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Original Article

Urinary level of 1,2-dichloroethane and its effects on blood biochemical markers among outdoor workers exposed to air pollution in Thailand

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Abstract

Air contamination by 1,2-dichloroethane (1,2-DCE) is recognized as a threat across countries. Addressing this problem is challenging due to the absence of clearly defined biological standards for monitoring 1,2-DCE exposure among humans. Moreover, studies on the impacts of 1,2-DCE exposure on human health are limited. The aim of this study was to determine the level of 1,2-DCE in urine—separated into the health behavior and occupation groups—as well as its effects on blood biochemicals among overall 200 outdoor workers, with 50 working in each of the following four occupations: fishers, street vendors, public bus drivers, and traffic police in an environmentally polluted community in Thailand. The subject's behaviors were categorized into four groups: desirable health behaviors (non-smokers and non-drinkers), non-smokers who consume alcohol, smokers who do not consume alcohol, and undesirable health behaviors (frequent smokers and alcohol consumers). Data were collected at the end of the workday using interview forms, urine, and blood samples. Urine was analyzed for 1,2-DCE, and blood was analyzed for complete blood count (CBC), liver, and kidney function enzymes. Data were analyzed using the Dunnett's test, Kruskal-Wallis H test, and independent sample t-test according to statistical conditions. Our findings revealed that the median urinary 1,2-DCE level was 0.080 mg/L (0.022–0.462 mg/L). Subjects with undesirable health behaviors had a significantly higher urinary 1,2-DCE level (0.108 mg/L) compared to those with desirable health behaviors (0.056 mg/L), with a *p*-value of 0.009. Among bus drivers and local fishers, the dose of exposure was strongly associated with creatinine levels (p=0.006). No significant association was observed between exposure dose and CBC across all groups. In conclusion, the urinary samples present a small variation in 1,2-DCE concentrations and thus can be used as a benchmark baseline value for monitoring exposure among outdoor workers in areas with intense air pollution. Kidney function markers can be considered in monitoring the health effects of 1,2-DCE.

Keywords: 1,2-dichloroethane, air pollution, blood biochemicals, outdoor workers

Introduction

Compound 1,2-dichloroethane (1,2-DCE), often referred to as ethylene chloride or ethylene dichloride, is a chlorinated hydrocarbon with a molecular formula of $C_2H_4Cl_2$ and a molecular

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weight of 98.96 g/mol [1]. In its normal state, 1,2-DCE appears as a clear liquid with a sweet odor and taste. About 95% of produced 1,2-DCE is used as an intermediate in the production of vinyl chloride [2]. It was formerly used as a solvent for processing pharmaceutical products, including fats, oils, waxes, gums, resins, rubbers, paints, varnishes, and finish removers [3]. In a previous investigation, high airway exposure to this chemical was found in individuals living near or working in factories where 1,2-DCE is used [4]. Air contamination by 1,2-DCE is an urgent matter as its potential carcinogenicity and genotoxicity have been recorded; though most studies used animal models, 1,2-DCE exposure, in the presence of key enzymes (including CYP450s and GSTs), leads to DNA adduct formation, gene mutations, and chromosomal aberrations [5]. The increase in cancer events has been linked to widespread toxic contaminants, including those in the air. One previous study investigated the mechanism of action for 1,2-DCE-induced mammary tumors in female mice [6].

In many countries, 1,2-DCE air contamination persists as a serious environmental problem [1-4,7]. Over the past 10 years, Japan has seen an increasing trend in 1,2-DCE air contamination, leading the government to classify it as a hazardous chemical requiring health-risk assessment [1,8]. In 2005, Thailand experienced elevated levels of volatile organic compounds (VOCs) in the air, surpassing the United States Environmental Protection Agency (EPA) quality standards [9,10]. The risk of 1,2-DCE exposure from air pollution varies with occupation, particularly affecting outdoor workers. Studies in Thailand found VOCs in blood samples from traffic police [11], public bus drivers [12], and street vendors [13]. However, none of the previously published studies have specifically analyzed 1,2-DCE exposure in hummers and its health effects, particularly among workers with high risk of exposure.

The Map Ta Phut Industrial Estate, located near the coastline, is home to a community of local fishermen who are at risk of exposure to VOCs because of their daily work activities [14]. This concern extends to other outdoor workers and the general public, who may also be exposed to 1,2-DCE. The primary route of 1,2-DCE exposure is through the inhalation of contaminated ambient air, with a lesser contribution from ingesting contaminated water [3]. Once inhaled, 1,2-DCE circulates in the bloodstream and is metabolized via two main pathways. The first involves microsomal oxidation, mediated by cytochrome P450 (CYP450), which converts 1,2-DCE to 2-chloroacetaldehyde and 2-chloroethanol, followed by conjugation with glutathione. The second pathway involves direct conjugation with glutathione to form S-(2-chloroethyl)-glutathione, which can be non-enzymatically converted to a glutathione episulfonium ion [15]. This biotransformation enables 1,2-DCE to dissolve in water and be excreted through the kidneys [3]. Thus, surveillance on 1,2-DCE exposure includes monitoring 1,2-DCE levels in urine and assessing its effects on the blood, liver, and kidneys.

