PVC	0(0%)
<b>Replacement of gloves</b>	
Every time	11(33%)
Every day	2(6%)
1/Week	3(6%)
<b>Foot protection</b>	
Shoes	7(21%)
Boots	25(76%)
<b>Cleaning</b>	
Shoes	5(15%)
Overalls	14(42%)
Respirator	21(64%)
Remove overalls at lunch break	15(46%)
Remove overalls before going home	26(79%)

#) More than one glove were used by subjects

with safety boots or they had bought a new pair of safety boots, the foot protections were cleaned once a week or two weeks. The respirator was often kept in contaminated areas, such as bench tops or the floor. Not everyone cleaned their respirator every time or daily.

Table 6. Training and Education among HDI Spray Workers

Items	Spray painters(n=33), % prevalence
Formal training in use	28(85%)
<b>Period of training</b>	
1 day course	0(0%)
> 2 days course	28(85%)
<b>Education</b>	
Health effects	27(82%)
PPE usage	29(88%)
MSDS	24(73%)

At lunch breaks, 46% removed overalls. Seventy nine percent of the exposed group removed contaminated overalls before going home.

### 3.5. Knowledge and Training

Table 6 gives the survey results for knowledge and training among the exposed group. A high proportion of the spray painters had attended formal training program(85%) about using isocyanates(e.g. HDI). Of the 33 spray painters, 85% had more than a 2-day training course. Over 70% had education about health effects, PPE usage and MSDS(material safety data sheet) to have had such training.

## 4. Conclusion and Discussion

This study considered isocyanate(HDI) spray painting to look at adverse health symptoms for users versus a control group and work practices. All subjects were touch-up spray painters and apprentice trainers working in automobile industries and a furniture manufacturer in SA. From the questionnaire survey there were evidences between adverse health symptoms like skin and respiratory symptoms, and the spray painters exposed to isocyanate, even though a sample size was small. Smoking was not related.

1) The similar survey results were reported from a previous study, and there was a strong relationship between skin symptoms(dry cracked skin, dermatitis and skin irritation) and exposure to HDI in terms of dermal exposure<sup>28)</sup>. In the case of dermatitis and skin irritation, the symptoms were likely to be from poor work practices and accidents from chemical spillage or splash as Karol<sup>8)</sup> expected. Headaches was likely

to be more common to the spray painters.

Of the pulmonary symptoms, phlegm was the common symptom in this study, even though Ucgun et al.<sup>18)</sup>, and Talini et al.<sup>32)</sup> reported high prevalence of cough, shortness of breath with wheezing, chest tightness and breathing become difficult. However, there was no significant difference between the groups. The similar results were reported by Randolph et al.<sup>33)</sup>. It was also found that spray painters in automobile and furniture industries are at high risk of occupational asthma, as reported by Ucgun et al.,<sup>18)</sup> and Redlich et al.,<sup>34)</sup>.

No specific eye symptom was reported, and this was also observed in a previous study<sup>28)</sup>. But eye irritation and conjunctivitis can be main symptoms from accidents in the eyes<sup>33,35)</sup>. While 72% reported using eye protection, 42% had experienced a splash in the eye. People who reported wearing safety goggles or full face-airline respirator did not suffer from a splash to the eyes.

2) In this study, skin symptoms were likely to be from the accidental splashes on the body(the face, head, forehead, lower arms and legs) during mixing, spraying and cleaning/washing equipment, or perhaps spray painting at home, even though 85% of the exposed group had formal training and education including in relation to health effects, PPE usage and MSDS.

Table 2 shows that 46% of painters spray outside of the dedicated booth, compared with 59% in 1988<sup>28,29)</sup>, and 25% in 1995<sup>36)</sup>. The variation in percentages may reflect changing awareness or levels of business activity relative to booth availability, but it is clear that such spraying is common<sup>37)</sup>. Bystander exposure may be significant<sup>14,38)</sup>.

3) Dermal exposure is likely to be caused by inappropriate PPE use and poor work practices, according to worksite observation. PPE was often maintained inappropriately. Before and after the spray painting, the spray painters put on the respiratory protection or eye protection which were contaminated and/or stored in contaminated area. Cushmac et al.,<sup>26)</sup> reported similar observations. Disposable latex gloves were commonly used. Liu et al.,<sup>39)</sup> suggested not to use latex gloves for isocyanate spraying. Inappropriate use of

PPE were also pointed out in this study and discussed by Pisaniello and Muriale,<sup>28)</sup> Cooper et al.,<sup>24)</sup>, Cushmac et al.,<sup>26)</sup>. Even though 76% used boots as a foot protection, some of the workers wore shoes which were likely to accumulate contaminants. Finally, there was no obvious different prevalence of the adverse health symptoms between it appears the apprentices and the touch-up spray painters.

To spray painters using HDI-based paints, there are several recommendations.

(1) Hardeners containing low levels of isocyanate (i.e. free isocyanate product) should be replaced.

(2) Appropriate glove should be recommended after glove permeation test with chemical mixtures rather than a single chemical.

(3) PPE like respirator, gloves and eye protection should be stored appropriately avoiding any cross contamination.

(4) A more comprehensive or repeated education program and regular training section could be also recommended to improve poor work practices and minimise the risk of secondary contamination possibly causing adverse health symptoms.

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