

Case Report



A case of acute organic solvent poisoning during epoxy coating

Sujin Lee¹, Inah Kim^{1*}, Dooyong Park², Jaechul Song¹, and Sang Gil Lee³

¹Department of Occupational and Environmental Medicine, College of Medicine, Hanyang University, Seoul, Korea

²Korea Occupational Safety & Health Agency, Ulsan, Korea

³Occupational Safety & Health Research Institute, Ulsan, Korea



Received: Apr 17, 2019

Accepted: Jun 5, 2019

*Correspondence:

Inah Kim

Department of Occupational and Environmental Medicine, College of Medicine, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Korea.
E-mail: inahkim@hanyang.ac.kr

Copyright © 2019 Korean Society of Occupational & Environmental Medicine
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abbreviations

BUN: blood urea nitrogen; CT: computed tomography; ESR: erythrocyte sedimentation rate; HbA1c: hemoglobin A1c; Hct: hematocrit; IDLH: Immediately Dangerous to Life and Health; MRI: magnetic resonance imaging; MSDS: Material Safety Data Sheet; RBC: red blood cell; STEL: short-term exposure limit; TWA: time-weighted average; WBC: white blood cell.

Competing interests

The authors declare that they have no competing interests.

Authors contributions

Conceptualization: Kim I; Data curation: Lee S, Kim I, Lee SG; Investigation: Lee S, Kim I;

ABSTRACT

Background: In the construction industry, maintaining health and safety of workers often challenging. Among the workers at construction sites, painters are at particular risk of respiratory diseases and neurotoxicity. However, in Korea there is weak enforcement of workers' health and safety practices in the construction industry in Korea. Poisonings frequently occur at (semi)closed construction sites. In this study, we report a case of acute organic solvent poisoning during construction site painting.

Case presentation: A 71-year-old man was found unconscious at a construction site and immediately transferred to the emergency room. The consciousness level was 'stupor state' and the body temperature was hypothermic, at 32 degrees (Celsius). There were no acute brain or cardiac lesions that would have accounted for the faintness. In addition, blood and urine tests did not indicate a cause of loss of consciousness. He had been painting epoxy to waterproof the basement floor before fainting. According to exposure simulation, the patient was overexposed to various organic solvents, such as approximately 316–624 ppm toluene during the work before fainting. Considering the ventilation status of the workplace and the status of no protection, it is considered that exposure through the respiratory tract was considerable.

Conclusions: The patient in this case lost consciousness during the epoxy coating in a semi-enclosed space. It can be judged as a result of acute poisoning caused by organic solvent exposure and considered to be highly related to work environment.

Keywords: Occupational diseases; Organic solvent; Poisoning; Construction industry; Epoxy

BACKGROUND

Health and safety of workers are often a problem in the construction industry, in which workers perform a wide variety of tasks, each with different risks [1]. The majority of the exposure to risks arises from inappropriate information, measurement techniques, and personal protective equipment [2]. There is little enforcement of workers' health and safety practices in the construction industry in Korea such as working environment measurement, special health examination, occupational safety and health education, and protective equipment payment obligation.

Validation: Park D, Song J; Writing - original
draft: Lee S, Kim I; Writing - review & editing:
Lee S, Lee SG

Among the workers at the construction site, painters are at particular risk of respiratory diseases [3] and neurotoxicity [4]. Moreover, in Korea, there are no statistics on organic solvent poisoning among construction site painters, though poisonings frequently occur at (semi)closed construction sites [5]. Painters can be exposed to various chemicals such as pigments, extenders, binders, solvents, additives, crystalline glass silicate, and asbestos. Organic solvents such as benzene in hydrocarbons that painters can be exposed are known to be involved in the development of cancer, and there is also the possibility of skin diseases, acute or chronic central nervous system poisoning, cardiovascular or renal damage, blood diseases, and reproductive toxicity [6]. It is known that the organic solvents have central nervous system toxicity because they easily dissolve in the adipose tissue of the central nervous system, though the exact mechanism is unknown [7]. Almost all lipid-soluble organic solvents have nonspecific central nervous system depression or anesthetic action [8].