Despite 1,2-DCE exposure being a persistent environmental problem, there is a significant research gap in evaluating biomarkers of such exposure given the absence of recommended biological standards for workers. While studies have been conducted on laboratory animals, human studies remain limited [2,15], particularly among high-risk workers, and there are no standard criteria for evaluating exposure in the body. Therefore, it is necessary to study the baseline values, particularly in Thailand, which can be used to monitor the exposure. It is important to note that confounding variables in the assessment of occupational exposure to 1,2-DCE should be treated with caution, especially personal factors (such as sex and age) and health behaviors [16]. Regarding health behaviors, smoking and drinking alcohol pose additional risks. Cigarettes contain many VOCs, including 1,2-DCE [17], and alcohol consumption can lead to liver inflammation [18], interfering with the liver's ability to metabolize and eliminate substances efficiently. This study is the first in Thailand to assess the biomarkers of 1,2-DCE exposure and evaluate its effects on the functions of the blood, liver, and kidneys. The aim of this study was to determine the urinary level of 1,2-DCE (separated by health behavior and occupation) as well as its effects on blood biochemicals among outdoor workers in an environmentally polluted community in Thailand.

Methods

Study population and design

The sample population comprised four groups of outdoor workers in the Map Ta Phut Pollution Control Area, Rayong Province, Thailand. The researchers have created a map showing where the data were collected (**Figure 1**). The research used the following formula with the program G*Power 3.1.9.7 [19] and set the effect size to 0.15, the α error value to 0.05, and the power 1-β value to 0.84. A total of 200 workers were included, with 50 working in each of the following occupations: fishers, street vendors, public bus drivers, and traffic police. For the sampling method, the researcher used the multi-stage random sampling method. The inclusion criteria were as follows: the participant must have been a worker in the Map Ta Phut area for at least six months, be over 18 years old, and be willing to participate in the research project voluntarily. The exclusion criteria were that the person was absent from work on the day the sample was collected or had an interview history of congenital diseases related to liver and kidney function. This study was conducted with the approval of the Burapha University Institutional Review Board for Protection of Human Subjects in Research (BUU-IRB) (Certificate No. HS 096/2023). Before the survey began, written informed consent was obtained from all the study participants.

Figure 1. Map Ta Phut polluted community of this study location.

Variables

The variables in this study were divided into three parts: (1) personal factors and health behaviors, including sex, age, alcohol consumption, smoking habits, resting points during work, and duration of residence in the Map Ta Phut pollution control area; (2) exposure to 1,2-DCE, assessed by urinary 1,2-DCE levels; and (3) effects on blood biochemistry, assessed by white blood cells (WBCs), red blood cells (RBCs), platelets (PLTs), alanine aminotransferase (ALT), aspartate aminotransferase (AST), blood urea nitrogen (BUN), and creatinine (Cr). The dose exposures were calculated by multiplying the number of years working in the Map Ta Phut pollution control area and the urinary 1,2-DCE level in mg/L-year.

Research tool and data collection

The interview form used in this study consisted of four items of demographic and health behavior information: sex, age, smoking habits, and alcohol consumption. The interview forms were collected after the researcher and team interviewed each participant. The interviews were conducted during breaks at appointed locations for each occupation that were conveniently accessible, such as a community hall, a public bus resting point, or a police station.

The quality of the interview form was tested through a consideration of validity regarding the content, structure, and objectives of the research. The experts included one university professor specializing in occupational health and two occupational medicine doctors. After quality testing, the researcher analyzed the Index of Item-Objective Congruence (IOC) values after adjustment. Each question had an IOC value between 0.67 and 1.00.

The equipment used to collect urine included plastic cups and a 50 mL polyethylene jar. The equipment and collection applied with organic solvents in the urine were in accordance with the No. 8305 method of the Centers for Disease Control and Prevention [20]. It was recommended that the participant collect mid-stream urine in a plastic cup and then pour at least 50 milligrams of the urine into a polyethylene jar. The participants had 10 minutes to collect their urine. The researcher obtained each urine sample, quickly packed it into a box with a temperature below 4°C, and transported it to the laboratory for 1,2-DCE analysis.

