ORIGINAL ARTICLE

Evaluation of Toluene Exposure in Workers at Industrial Area of Sidoarjo, Indonesia by Measurement of Urinary Hippuric Acid

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Abstract

Background: Toluene is a harmful substance still being used as a solvent and catalyst in many industries that can increase the level of urinary hippuric acid (UHA). This study was designed to examine the level of toluene and UHA among workers of industrial site in seven companies in Sidoarjo, Indonesia and to analyze the risk factors for abnormal UHA.
Methods: This study was an analytical cross-sectional study conducted during August to September 2008. The locations were selected based on the fact that toluene was utilized in the production process of these companies. Urinary hippuric acid was analyzed with screen spectrophotometer 3000 on obtained urine samples from workers. Urinary hippuric acid of higher than 1.6 g/g creatinine was considered as abnormal. Workers' characteristics were collected via questionnaires completed by the workers. Toluene in workplace air was obtained with the reagent tube and the samples were analyzed using gas chromatography.
Results: In total, 96 subjects were studied. Workers examined in this study suffered from watery eyes, shortness of breath, cough, runny nose, fatigue, and skin irritation. Urinary hippuric acid level was normal in 91 workers (95%). Five subjects had abnormal levels of urinary hippuric acid. Levels of toluene in workplace air at all companies were below the ratified governmental regulatory threshold value (< 50 ppm) with the maximum level of 28.1 ppm. Abnormal HPA was higher in workers with older ages, lower educational attainments and not using the personal protective equipment (PPE).
Conclusion: Toluene concentration in the air of the ink, paint and printing companies in Sidoarjo, Indonesia was within ratified limit. Workers with older ages, lower educational attainment and not using the PPEs are probably more vulnerable to toluene toxicity.

Keywords: Hippuric Acid; Indonesia; Occupational Exposure; Toluene

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INTRODUCTION

Rapid development of industry in Indonesia, in addition to carrying a lot of progress in the development and prosperity of the nation, has also contributed to environmental problems, both at the workplace and in the environment in general. Production process that does not consider the established threshold values has aggravated pollution in working environments; therefore, a major part of manpower is very easily exposed to toxic gases (1). Handling industrial waste that pays less or no attention to the environmental quality standards, set by the government, could as well aggravate environmental pollution in general. Many efforts can be pursued to reduce the negative impact of industrial process and waste, including industrial hygiene programs that have been established in almost all companies in Indonesia (2). This has also been proclaimed by the employer or by the government. Another effort is waste minimization program, which can also control pollution at its source (1-3). However, in reality, there are always very high toxic gas levels and waste resulting from an industrial activity with complex content. The chemical industry, for instance, paint industry, uses both compounds of benzene and toluene as a solvent and as a chemical reagent. Use of such compounds will undoubtedly generate industrial waste that reacts with other compounds, producing derivatives, or may enter the waste stream.

Toluene, also known as methylbenzene or phenylmethane with the chemical formula of C_6H_5-CH_3,

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is a colorless clear liquid that is soluble in water with a paint-thinner-like smell and a fragrance similar to benzene. The nature of being hard to decompose increases the pollutant-ability of benzene and toluene. Toluene is an aromatic hydrocarbon that is widely used as a solvent and raw material, though it has been known to have a negative impact on the workers' health (1). This impact can be minimized by regular monitoring of the toluene-exposed working environment and the health of the workers. A research by Sopianita regarding correlation between urinary hippuric acid (UHA) levels induced by exposure to toluene with acute health effects on Indonesian workers showed that signs and symptoms of acute health effects, such as watery eyes, chest tightness, fatigue, skin reactions and cough are more prevalent in these workers (4). It was also found a strong relationship between age, length of employment and smoking habit of the study subjects with elevated levels of UHA (4).

One of the factors influencing on the workforce health is chemical agents, including gas, vapor, fume, dust and mist. In fact, the chemicals commonly used as solvents are volatile materials such as toluene. Since volatile materials often cannot be identified, poisoning with them is inevitable.