The central nervous system depression symptoms due to organic solvent acute poisoning are similar to those of alcohol drinking. Anesthetic symptoms appear after symptoms such as headache, dizziness, nausea, vomiting, decreased motor function, sensory abnormality, salivation, and tachycardia [9]. Long-term exposure to high concentrations of organic solvents may lead to loss of consciousness and paralysis, and death due to respiratory depression [7]. Over time, as the concentration of organic solvents dissolved in the central nervous system lowers, the symptoms disappear. Usually, the symptoms disappear from a few minutes to a few hours after the exposure ends, and they rarely continue longer than 24 hours. Acute central nervous system toxicity by these organic solvents does not require any treatment, and preventing further exposure is sufficient for recovery [6].

We encountered a patient who fainted during construction site painting. We will explain the case below and see if this is due to organic solvent exposure. This will help to diagnose and judge occupational diseases in future cases.

CASE PRESENTATION

Patient information

Seventy-one-year-old man.

Chief complaint

Mental change.

Present illness

The patient was found unconscious at 23:00 on May 22, 2016, and immediately transferred to the emergency room. When found, the patient was in a prone position, had dribbled a lot of spit, and appeared to have vomited. At the time of admission to the emergency room, he had a smell of paint on his breath, the consciousness level was 'stupor state,' and the body temperature was hypothermic, at 32°C. There were also 3 broken teeth. At the visit to the emergency room, the oxygen saturation was 97%, respiratory rate was 30 /min, blood pressure was 90/60 mmHg, and pulse rate was 60 /min.

Medical records of the emergency and neurology departments revealed present illness, test results, diagnosis, and treatment and progress.

Laboratory findings

The results of the blood tests performed when arriving at the hospital, are as follows.

White blood cell (WBC) count increased ($11.2 \times 10^3/\mu\text{L}$), on differential count: neutrophil increased (80.4%), lymphocyte decreased (14.3%), eosinophil was within normal range (0%), basophil was within normal range (0.8%), red blood cell (RBC) count decreased ($3.66 \times 10^6/\mu\text{L}$), hemoglobin decreased (11.6 g/dL), hematocrit (Hct) decreased (35.7%), and platelet count was within normal range ($144 \times 10^3/\mu\text{L}$).

Fast blood glucose increased (258 mg/dL). Hemoglobin A1c (HbA1c) increased (7.2%).

Erythrocyte sedimentation rate (ESR) increased (41 mm/hr) and C-reactive protein was within normal range (0.21 mg/dL).

Cardiac markers (CK-MB, 2.65 ng/mL; Troponin I, 0.005 ng/mL) were normal. Coagulation profiles, blood urea nitrogen (BUN), creatinine, total protein, albumin, electrolytes, ionized calcium, and magnesium were normal.

On urinalysis, glucose increased (2+), protein increased (1+), and ketone increased (1+).

Radiologic findings

Brain computed tomography (CT) findings were old infarction sequelae (left basal ganglia) and mild chronic ischemic change (both periventricular white matter).

On brain, head and neck diffusion magnetic resonance imaging (MRI), there were old infarction sequelae (left basal ganglia and both thalamus) and chronic ischemic change (both periventricular white matter), but no evidence of diffusion restriction or acute lesion.

On transthoracic echocardiography, there was mild aortic stenosis with aortic regurgitation, and ejection fraction was normal, 74%. The Holter monitoring findings were non-specific.

On chest X-ray, there were subsegmental atelectasis in both lower lobes, diffuse bronchial wall thickening in both lower lobes, and hypertensive heart. Abdomen X-ray findings were nonremarkable.

Past medical history

The patient had undergone right nephrectomy with kidney cancer and had type-2 diabetes mellitus with end-stage renal disease. There was also a history of coronary artery disease and stent implantation.

Social history

Smoking 12 pack-years, no alcohol drinking.

Clinical course

After conservative treatment, applying of warm blanket, and fluid injection, the patient recovered gradually without any special treatment after about 8 hours. At about 7:00 on May 23, the day after admission, the state of consciousness and cognitive function had recovered to normal.