The materials used included cotton balls soaked in alcohol, gauze, rubber gloves, tourniquets, blood collection kits with size 22 needles, and 5- or 10-mL blood sample collection tubes coated with ethylenediaminetetraacetic acid (EDTA), anticoagulant, and heparin. Data collection took place at the same location as the interviews. Those responsible for drawing blood included medical technicians and nurses. Blood was drawn from a vein in the inner crook of the arm using an 8-mL vacuum collection tube. For complete blood count (CBC) analysis for WBCs, RBCs, and PLTs, the blood was placed in an EDTA tube. Meanwhile, samples designated for liver (such as ALT and AST) and kidney enzyme parameters (BUN and Cr) were collected in the anticoagulant tube. All the blood samples were immediately stored in a cooling box (4°C) before being transported to the laboratory. The biochemical analysis laboratory has passed the quality certification of the International Organization for Standardization (ISO) 15189: 2012 No. 4247/63 and the MOPH standard of the Thai Ministry of Public Health.

Health behavior groups

Health behaviors were assessed using a questionnaire-based survey that evaluated the sample group's behaviors over the past year. Based on the results, the subjects were categorized into four groups: (1) those with desirable health behaviors (non-smokers and non-drinkers), (2) non-smokers who consume alcohol, (3) smokers who do not consume alcohol, and (4) those with undesirable health behaviors (frequent smokers and alcohol consumers).

Laboratory analysis

For the urine samples, the urine containers were closed tightly, inverted, and shaken; 10 mL of the urine was then poured into the tube. Each tube was spun at a speed of approximately 1,800 rpm for 5 minutes. Urinary 1,2-DCE was determined using a C18 column. A mobile phase consisting of water/acetonitrile in a ratio of 50:50 by volume (50:50 v/v) was used with a flow rate of 1.0 mL/min at a temperature of 37.0°C, followed by ultraviolet detection at a wavelength of 254 nm and gas chromatography analysis (mg/L).

The blood sample was spun using a centrifuge at 3,000 rpm for 10 minutes. WBCs were analyzed with an automatic machine, followed by the flow cytometry method using a semi-conductor laser. The machine diluted the blood with stromatolyder-4DL solutions, sent it to the flow cell, and directed it to the sheath flow, where fluorescent light was used for detection. For the RBCs and PLTs, the principle hydrodynamic focusing method was used, where the blood sample was drawn into the machine, sent to the RBC/HGB sample chamber, and mixed with a cell pack solution to dilute and maintain the cells before being sent to the RBC/PLT detection channel for RBCs and PLT counts.

Liver function analysis included ALT and AST measurements using the Cobas Integra 400 Plus® (Roche Diagnostics Intl., Ltd., Rotkreuz, Switzerland) via the spectrophotometric technique by coupling the transamination reaction to the oxidation-reduction reaction at

nicotinamide adenine dinucleotide (NAD), instrument, and Westgard standard (unit expressed in U/L). For kidney function, BUN and serum Cr were determined using the enzymatic method principle via the EZCR Flex® reagent cartridge (Siemens Healthcare Diagnostics Inc., Malvern, USA) for analysis. The color substance that was produced in the final step of the reaction was used to measure the intensity of light that occurs at wavelengths of 540 and 700 nm (in mg/dL).

The following values were determined (for the normal range): WBC=4.0–6.0×10^3/µL; RBC, male=4.40–6.00×10^6/µL, female=4.20–5.50×10^6/µL; PLT=140–400×10^3/µL; AST, male=17–59 U/L, female=14–36 U/L; ALT, male=0–50 U/L, female=0–35 U/L; BUN, male=9–20 mg/dL, female=7–17 mg/dL; Cr, male=0.66–1.25 mg/dL, female=0.52–1.04 mg/dL.

Data analysis

The normality test for data distribution was carried out based on the Kolmogorov-Smirnov test and was displayed in a histogram. Urinary 1,2-DCE level was presented as the median (min-max). For normally distributed data, it was presented as the mean ± standard deviation (SD). Dunnett's test was performed to compare urinary 1,2-DCE levels and blood biochemicals based on health behavior. The Kruskal-Wallis H test was performed to compare urinary 1,2-DCE levels based on occupation. To compare the blood biochemicals based on the 1,2-DCE exposure dose, the independent sample t-test was utilized. Statistical significance was determined at $p<0.05$. The dose exposure was calculated by multiplying the number of years the subjects worked in the Map Ta Phut pollution area by the amount of 1,2-DCE in urine (mg/L-year). This study's cutoff point from the second calculated quartile (Q2) of dose exposure was 0.82. In terms of 1,2-DCE exposure, the doses were classified into two groups: ≤0.82 and >0.82 mg/L-year.

Results

Level of 1,2-DCE in urine

The results of 1,2-DCE in urine (n=200) showed a non-normal distribution curve (**Figure 2**). The central tendency statistic showed an appropriate value, with a median equal to 0.080 mg/L; for dispersion, the min-max was less than 0.022–0.462 mg/L.

