Avens Publishing Group
J Toxins
April 2017 Volume 4, Issue 1

Open Access Research Article

Journal of Toxins

Do Diesel Exhaust Exposure and Smoking Affect Health of Employees at A Logistic Company in Western Australia?

Le Jian[1,2]* and Janis Jansz[1]

[1]*School of Public Health, Curtin University, Australia*
[2]*Department of Health, Government of Western Australia*

***Address for Correspondence**
Dr. Le Jian, Epidemiology Branch, Public Health Division, Department of Health, Level 3, C Block, 189 Royal Street, East Perth, Western Australia, 6004, Australia, Tel: +61 8 9222 4201; Fax: +61 8 9222 4055; E-mail: le.jian@health.wa.gov.au

Submission: 6 April, 2017
Accepted: 30 April, 2017
Published: 10 May, 2017

Keywords: Australia; Diesel exhaust; Health effects; Occupational exposure; Smoking

Abstract

Objective: This study aimed to introduce a semi-quantitative approach and assess historical occupational diesel exhaust exposure, tobacco smoking and related health effects in workers in Western Australia.

Materials and Methods: A cross-sectional occupational survey was conducted at an Australian logistics company with a total of 87 male voluntary participants.

Results: 53 employees were exposed to diesel exhaust in the workplace for between 2 and 41 years and their Cumulative Occupational Exposure Indexes (CEIs) were between 1.73 and 66.63. When CEI was used to classify the exposure groups, a collective cancer indicator "all cancers" appeared higher in long term exposure groups ($p<0.05$). Further examinations on smoking habit and Smoking Index (SI) revealed that long term heavy smoking can be a significant confounding factor for respiratory diseases and symptoms (e.g. cough, $p<0.05$). Moreover, respiratory ill health risk in ex-smoker should not be ignored.

Conclusions: This study has identified that a semi-quantitative approach may be useful in assessing long term exposure to diesel exhaust and tobacco smoking and their possible link with adverse health effects. It is necessary to conduct larger scale analytical studies to examine and confirm the findings from this initial study.

Introduction

Diesel exhaust has recently been classified as carcinogenic to humans by the International Agency for Research on Cancers [1]. Diesel exhaust is a complex mixture of up to hundreds of gaseous and particulate components formed from the complete and incomplete combustion of organic compounds in diesel fuel. Toxic gaseous components in traditional diesel exhaust include carbon monoxide, nitrogen oxides, sulfur oxides aldehydes, benzene, butadiene, low molecular weight Polycyclic Aromatic Hydrocarbons (PAHs) and nitro-PAHs [2,3]. Diesel particulate is composed of a carbon core and adsorbed organic compounds on its surface including high molecular PAHs and nitro-PAHs. Although advances in technology have resulted in a reduction in the amounts of toxic emissions, particles, nitrogen oxide, carbon monoxide and hydrocarbons still can be found from old engine emissions [3-5]. Hazardous level of diesel exhaust can be found in occupations in Australia ranging from mining to driving diesel-fuelled trucks, graders, cranes or forklifts [6,7]. Mechanics in Australia who repair diesel fuelled equipment are also exposed to diesel exhaust. Epidemiological studies often have a lack of information on quantitative exposure assessment data [8], or fail to adjust for confounding factors, such as smoking habit. The relatively long latency period of chronic diseases, such as cancers, owing to the lack of exposure measurements decades ago, make the diagnosis linking exposure with the disease extremely difficult. In addition, exposures can vary widely depending on individual work environments, fuel types and other conditions mentioned above. Currently, there is a lack of studies assessing the health effects of diesel exhaust in the Australian working populations. There are also very rare published studies which have focused on examining the health effects of cumulative exposure to both tobacco smoke and diesel exhaust [9-11]. In order to add to the research based body of knowledge about assessing the health effects of exposure to diesel exhaust, particularly by workers who also smoke tobacco, a cross-sectional study was conducted in Western Australia (WA).