Evaluation of the cause of faintness

No one had witnessed the patient's faintness, and he had some underlying diseases, so it was necessary to judge the cause of the loss of consciousness. The likeliest reasons for faintness in this patient include toxic encephalopathy, asphyxia, hypothermia, stroke, epilepsy, cardiac syncope, and complications of underlying diabetes or kidney disease. Based on the test results and patient's clinical course, the causes were evaluated.

The organic solvent intoxication and asphyxia were judged in the following 'Work-relevance evaluation.' Other possibilities are evaluated here.

At first, the average temperature of the day the patient fainted was 24.7°C, which is not low enough to cause hypothermia. Furthermore, the patient also had already appeared abnormal on the telephone at around 16:00, and he has not fallen after the temperature dropped at night. Thus, the faintness was not because of hypothermia, which presumably developed after faintness.

There were no acute lesions on brain CT and MRI images to discriminate brain damage such as cerebrovascular disease and brain infection. There was chronic multiple stenosis but it was also possible to rule out loss of consciousness due to brain disease. Epilepsy can be ruled out because he had no history of seizure, brain lesion nor other special causes or test results of seizure.

Cardiac markers on blood, chest X-ray, cardiac sonography, and Holter monitoring for cardiac disease did not reveal any abnormality that could lead to loss of consciousness such as cardiac arrest, aortic dissection, or aneurysm rupture and pulmonary embolism.

Blood fasting glucose was 258 mg/dL at the time of admission, electrolytes were normal and patient recovered without glucose or insulin injection. Therefore, syncope due to hypoglycemia or diabetic ketoacidosis was also excluded.

In addition, there were no specific findings that could account for loss of consciousness in the urine test, except mildly elevated glucose, ketone and protein level due to diabetes and chronic renal failure. By the urine tests we could exclude diseases such as severe hemorrhage, liver diseases and uremia.

Increased neutrophil counts on the test results are due to neutrophilia, infection, injury, inflammation, and some medications. However, with the mild increase in ESR and rapid normalization of WBC count (after 24 hours of hospitalization), elevation of WBC count was the result of a temporary inflammatory response.

In conclusion, the above factors do not appear to be the cause of loss of consciousness in this patient. The final diagnosis in the neurology department was toxic encephalopathy due to paint inhalation and hypothermia.

Occupational history

The patient had worked as a painter for decades and at the time of the accident, he was working at the new construction site as a daily and temporary employee for a construction company. The company had taken out industrial accident compensation insurance.

Since April 1, 2016, he had done floor waterproofing, painting and cleaning work on the new building construction site. On May 22, 2016, an epoxy coating was applied to waterproof the basement floor. On the morning of the day, he completed the epoxy work first, ate lunch at 12:00, and restarted working around 13:00. The colleague who worked with him left the workplace early, so in the afternoon, he was alone at the work site. When the patient's son called the patient at about 16:00, the patient could not communicate correctly as if he was drunk (according to a statement of the patient's son). The patient reported no memory after starting the painting at 13:00.

Work-relevance evaluation

The workplace was a building construction site, and the working environment measurement could not be accomplished because the work was already completed at the time of the survey. Instead, descriptions from the patient and the company, information about occupational history, work contents and environment, business start-up declarations, and Material Safety Data Sheet (MSDS) of hazardous substances were collected. In addition, we estimated the exposure level of hazardous substances during the work based on the workspace environment and the products used during the work, and evaluated the work-relatedness. Especially, we examined the possibility of organic solvent acute poisoning and asphyxia.

Workplace environment

The work space was an approximately 66 m² and 6m high underground space so the volume of the space was 396 m³.