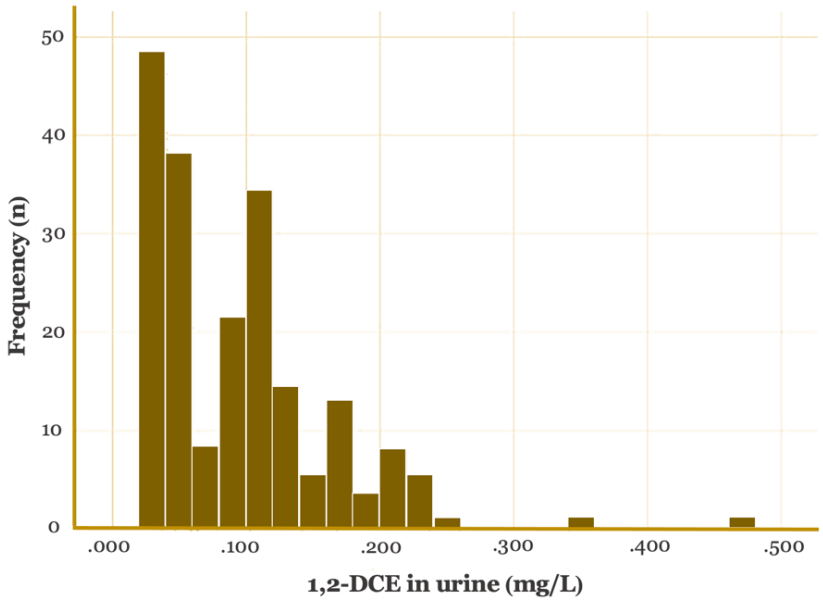

Figure 2. Histogram of 1,2-DCE in urine illustrating a non-normal distribution curve.

Associations of urinary 1,2-DCE with sex and health behavior

The results of comparing 1,2-DCE levels in urine revealed significant differences between males and females ($p<0.05$). Males and females had median values of 0.097 and 0.045 mg/L, respectively. Those who drank alcohol and those who did not had 1,2-DCE levels in urine that were significantly different ($p<0.05$), with median values of 0.097 and 0.056 mg/L, respectively.

However, no significant differences in 1,2-DCE levels in urine were found for the factors of age or smoking habits.

Association of urinary 1,2-DCE with health behavior

The associations between urinary 1,2-DCE levels and health behaviors are presented in **Table 1**. The urinary 1,2-DCE values for all samples (n=200) were divided into the following groups: (1) desirable, (2) nonsmoking and drinking, (3) smoking and nondrinking, and (4) undesirable, with significantly different median values of 0.056, 0.085, 0.114, and 0.108 mg/L, respectively (p=0.009) (**Table 1**).

Table 1. Values of 1,2-DCE in urine separated by health behavior (n=200)

Group	n (%)	1,2-DCE, median (min-max) (mg/L)	F-test	p-value
Male (<35 years)				
Desirable	5 (13.5)	0.080 (0.041–0.184)	0.218	0.883
Nonsmoking and drinking	19 (51.4)	0.080 (0.023–0.172)		
Smoking and nondrinking	3 (8.1)	0.087 (0.045–0.161)		
Undesirable	10 (27.0)	0.097 (0.022–0.219)		
Male (≥35 years)				
Desirable	26 (27.4)	0.085 (0.022–0.462)	2.194	0.094
Nonsmoking and drinking	45 (47.4)	0.103 (0.022–0.230)		
Smoking and nondrinking	9 (9.4)	0.172 (0.172–0.246)		
Undesirable	15 (15.8)	0.114 (0.114–0.184)		
Male (all ages)				
Desirable	31 (23.5)	0.080 (0.022–0.462)	1.660	0.179
Nonsmoking and drinking	64 (48.5)	0.097 (0.022–0.230)		
Smoking and nondrinking	12 (9.1)	0.161 (0.033–0.346)		
Undesirable	25 (18.9)	0.103 (0.022–0.219)		
Female (<35 years)				
Desirable	9 (81.8)	0.033 (0.022–0.103)	1.463	0.287
Nonsmoking and drinking	0 (0.0)	Not applicable		
Smoking and nondrinking	1 (9.1)	0.103 (not applicable)		
Undesirable	1 (9.1)	0.114 (not applicable)		
Female (≥35 years)				
Desirable	43 (75.5)	0.045 (0.022–0.242)	1.287	0.289
Nonsmoking and drinking	8 (14.0)	0.032 (0.022–0.149)		
Smoking and nondrinking	2 (3.5)	0.097 (0.080–0.114)		
Undesirable	4 (7.0)	0.083 (0.033–0.219)		
Female (all ages)				
Desirable	52 (76.5)	0.045 (0.022–0.242)	1.899	0.139
Nonsmoking and drinking	8 (11.8)	0.032 (0.022–0.149)		
Smoking and nondrinking	3 (4.4)	0.103 (0.080–0.114)		
Undesirable	5 (7.3)	0.114 (0.033–0.219)		
Overall (all sexes and ages)				
Desirable	83 (41.5)	0.056 (0.022–0.462)	3.974	0.009*
Nonsmoking and drinking	72 (36.0)	0.085 (0.022–0.230)		
Smoking and nondrinking	15 (7.5)	0.114 (0.033–0.346)		
Undesirable	30 (15.0)	0.108 (0.022–0.219)		