Materials and Methods

Study design and participants

This study was designed to assess the patterns of occupational diesel exhaust exposure and smoking conditions and related spectra of chronic diseases, if any, in a working population in Western Australia. Study participants were recruited from a local logistics company. The inclusion criteria were defined to be male full time current employees who have worked for the organization for at least 2 years. The Safety Professional at the logistic company notified employees, at a tool box meeting, who met the inclusion criteria of the opportunity to participate in this study. All employees at this logistic company were given a brief information session and invited to participate in the study on a voluntary base. This study was approved by the Human Research Ethics Committee of Curtin University.

Questionnaire design

The occupational exposure and health survey questionnaire was developed based on the following resources: (1) OccIDEAS, a web-based application (http://www.occideas.org/) which provides an estimate of the risk that a worker has been exposed to for any particular potentially hazardous substances in his past and current jobs; (2) A standardized questionnaire used by Harvard School of Public Health in an occupational survey on diesel fume exposure and cardio respiratory ill health with minor modifications adopted from the American Thoracic Society Questionnaire [12]; (3) Components from a validated questionnaire developed by the first author and used in a cancer study which included questions on diet, smoking, alcohol drinking and occupational hazards exposure [13]. The questionnaire contains 29 main questions with further 94 components. It includes questions related to exposure to hazardous substances at workplaces and after work exposures, health status and medical history, family history, lifestyle factors (including smoking; drinking tea, coffee, beer and spirits; and eating habits for fresh vegetables and preserved foods), and other potential confounding factors (e.g. BMI and medication use). The test-retest agreement and reliability of the questionnaire were assessed. The variables assessed demonstrated the good validity and reliability of this questionnaire [14].

Exposure assessment

For exposure assessment, information on occupational history was recorded, including job titles, time worked and years employed in current and previous companies; shift work features; frequent work locations; types and conditions of engine and fuel use; workplace exposure to diesel fume and/or other confounding hazardous substances, and exposure control measures; information on proximity of housing to busy roads and outside of work exposures. All participants were first classified as "Exposure" and "Non-exposure" group according to the assessment of their job history and current employment titles. In order to estimate long term exposure conditions, personal diesel exhaust Cumulative Exposure Index (CEI) throughout employees' career was estimated from the information on the working hours per day (h), the days per week worked (day), and the number of years in the role (yr). The CEI was calculated based on the following equation:

$$CEI = (h) \times (day) \times (yr)/1920$$

where 1920 is a constant representing the reference working hours per year for a worker who works 8 hours a day for 5 days a week and 4 weeks a month for 12 months annually ($8 \times 5 \times 4 \times 12 = 1920$ h).

The employees were then divided into 3 groups based on the distribution of the tertiles of the variable CEI: 1. "non-exposure" group, which included all office based workers, and those occasionally exposure to diesel fuel during their work with CEI lower than 1.73; 2. "short term exposure" group with CEI between 1.73 to 5.85; and 3. "long term exposure" group with CEI higher than 5.85.

Health assessment

Health information, including current health conditions and medical history, with a focus on the diagnosed chronic diseases (including cancers) in respiratory and cardiovascular systems, were recorded. Common respiratory symptoms (cough, phlegm, shortness of breath etc.) and their correlation with workplace exposure were included. Information on medication use and family history of chronic diseases was also collected.

Smoking assessment

Cigarette smoking is an important unhealthy lifestyle factor, which may interact with many workplace hazardous substances such as diesel exhaust, PAHs and aromatic amines, and increase cancer risks [15-17]. To assess smoking habits, participants were classified as current, former (ex-smoker), and never smokers. A current regular smoker was defined as smoked a total of 20 or more packs of cigarettes during his lifetime or at least one cigarette a day or one cigar a week or 50 g of pipe tobacco a month for at least one year. The current smokers were asked when they started regular smoking, their daily average, and if they smoked at the workplace and/or at home. An ex-smoker was defined as a person who had stopped smoking for at least one year and was asked when he ceased smoking. In order to quantitatively assess lifetime smoking habit, a Smoke Index (SI) was introduced and was calculated as:

$$SI = \text{years of smoking} \times \text{average numbers of cigarette per day.}$$

Other possible confounding factors such as alcohol drinks, dietary intakes, general demographics, including self-reported height and weight, were also recorded.