The sliding window (2 × 1 m) was open at a height of 2 m or more, and the opening area was 1–2 m², and the underground door was open. The ventilator did not work, and the patient did not wear respiratory protection equipment. It was assumed that the air escaped through the window at 0.25 m/s. The maximum airflow rate is 0.25 m/s when natural ventilation is performed when there are no special mechanical conditions, temperature gradients, nor ambient airflow. The minimum ventilation volume will have been close to zero and the maximum is estimated as follows. The minimal ventilation capacity (window) = 1 m² × 0.25 m/s × 60 s/min = 15 m³/min and the maximum ventilation capacity (window) = 2 m² × 0.25 m/s × 60 s/min = 30 m³/min. However, when air flows through the basement door and exits through the window, it must go through the shortest path, not the entire underground space, so mixing factor (K) should be considered. We do not know the exact positions of the basement door and window, but it is estimated that the K value is usually about 2 in the case of the basement. Therefore, the actual (effective) ventilation volume, Q', is calculated as follows: Q' = Q/K. Therefore, the minimal Q' = (15 m³/min)/2 = 7.5 m³/min and the maximum Q' = (30 m³/min)/2 = 15 m³/min.

Organic solvent exposure assessment

'A' is a paint product that had been used by the injured worker. The total amount of use on that day for the basement painting was 54 L. Various organic solvents were identified on the MSDS of 'A.' The total organic solvent content in the paint is 60% to 70%. Thus, the organic solvent content is calculated to be 65%. There are 8 main organic solvents (Toluene 18%, Phenol, 4-dodecyl-, branched 9%, Xylene 9%, 2-Propanol 9%, Ethylbenzene 9%, Isobutanol 9%, Solvent naphtha (petroleum), light arom 0.9%, Stoddard solvent 0.9%).

Immediately after coating, more than 90% of the organic solvent evaporates within 30 minutes in case of 'Touch Dry' of Epoxy at 25°C (The average temperature of that day was

24.7°C). Based on the amount of paint used and the percentage of toluene in the paint 'A,' total gas generation is 7.487 m³ and Toluene (2.272 m³), 2-Propanol (1.551 m³), and Isobutanol (1.283 m³) are the most abundant gases produced. Calculated that the patient worked for 8 hours (480 minutes), gas generation rate per minute is 0.004733 m³/min for toluene, 0.003232 m³/min for 2-Propanol, and 0.002670 m³/min for Isobutanol.

The concentrations of organic solvents in the air during the working hours were estimated according to the amount of ventilation, the minimal and maximal ventilations. As the coating progressed over time, the amount of gas generated would increase, but it is assumed that the gas was uniformly generated because the drying of the epoxy paint progresses relatively rapidly. There is no significant difference in the concentration estimation because there is no change in the total amount. During the operation, the hourly concentration can be calculated by the following formula:

$$C = \frac{G \left\{ 1 - e^{\left(\frac{Q'}{V_{Total\ Air}} \Delta t \right)} \right\}}{Q'}$$

$$Q' = 7.5 \text{ m}^3/\text{min} \text{ or } 15 \text{ m}^3/\text{min}. \quad V = 396 \text{ m}^3 \quad (G: \text{ gas generation rate per minute})$$

Based on this, it is estimated that the concentration of toluene in the air was approximately 316–624 ppm when the patient restarted to work after lunch. It would exceed 'Immediately Dangerous to Life and Health (IDLH)' criteria of toluene, 500 ppm, which comes with a recommendation of getting out of the workplace immediately, as it would have a life- or health-critical impact immediately upon exposure. Considering exposure to multiple organic solvents, the patient would have already been exposed in excess of IDLH standards at around 9:30. Therefore, it is judged that there had been organic solvent poisoning. Organic solvents are also well absorbed into the skin, and skin exposure was possible because of lack of proper protection. However, exposure to the respiratory tract was sufficient to suspect poisoning, since the concentration in the air was extremely high and no respiratory protection was worn.

Possibility of oxygen deficiency assessment

It is also necessary to examine the possibility of health effects due to oxygen deficiency since the work was done in a confined space or semi-enclosed space. Oxygen concentration criteria is below 16% for certain symptoms, and 10% for coma or death.