1,2-DCE: 1,2-dichloroethane
Analyzed using Dunnett's test for equal variances not assumed; * Statistically significant at p<0.05

Association of urinary 1,2-DCE with factors related to occupation

The results of the association between 1,2-DCE levels in urine and occupations were significantly different (p<0.05). Local fishers had the highest median value of 1,2-DCE in urine, equal to 0.114 mg/L, followed by public bus drivers and traffic police vendors, equal to 0.103 mg/L and 0.097 mg/L, respectively. Street vendors had the lowest median value of 1,2-DCE in urine, equal to 0.032 mg/L.

1,2-DCE in urine separated by occupation

The results show that occupation (local fishers, street vendors, public bus drivers, and traffic police), years of working in the Map Ta Phut Industrial Estate (≤10 years vs >10 years), and working hours per week (≤48 hours vs >48 hours) may be variables that significantly affect 1,2-DCE in urine; they were classified into 20 groups. They also show relatively similar levels of 1,2-DCE in urine (**Table 2**).

Table 2. Values of 1,2-DCE in urine separated by occupation (n=200)

Occupations and working years	≤48 hours		>48 hours		Z-test	*p*-value
	n (%)	1,2-DCE, median (min-max) (mg/L)	n (%)	1,2-DCE, median (min-max) (mg/L)		
Local fishers (n=50)						
≤10 years	9 (36.0)	0.114 (0.041–0.184)	16 (64.0)	0.108 (0.041–0.184)	0.350	0.432
>10 years	9 (36.0)	0.103 (0.041–0.184)	16 (64.0)	0.143 (0.041–0.184)	-1.069	0.285
Street vendors (n=50)						
≤10 years	9 (47.4)	0.023 (0.022–0.111)	10 (52.6)	0.022 (0.022–0.045)	0.972	0.769
>10 years	9 (29.0)	0.061 (0.022–0.067)	22 (71.0)	0.033 (0.033–0.084)	0.108	0.914
Public bus drivers (n=50)						
≤10 years	9 (40.9)	0.114 (0.045–0.230)	13 (59.1)	0.068 (0.022–0.172)	0.264	0.792
>10 years	7 (25.0)	0.114 (0.056–0.172)	21 (75.0)	0.068 (0.033–0.462)	0.952	0.341
Traffic police (n=50)						
≤10 years	15 (62.5)	0.091 (0.045–0.161)	9 (37.5)	0.103 (0.045–0.207)	-0.797	0.426
>10 years	12 (46.1)	0.103 (0.056–0.184)	14 (53.9)	0.103 (0.045–0.184)	0.066	0.986
Overall (n=200)						
≤10 years	42 (46.7)	0.097 (0.022–0.097)	48 (53.3)	0.074 (0.022–0.091)	1.033	0.301
>10 years	37 (33.6)	0.091 (0.022–0.091)	73 (66.4)	0.068 (0.022–0.068)	0.295	0.824

1,2-DCE: 1,2-dichloroethane
Analyzed using the Mann-Whitney U test

Association of blood biochemical markers according to health behavior and occupation

Health behavior was tested according to four health status groups: desirable, nonsmoking and drinking, smoking and nondrinking, and undesirable. In pairwise comparisons, the desirable group was used as the reference group. The results of the study found that those who smoked and did not drink had WBC values that were significantly different from those of the desirable group (p=0.041). The nonsmoking and drinking group had significantly different values of RBC, PLT, and Cr compared to the desirable group with statistical significance (p=0.007).

The subjects working in four occupations (local fishers, street vendors, public bus drivers, and traffic police) were tested. In pairwise comparisons, traffic police were used as the reference group. The results of the study found that local fishers and street vendors had RBC and Cr values that were significantly different from those of the traffic police group (p=0.037) (**Table 3**).