Health effects due to exposure to toluene are divided into two categories, acute and chronic (5,6). Acute effects of inhalation or ingestion can cause euphoria, drunkenness, dizziness, trembling, convulsions, respiratory disorders and tremors. Local effects via inhalation include irritation of nose, throat and respiratory tract, and via ingestion are the oropharyngeal and digestive tract irritation. On the eyes, it can cause lacrimation and corneal damage, while it may cause erythema and dry skin through dermal exposure. Exposure to high concentrations (estimated at more than 1000 ppm) can cause coma until death (1,5). Effects due to chronic exposure to toluene via inhalation are damage to the liver, kidneys and nerves, while to the skin it may cause contact dermatitis and irritation (6). In the body, toluene is metabolized to hippuric acid ($C_9H_9NO_3$) (7,8). Hippuric acid is excreted through kidneys and may produce a syndrome that resembles transient distal renal tubular acidosis causing hypokalemia. In addition, chronic exposure to toluene may produce carcinogenic effects. There is a possibility that toluene includes components toxic to the reproductive system, hence leading to miscarriage and birth defects (9).

Toluene can be found in many industries such as benzoic acid industry, benzaldehyd industry, and other industrial organic compounds (1-3). Toluene is also used as a solvent for paints and rubber, as a thinner in ink and perfume and as a reagent in various industries. Moreover, toluene is utilized as a denaturant additive in gasoline. It is necessary to test toluene levels in the workplace and the concentration of UHA levels and also identifying its side-effects. However, most companies do not adhere to governmental regulations and also do not check their workers for toluene exposure.

This study was designed to examine the level of toluene and UHA among workers of industrial site in seven companies in Sidoarjo, Indonesia. In addition, we aimed to evaluate the correlation between age, working hours, smoking habits, use of personal protective equipment (PPE), educational level and UHA.

METHODS

This study was an analytical cross-sectional study conducted on workers of seven companies in the field of paint and ink production and printing in industrial environment of Sidoarjo, Indonesia during August to September 2008. The locations were selected based on the fact that toluene was utilized in the production process of these companies. Samples were collected via random sampling. Toluene in workplace air was obtained with the reagent tube and the samples were analyzed using gas chromatography. NIOSH method 1501 was used for measurement of toluene level in the air of target companies. UHA was analyzed with screen spectrophotometer 3000 on obtained urine samples from the workers. UHA of higher than 1.6 g/g creatinine was considered as abnormal. Workers' characteristics, including age and working hours were obtained via questionnaires completed by the workers. Correlation of the variables was analyzed with chi-square test using Statistical Package for Social Sciences (SPSS Inc. Chicago, IL). P values of less than 0.5 were considered as significant.

RESULTS

Demographic

One hundred twenty seven workers were working in the seven selected companies during the study period. In total, 96 subjects (76%) out of them were studied. Regarding age, the subjects were divided into 2 groups of a) adolescent and young adults (< 30 years of age), and b) adults (≥ 30 years). Most patients were adults (80 workers (83%)) and the majority of them aged 30 years. Regarding working hours per day subjects were divided into 2 categories of equal and less than 8 hours/day which included as many as 73 workers (76%) and over 8 hours/day with 23 workers (24%). Fifty-three Subjects (55%) had smoking habit. Subjects with senior high school education were as many as 78 persons (82%), with junior high school were 10 persons (10%) and with elementary school were 8 persons (8%). Subjects who complied to wear PPE during work were as many as 30 workers (31%)

Clinical and Laboratory findings

Workers examined in this study suffered from watery eyes, shortness of breath, cough, runny nose, fatigue, and skin irritation. UHA level was normal in 91 workers (95%). Five subjects had abnormal levels of UHA. Levels of toluene in workplace air at all companies were below the ratified governmental regulatory threshold value (< 50 ppm) with the maximum level of 28.1 ppm.

All young workers had normal UHA concentrations

Table 1. Analysis of risk factors for abnormal urinary hippuric acid levels (n = 96)

	Normal Urinary Hippuric Acid, n (%)	Abnormal Urinary Hippuric Acid, n (%)	P value
Age group			
Young (n = 16)	16 (100)	0 (0)	0.30
Adult (n = 80)	75 (94)	5 (6)	
Working hour			
≤ 8 hours (n = 73)	68 (93)	5 (7)	0.19
> 8 hours (n = 13)	13 (100)	0 (0)	
Smoking habit			
Smoker (n = 53)	50 (94)	3 (6)	0.82
Non-smoker (n = 43)	41 (95)	2 (5)	
Educational level			
Elementary school (n = 8)	7 (87.5)	1 (12.5)	0.04
Junior high school education (n = 10)	8 (80)	2 (20)	
Senior high school education (n = 78)	76 (97)	2 (3)	
Wearing Personal Protection Equipment			
Yes (n = 30)	30 (100)	0 (0)	0.12
No (n = 66)	61 (92)	5 (8)	

while abnormal hippuric acid concentrations were found in 5 workers of the adult group. Data analysis showed no significant correlation between UHA levels and age of the subjects. All five workers who had abnormal UHA content worked less than 8 hours per day. However, there was no significant correlation between UHA content and working hours of the subjects (Table 1).