1) Estimation of oxygen concentration (assuming the worst-case scenario)

When all the work was done by the operator—that is, the organic solvent (65% of content) contained in 54 L of the epoxy resin used for painting was completely evaporated and no ventilation had been carried out and all the gases were in the basement—the estimation of oxygen concentration is as follows:

$$C = \text{Part/Total} = \text{Gas Volume of Contaminant/Total Air Volume}$$

$$\therefore C = 7.487 \text{ m}^3/396 \text{ m}^3 \approx 1.89\%$$

Therefore, the concentration of underground indoor gases cannot theoretically exceed 1.89% or 18,900 ppm. The air constituents are constantly reduced by the concentration due to organic solvent contamination. For example, when the total organic solvent concentration is 1.89%, concentrations of nitrogen, oxygen, and argon decrease by about 1.89%. Therefore,

even when the entire organic solvents in the paint are evaporated and mixed into the basement, the oxygen concentration is almost unchanged from 20.948% to 20.553%.

2) Consideration of partial oxygen deficiency

The molecular weights of organic solvents are high and organic solvents could spread on the basement floor, so it is possible that partial oxygen deficiency had occurred. The feasibility can be evaluated by calculating the height of the space where oxygen deficiency occurred.

Oxygen concentration should fall below 16% for symptoms such as confusion or unconsciousness due to lack of oxygen. The reduced oxygen concentration due to the organic solvent can be calculated as follows:

$$\text{O}_2 \text{ Concentration} = 20.948\% - (20.948\% \times X/100)$$

When O₂ Concentration is 16%,

$$\begin{aligned} X &= (20.948\% - \text{O}_2 \text{ Concentration})/20.948\% \times 100 \\ &= (20.948\% - 16\%)/20.948\% \times 100 = 23.6\% = 236,000 \text{ ppm} \end{aligned}$$

Therefore, if the oxygen concentration falls below 16%, the organic solvent concentration should be 23.6% or 236,000 ppm. In addition, since the total amount of organic solvent gas generated in the basement was 7.487 m³ as calculated above, the space volume is calculated as follows in order for the organic solvent concentration to be 23.6%.

$$\begin{aligned} \text{Total Air Volume} &= \text{Gas Volume of Contaminant}/C \\ &= (7.487\text{m}^3/23.6\%) \times 100 \approx 31.72 \text{ m}^3 \end{aligned}$$

Since the basement has a floor area of 66 m², the height should be 48.1cm for a space of 31.72 m³ (h = Volume/Area = 31.72 m³/66 m² ≈ 0.481 m = 48.1 cm).

That is, if all the organic solvents in the paint are evaporated and nothing comes up to the top and all the gases lie at 48.1 cm from the bottom, the oxygen concentration lower than this height is 16%. However, this is practically impossible for three reasons: 1) Evaporated organic solvent not spreading upward and spreading only on the floor cannot occur due to the natural diffusion caused by the kinetic energy of the gas. 2) The instantaneous concentration during continuous generation for 6 to 7 hours is only a few hundredths of the assumed concentration. Thus, the height of the space in which the oxygen concentration is less than 16% would be only 0.1 cm, or 1 mm, from the floor. 3) When the mixing air starts to go down, the difference in specific gravity is at least 10% in the enclosed space, and at least 20% in a typical semi-enclosed space such as a basement. The molecular weight of the standard air is 28.962, and that of mixed air containing 1.89% of organic solvent is 30.618. In addition, the specific gravity of the mixed air is 1.057 as shown below, and the specific gravity difference is only 5.7%. Thus, it is impossible for the air contaminants to float on the floor.

$$\begin{aligned} \text{SG (gas mixture)} &= \rho (\text{gas mixture})/\rho (\text{standard air}) \\ &= \{\text{mass (gas mixture)}/\text{volume (gas mixture)}\}/\{\text{mass (standard air)}/\text{volume (standard air)}\} \\ &= \{30.618 \text{ g}/24.45 \text{ L}\}/\{28.962 \text{ g}/24.45 \text{ L}\} = 1.057 \end{aligned}$$

In conclusion, it is unlikely that this patient has been affected by the low oxygen level in the air.

Taken together, the patient was overexposed to various organic solvents, such as approximately 500 ppm of toluene, as identified above during the work. Considering the ventilation status of the workplace and the status of no protection, it is considered that organic solvent exposure through the respiratory tract was considerable.