Table 3. Levels of blood biochemical markers based on health behavior and occupation (n=200)

Variables	Complete blood counts					
	WBC (10^3/µL)	*p*-value	RBC (10^6/µL)	*p*-value	PLT (10^3/µL)	*p*-value
Health behavior						
Desirable (n=83)	7.34±1.94	Ref.	4.65±0.60	Ref.	259.05±83.59	Ref.
Nonsmoking and drinking (n=72)	6.87±1.53	0.248	5.00±0.56	0.002*	240.28±60.15	0.007*
Smoking and nondrinking (n=15)	8.36±1.89	0.012*	4.58±0.86	0.977	280.00±80.03	0.298
Undesirable (n=30)	7.10±7.21	0.880	4.88±0.42	0.207	256.03±73.32	0.996
Occupations						
Traffic police (n=50)	6.74±1.48	Ref.	5.05±0.46	Ref.	242.68±62.77	Ref.
Local fishers (n=50)	7.29±1.89	0.278	4.50±0.73	<0.001*	267.60±94.08	0.223
Street vendors (n=50)	7.42±2.00	0.137	4.80±0.58	0.040*	262.78±64.72	0.387
Public bus drivers (n=50)	7.40±1.69	0.155	4.87±0.65	0.329	240.58±70.11	0.998

PLT: platelet count; RBC: red blood cell count; WBC: white blood cell count
Analyzed using Dunnett's test for equal variances assumed; * Statistically significant at p<0.05

Table 3 (continued). Levels of blood biochemical markers based on health behavior and occupation (n=200)

Variables	Liver function test				Kidney function test			
	AST (U/L)	*p*-value	ALT (U/L)	*p*-value	BUN (mg/dL)	*p*-value	Cr (mg/dL)	*p*-value
Health behavior								
Desirable (n=83)	26.25±11.64	Ref.	31.05±19.79	Ref.	13.88±5.23	Ref.	0.80±0.23	Ref.

Variables	Liver function test				Kidney function test			
	AST (U/L)	*p*-value	ALT (U/L)	*p*-value	BUN (mg/dL)	*p*-value	Cr (mg/dL)	*p*-value
Nonsmoking and drinking (n=72)	28.04±12.46	0.812	39.42±28.61	0.202	13.63±3.32	0.973	0.89±0.19	0.017*
Smoking and nondrinking (n=15)	31.93±24.28	0.393	43.40±47.72	0.331	13.47±4.45	0.978	0.88±0.15	0.389
Undesirable (n=30)	31.63±18.83	0.214	40.33±39.02	0.340	12.83±3.03	0.561	0.80±0.15	1.000
Occupations								
Traffic police (n=50)	26.96±13.68	Ref.	38.96±35.12	Ref.	12.92±3.07	Ref.	0.93±0.15	Ref.
Local fishers (n=50)	31.26±17.21	0.301	31.30±17.66	0.408	14.12±5.07	0.356	0.82±0.21	0.004*
Street vendors (n=50)	23.36±7.85	0.443	30.74±28.00	0.351	13.18±4.02	0.981	0.77±0.14	<0.001*
Public bus drivers (n=50)	30.94±16.14	0.362	44.52±31.89	0.653	14.18±4.55	0.318	0.86±0.26	0.264

ALT: alanine aminotransferase; AST: aspartate aminotransferase; BUN: blood urea nitrogen; Cr: creatinine
Analyzed using Dunnett's test for equal variances assumed; * Statistically significant at p<0.05

Association of 1,2-DCE exposure with blood biochemical markers

Via the CBC, the study found that each occupation with different doses of 1,2-DCE exposure had no difference in terms of CBC parameters. According to the liver and kidney function tests, the association results found that subjects with different doses of 1,2-DCE exposure had statistically significant differences in kidney functions ($p<0.05$). When analyzing each occupation, it was found that the public bus driver group (with 1,2-DCE exposure >0.82 mg/L-year) had significant BUN and Cr levels ($p=0.02$ and 0.01, respectively). The local fisher group (with 1,2-DCE exposure >0.82 mg/L-year) had significant Cr levels ($p=0.04$). However, the effect was reversed in the public bus driver group (with 1,2-DCE exposure ≤0.82 mg/L-year), which had significantly higher ALT levels than the group with 1,2-DCE exposure >0.82 mg/L-year ($p=0.02$) (**Table 4**).

Table 4. Association of dose of 1,2-DCE exposure with blood biochemicals (n=200)