Abnormal UHA content was detected in 3 workers with smoking habit, in contrast to 2 non-smoker workers. Chi square test revealed no correlation between UHA level and smoking habit. Abnormal UHA content was found in two senior high school-educated workers (12.5%), in two junior high school-educated workers (20%) and in one elementary school-educated worker (3%) that after analysis showed a significant relationship between educational level and abnormal UHA level (P = 0.04). In addition, abnormal UHA was found in five workers who did not wear PPE (100%), while UHA content in workers who had used PPE was normal. Chi-square test revealed a p value of 0.12 indicating no significant correlation between UHA content with the use of PPE among the workers (Table 1).

DISCUSSION

Normally, urine contains hippuric acid, but its concentration elevates in the workers exposed to toluene. Biological exposure index (BEI) for UHA is 1.6 g/g creatinine. According to TLVs devised by American Conference of Governmental Industrial Hygienists (10), and the SNI-19-0232-2005 that refers to the circular letter of the Indonesian Ministry of Manpower (no. SE-01/MEN/1997) on TLV of chemical compounds in the work environment air, the permitted TLV for toluene is 50 ppm. In this study, it was found that levels of toluene in workplace air at all 7 companies studied were within permitted thresholds (< 50 ppm). In addition, UHA level was normal in 95% of subjects since the inhaled toluene was also too small. This may be due to the fact that the selected workplaces were well-spacious with satisfying air conditioning and air circulation.

According to the American Agency for Toxic Substances and Disease Registry (ATSDR), the effect of toluene on health is strongly influenced by genetic factors, workers' susceptibility, duration of exposure, age, body composition (body fat), smoking and alcoholism (11). It can be said that the older the workers, the higher the effect of toluene. Correspondingly, in this study, we found that all patients with abnormal UHA levels were older adults (≥ 30 years) though the difference was not statistically significant. This is because along with the increase in age, the metabolic system of the body dwindles as well. Glomerular filtration rate (GFR) in the elderly people may decrease

even by 35% (12). In addition, older workers have a higher ratio of fat to muscle compared to the younger workers, so that biological excretion ratio is lower.

It has been previously shown that longer duration of exposure to toluene is associated with more clinical damages (13). However, in the present study, all patients with abnormal UHA levels were working less than 8 hours and all workers with more than 8 working hours had normal UHA levels. This discrepancy can be due to small number of subjects with abnormal UHA levels in this study and also to the fact that toluene levels in the air of all seven companies were within acceptable range.

Although there is a doubt on the effect of smoking on xenobiotics metabolism (14), some scientists believe that smoking will increase the level of xenobiotic in an exposed person (11). In the present study, we found no correlation between smoking and increase in UHA level. Moreover we found that the incidence of abnormal UHA is significantly lower in workers with higher educational attainment.

However, due to the limited number of workers with this complication in this study, and also less than expected count in variables, the result of analysis with chi square test is unreliable.

Use of PPE protects workers from direct contact to xenobiotics (15,16). However, in the present study, many workers did not wear PPEs. Workers who did not wear PPEs, especially masks, were directly exposed to toluene vapor in work environment. In addition, some workers wore a cloth mask that did not match the type of hazards existing

in the work environment. Thus, workers who did not wear PPEs or wore unfit PPEs had a risk of experiencing health problems due to exposure to toluene. We found that all workers with abnormal UHA levels were those who did not use PPEs, though the difference was not statistically significant.

LIMITATIONS

Regarding the UHA test, there are a number of affecting factors. One of the factors is the relatively short half-life of toluene (T1/2 = 16.1 hours). Hence, it is excreted in a rather short time, 12-16 hours post-exposure. In addition, some workforce might have previously excreted their urine before the sampling; therefore, the urine obtained and analyzed may not be representative. In order to establish a reliable analysis of UHA, a control group who were not working in these companies was also needed to compare the findings with them. The main limitation of this study was that in some analyses the samples were less than expected count and insufficient for chi square test.

CONCLUSION

Toluene concentration in the air of the ink, paint and printing companies in Sidoarjo, Indonesia was within ratified limit. Abnormal UHA level was detected in small number of workers. Workers with older ages, lower educational attainment and not using the PPEs are probably more vulnerable to toluene toxicity. It is suggested that companies provide training on health hazards, performing both pre-placement and periodic health examinations as well as appropriate PPE to all employees exposed to toluene.

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