Ethics statement

This study was approved by the Institutional Review Board of Hanyang university (HYI-18-194-1). Written informed consent for publication of this case report was obtained from the patient.

DISCUSSION AND CONCLUSION

Floor surfaces of underground parking lots are mostly painted with epoxy resin. Epoxy resin coating is classified as high-exposure work due to the unventilated nature of underground space and high exposure to organic compounds due to high content of solvents. The epoxy coating is conducted by applying a primer to improve adhesiveness first and then applying an epoxy resin mortar, a lining, a coating agent, and etc. The primer contains 60 to 70% solvents such as xylene, toluene, isobutyl alcohol, and ethylbenzene, and 30% to 40% resin. Epoxy resin coatings have very different contents of solvents depending on the manufacturer, such as 20% to 40% solvent and 60% to 80% resin [10]. Due to complex organic solvents, which exceed the exposure limits, there is a high prevalence of central nervous system toxicity in paint workers [11]. In our case, the exposure to organic solvents far exceeded the exposure limits. The American Conference of Governmental Industrial Hygienist has set an exposure limit for toluene of 100 ppm as an 8-hour time-weighted average (TWA) and 150 ppm as a 15-minute short-term exposure limit (STEL); the National Institute for Occupational Safety and Health recommends a 100-ppm 8-hour TWA and a 10-minute ceiling of 200 ppm for toluene. In this case, air concentration of toluene was estimated to have been 316 to 624 ppm already at the end of the morning shift. The STEL was exceeded even if only toluene exposure is considered. Reducing exposure to organic solvents in painters reduces hazardous effects [12]. Reducing the amount used or ventilating properly will reduce exposure.

In domestic asphyxiation and poisoning cases of the Korea Occupational Safety and Health Agency, there were cases of a death due to the acute poisoning of organic compounds such as toluene during coating work at the new construction site, a death due to suffocation or poisoning during primer painting in a manhole, and a death due to organic solvent vapor poisoning during the waterproofing work of a railway tunnel [13]. In these accidents, as in our case, no respiratory protection was given to workers, and no ventilation was provided. In addition, there was usually no MSDS, and the safety and health education for harmful substances was not carried out. If the obligation of basic protection, ventilation, and safety education is followed, it could reduce the accidents due to poisoning on construction sites [14]. Working alone in a dangerous workplace is also a risk factor as in our case, so it is also necessary to prohibit work alone. Those precautions would be applicable to other injuries and diseases.

In our case, the branch office of the Korea Workers' Compensation & Welfare Service regarded the cause of loss of consciousness might be other underlying diseases because the patient was found to have fallen by himself, and there was no 'working environment measurement data.' Thus, the case was not managed as an accident and went through a professional investigation of work-relatedness, which took considerable time. The patient in this case had to wait for a long period for an evaluation after the industrial accident. On May

22, 2016, the emergency and neurology department diagnosed acute toxic encephalopathy and the patient filed a petition to Korea Labor Welfare Corporation on June 3, 2016. Then, on June 27, 2016, Korea Labor Welfare Corporation asked to Institute of Occupational Safety and Health for epidemiological investigation to decide whether the illness was work-related. Finally, on March 31, 2017, the process of assessing work relevance was completed. The difficulty in assessing exposure to hazardous substances in the work environment may be an important factor for assessing work relatedness. There are lots of hazardous material exposures on construction sites by nature, but it is often the case that the work environment is not measured because the work is not continual. Although asphyxia or poisoning is common, studies on exposure to personal harmful substances are rare [15]. In our case, organic solvent exposure levels were estimated using logical formulas. In the case of short-term or one-time exposure, the existing methods such as 'Job exposure matrix' [16] cannot be selected. Therefore, we thought that formulas in our case could be useful for exposure assessment and evaluation of work-relatedness. If evaluating the work relevance of a worker's loss of consciousness using the epoxy formulation in a semi-enclosed construction site, then the emergency room records, the opinions of the physicians, and the progress of recovery should be reviewed. In addition, it should be assessed for the possibility of acute organic poisoning and be promptly handled as an accident.