Occupation (n)	1,2-DCE exposure		t-test	*p*-value
	≤0.82 mg/L-year	>0.82 mg/L-year		
Local fishers (11 vs 36)				
WBC	8.02±2.80	7.09±1.53	1.065	0.309
RBC	4.71±0.82	4.44±0.71	1.057	0.296
PLT	266.73±68.00	267.85±100.98	-0.043	0.966
AST	29.45±19.83	31.77±16.65	-0.391	0.693
ALT	31.27±23.20	31.31±16.14	-0.006	0.995
BUN	12.91±4.39	14.46±5.25	-0.894	0.376
Cr	0.701±0.71	0.833±0.21	-2.064	0.041*
Street vendors (45 vs 5)				
WBC	7.44±2.02	7.35±1.75	0.177	0.860
RBC	4.80±0.54	4.78±0.95	0.068	0.967
PLT	262.04±65.45	269.42±64.23	-0.239	0.812
AST	23.38±8.28	23.20±1.09	0.048	0.962
ALT	31.51±9.39	23.80±6.14	0.580	0.565
BUN	13.00±4.10	14.80±3.11	-0.470	0.349
Cr	0.768±0.14	0.812±0.04	-0.658	0.177
Public bus drivers (15 vs 35)				
WBC	7.53±1.59	7.35±1.75	0.359	0.721
RBC	4.96±0.67	4.83±0.65	0.636	0.528
PLT	268.47±86.25	228.63±59.42	1.889	0.065
AST	39.67±25.12	27.20±8.23	2.652	0.079
ALT	65.33±46.48	35.60±17.40	3.315	0.020*
BUN	12.53±2.23	14.89±5.11	-1.705	0.028*
Cr	0.730±0.16	0.928±0.27	-2.590	0.013*
Traffic police (29 vs 21)				
WBC	6.69±1.69	6.80±1.16	-0.241	0.811
RBC	5.10±0.51	4.98±0.38	0.863	0.392
PLT	247.48±74.73	236.05±42.79	0.632	0.496
AST	25.55±11.73	28.90±16.09	-0.853	0.398

Occupation (n)	1,2-DCE exposure		t-test	*p*-value
	≤0.82 mg/L-year	>0.82 mg/L-year		
ALT	32.90±22.61	47.33±46.68	-1.451	0.153
BUN	13.24±3.17	12.48±2.96	0.908	0.391
Cr	0.939±0.15	0.923±0.15	0.345	0.732
Overall (100 vs 100)				
WBC	7.30±1.99	7.13±1.56	0.697	0.487
RBC	4.90±0.60	4.71±0.67	2.106	0.063
PLT	259.30±71.07	247.52±77.48	1.120	0.264
AST	27.12±15.16	29.14±13.70	0.280	0.324
ALT	36.96±32.13	35.80±26.25	0.075	0.780
BUN	12.99±3.61	14.21±4.75	-2.044	0.042*
Cr	0.804±0.17	0.884±0.22	-2.780	0.006*

1,2-DCE: 1,2-dichloroethane; ALT: alanine aminotransferase; AST: aspartate aminotransferase; BUN: blood urea nitrogen; Cr: creatinine; PLT: platelet count; RBC: red blood cell count; WBC: white blood cell count
Analyzed using independent sample t-test; * Statistically significant at $p<0.05$

Discussion

Males had higher levels of 1,2-DCE in their urine than females. Additionally, subjects who drank alcohol had more 1,2-DCE in their urine than those who did not drink. This proves that exposure to 1,2-DCE depends on personal factors and health behaviors. Previous research indicates that higher levels of 1,2-DCE can be found in subjects who smoke because cigarettes contain various chemicals [21], including 1,2-DCE [16]. As for why there are higher amounts of urinary 1,2-DCE in males than in females, the reasons may be twofold. In the first case, differences between sex and health behavior are often related—that is, there are reports that males have significantly more smoking and drinking habits than females [22], meaning that males may be more exposed to 1,2-DCE than females. The second case involves different types of work. The study found that males' workplaces are closer to the streets than those of females. Almost all drivers of public vehicles and traffic police officers are male; hence, a higher risk of exposure to 1,2-DCE for males than for females. Thus, urinary 1,2-DCE is a reliable reference, and close attention should be paid to considering reference values based on sex, smoking habits, and alcohol consumption.

The results of the study show that the median 1,2-DCE values in urine were between 0.022 and 0.462 mg/L; as such, the subject working groups have similar amounts of 1,2-DCE in their urine. For example, subjects who had worked in the area for less than 10 years and whose working hours were less than 48 hours per week (classified as the group with the smallest amount of working time) had a median value of 1,2-DCE in urine of 0.097 mg/L. Meanwhile, those who had been working in the area for more than 10 years and for more than 48 hours per week (classified as the group with the longest working hours) had a median value of 0.068 mg/L. The data indicates that the working hours in this area do not affect 1,2-DCE levels in urine. This may be due to exposure to 1,2-DCE occurring through several routes, such as eating contaminated food or drinking contaminated water. In Map Ta Phut, 1,2-DCE contamination in the air exceeds the standard [7,8], which may affect the surrounding environment. In addition, it was found that general lifestyles are exposed to 1,2-DCE; the compound is mostly used in the production of vinyl chloride, and 1,2-DCE was found in ambient air samples and in residential areas as well as in groundwater, surface water, and drinking water. Therefore, all occupational groups may be exposed to environmental contamination [5]. However, this information supports the establishment of standard values for urine in occupational groups, for which there are no reference values to recommend from any agency.

Moreover, this study found that urinary 1,2-DCE levels were higher among local fishers compared to the other groups. This may be due to fishers living together in a village. The fishing village is close to the edge of the industrial estate, and the living and working areas are the same. Therefore, it can be said that they may stay in that area all day (the distance is only 1.3 kilometers). Further, it was found that the street vendor group had the lowest urinary 1,2-DCE values, possibly because they work further away. Also, their working hours depend on the closing and opening times of the market, resulting in less exposure.

The comparison is based on dose exposure calculations that have been used in several studies [23,24]. This approximates historical and current exposure values. The results of the study showed that in each occupation with different dose exposures, CBC parameters were not

significantly different. This indicates that the dose of 1,2-DCE received has not been found to affect CBC. This is in line with a report by the Agency for Toxic Substances and Disease Registry (ATSDR), a compilation of studies that have discussed the toxicity of 1,2-DCE concluding that there is no indication of a relationship between 1,2-DCE and changes in the blood cells of animals. The report gives examples of experiments in rats, guinea pigs, rabbits, and dogs following intermittent exposure to 200–400 ppm for 32–35 weeks [2]. However, future studies in humans should be conducted to confirm this relationship, especially epidemiological research models to track results over the long term.

Dose exposure with liver and kidney function tests found that subjects with different dose exposures had significantly different levels of kidney function ($p<0.05$). It has been reported that the toxicity of 1,2-DCE on the kidneys and its molecular mechanism remains elusive. Excessive reactive oxygen species (ROS) generation may be the cause of the apoptosis effects induced by 1,2-DCE on the kidneys [25]. Thirteen-week studies were conducted to investigate potential differences in rat strain susceptibility to 1,2-DCE toxicity, with the results showing that kidney weights were significantly increased in dosed males and females [26]. Therefore, health screening of subjects exposed to 1,2-DCE should take kidney function testing as an important consideration.

However, the results of the study found the opposite effect. In the public bus driver group, those with dose exposure of ≤0.82 mg/L-year had higher AST levels than those with dose exposure of >0.82 mg/L-year. This may be due to confounding variables that affect liver function, such as taking muscle relaxants, as driving causes vibrations throughout the body. A previous study found that between 43.1% and 93.0% of people who drive public vehicles have musculoskeletal disorders [27]. In this group, the behavior of taking painkillers or muscle relaxants may be greater than those of the other groups. Anti-inflammatory painkillers have a greater effect on hepatitis [28]. Therefore, future studies should take care and control for variables arising from behavior and occupational contexts to clarify the effect on liver function.

This study represents a significant contribution by examining 1,2-DCE levels in urine, providing up-to-date data both for Thailand and on an international scale. Furthermore, the laboratory analyses were conducted in a standardized facility, ensuring the reliability and reproducibility of the results. The statistical analysis also strengthened the study by categorizing the participants into various groups to control for confounding variables. Nonetheless, several limitations should be recognized when interpreting the findings of our investigation. Urine and blood samples were collected after the participants completed their work shifts, which may introduce variability because of differing work conditions, such as activity levels, duration of exposure, and environmental factors in industrial areas. These variations suggest multiple potential sources of 1,2-DCE. This study was cross-sectional, meaning it measured exposure at a single point in time. Urinary concentrations of 1,2-DCE may fluctuate with daily air quality changes. Despite the adequate sample size of 200 participants providing sufficient statistical power, establishing a standard or reference value for 1,2-DCE exposure specific to the Thai population may require a larger sample size. Additionally, the COVID-19 pandemic may have impacted industrial processes, as reports indicate a global decrease in chemical usage during the outbreak [29]. To validate these findings, follow-up studies are recommended in the future.

Conclusion

The median of 1,2-DCE in the urinary samples of outdoor workers in industrial areas with high air pollution in Thailand was 0.080 mg/L. Our findings imply that careful consideration of sex and alcohol consumption should be given when analyzing urinary 1,2-DCE, as its concentration is greatly influenced by these factors. For the occupational groups, it was found that local fishers had the highest median of urinary 1,2-DCE concentration, while the street vendors had the lowest concentration. The analysis indicates that dose exposure did not significantly impact blood cell integrity but was associated with changes in kidney function enzymes. Therefore, it is recommended to use such parameters for health surveillance. Future research should include the analysis of 1,2-DCE metabolites than the compound alone.

Ethics approval

This study was approved by the Human Ethics Committee of Burapha University (No. HS 096/2023) and performed in accordance with the principles of the Declaration of Helsinki.

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Competing interests

All the authors declare that they have no known conflict of interest in relation to the publication of this work.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

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