The patient in this case lost consciousness during epoxy coating for waterproofing of the basement floor at the construction site. He could have been exposed to various organic solvents at the time of the epoxy work, and MSDS of the used epoxy includes substances that cause central nervous system poisoning. Furthermore, the patient underwent the epoxy painting without any protective equipment in an underground space where the ventilator did not work. There was no specific finding to cause acute brain lesion or syncope in the examinations. It could be judged as a result of acute poisoning due to organic solvent exposure. Therefore, the acute poisoning and hypothermia caused by loss of consciousness were considered to be highly related to work.

The significance of this study is to estimate the exposure levels in a working situation where it was not possible to measure directly, using workspace environment data and the type and amount of material used. Using this methodology, we will be able to reduce the time and effort needed to assess acute poisoning and contributing factors in the workplace in future incidents.

REFERENCES

1. López-Valcárcel A. Occupational safety and health in construction work. *Afr News Occup Health Saf* 2001;11(1):4-7.
2. Ringen K, Seegal J, England A. Safety and health in the construction industry. *Annu Rev Public Health* 1995;16:165-88.
CROSSREF
3. White MC, Baker EL. Measurements of respiratory illness among construction painters. *Br J Ind Med* 1988;45(8):523-31.
PUBMED
4. Fidler AT, Baker EL, Letz RE. Neurobehavioural effects of occupational exposure to organic solvents among construction painters. *Br J Ind Med* 1987;44(5):292-308.
PUBMED | CROSSREF
5. Korea Occupational Safety & Health Agency. National accident case: construction industry. 2019. <http://www.kosha.or.kr/kosha/data/construction.do?>. Accessed 17 May 2019.

6. Kim H. Occupational diseases in workers exposed to organic solvents. *Hanyang Med Rev* 2010;30(4):313-8.
[CROSSREF](#)
7. Ridgway P, Nixon TE, Leach JP. Occupational exposure to organic solvents and long-term nervous system damage detectable by brain imaging, neurophysiology or histopathology. *Food Chem Toxicol* 2003;41(2):153-87.
[PUBMED](#) | [CROSSREF](#)
8. Ikeda M. Public health problems of organic solvents. *Toxicol Lett* 1992;64-65:191-201.
[PUBMED](#) | [CROSSREF](#)
9. van Valen E, Wekking E, van der Laan G, Sprangers M, van Dijk F. The course of chronic solvent induced encephalopathy: a systematic review. *Neurotoxicology* 2009;30(6):1172-86.
[PUBMED](#) | [CROSSREF](#)
10. Choi JW, Mun JS, Kim JA, Won JI, Park HC. Health hazardous substances in construction work in Korea. *Korean Ind Hyg Assoc J* 2000;10(1):74-92.
11. Wolford R. Intervention research in construction: a hypothetical case study of painters. *Am J Ind Med* 1996;29(4):431-4.
[PUBMED](#) | [CROSSREF](#)
12. Kaukiainen A, Riala R, Martikainen R, Akila R, Reijula K, Sainio M. Solvent-related health effects among construction painters with decreasing exposure. *Am J Ind Med* 2004;46(6):627-36.
[PUBMED](#) | [CROSSREF](#)
13. Korea Occupational Safety Health Agency. Industrial accident cases. 2018. <http://english.kosha.or.kr/kosha/data/intoxication.do>. Accessed 23 May, 2018.
14. DiNardi S. *The occupational environment: its evaluation, control, and management*. 2nd ed. Falls Church: American Industrial Hygiene Association; 2003.
15. Park H, Park HD, Jang JK. Exposure characteristics of construction painters to organic solvents. *Saf Health Work* 2016;7(1):63-71.
[PUBMED](#) | [CROSSREF](#)
16. Wang SW, Qian H, Weisel C, Nwankwo C, Fiedler N. Development of solvent exposure index for construction painters. *J Occup Environ Hyg* 2011;8(6):375-86.
[PUBMED](#) | [CROSSREF](#)