Statistical analysis

All data was checked for completeness. Whenever possible, participants were contacted again, on a voluntary basis, to provide any missing information in their questionnaire answers. Collected data ware coded, categorized and analyzed using the PASW Statistics 18, Release Version 18.0.1 (SPSS Inc., Chicago IL, USA, http://www.spss.com). Respiratory symptoms and diseases, cardiovascular conditions or cancers were dichotomised as to their presence or not. To better assess health effect on targeted organs, some collective disease indicators were created which were the sum of total diseases reported located in the same organs and systems such as "all respiratory diseases", "all respiratory symptoms" and "all cardiovascular diseases". Based on if a cancer condition presented in multiple sites or there were more than one type of cancer, a category called "all cancers" also be created and categorised into 0, 1 (single site) or >1 (multiple sites). To assess the effect of long term and heavy smoking habit on cardio respiratory health, SI was divided into 0 (Non-smoker), SI<225 (Mild smoker) and SI>225(Heavy smoker) based on the tertiles of the variables' distributions. While continuous variables were described by median and ranges, percentages (%) were used for categorical variables. Pearson Chi-square test was used to compare variables between groups. A p value of less than 0.05 is considered as a statistical significance level.

Results

Demographic characteristics of participants in exposure and control groups

Table 1 presents the main results of the demographic data for participants in exposure and control group where exposure group includes all mechanics/fitters, crane/truck drivers and riggers and the control group includes officers. Significant differences between the two groups were found in educational levels, beer consumption, eating tomatoes and smoked food ($p<0.05$). For details refer to Table 1.

Occupational history and job characteristics in workers exposed to diesel exhaust

These workers had a wide range (from 2 to 41 yr) of working years. The CEI ranged from 1.73 to 66.63 with the medians at 4.06 in

ISSN: 2328-1723

Table 1: Demographic characteristics between control and exposure groups.

	Control (n=34)	Exposure (n=53)	Pearson Chi-Square (*p*)
Age (%)			
<40	41.4	43.6	0.039 (0.842)
≥40	58.6	56.4	
BMI (%)			
<25	25.8	26.4	1.907 (0.385)
<30	54.8	41.5	
>30	19.4	32.1	
Smoking ID (%)			
0	71.0	56.6	1.845 (0.397)
≤225	12.9	22.6	
>225	16.1	20.8	
Ever smoker (%)			
No	71.0	54.5	2.364 (0.307)
Yes	12.9	23.6	
Ex-smoker	16.1	21.8	
Live near busy road (%)			
No	88.9	64.0	1.975 (0.160)
Yes	11.1	36.0	
Medication (%)			
No	77.8	68.0	0.305 (0.581)
Yes	22.2	32.0	
Education (%)			
Secondary school	15.6	60.0	46.078 (**0.000**)
TAFE/College	12.5	36.4	
University	71.9	3.6	
Drink beer (%)			
No	45.2	19.6	6.081 (**0.014**)
Yes	54.8	80.4	
Drink spirit (%)			
No	65.5	48.9	1.994 (0.158)
Yes	34.5	51.5	
Tomato (%)			
No	7.1	31.4	5.602 (**0.018**)
Yes	92.9	68.6	
Smoked food (%)			
No	50.0	80.0	5.169 (**0.023**)
Yes	50.0	20.0	

the short term exposure group and 13.41 in the long term exposure group. The most common employment position was crane/truck drivers (54.7%) and the most common place they worked at was on construction sites (32.1%). Prior to their current job 80% of these employees reported that they had been exposed to diesel exhaust in their previous employment position.

During their current employment, the average age of the vehicles driven by exposure employees was 15 yr old with the range being between 2 to 27 yr. The number of kilometers driven per month varied between 20 and 18,000. The engine working hours per month varied from 5 to 240 hrs. Most of these employees (82.6%) filled the vehicle tank themselves. More than half (53.5%) of the vehicles were reported as generating black smoke indicating incomplete combustion of the diesel fuel for these vehicles. The most common risk control measure for minimising exposure to diesel particulates was the provision of adequate ventilation reported by 72.2% of exposed workers.

Comparison of health status of employees with diesel exhausts exposure

When comparisons were made between the exposure and control groups, the results showed that among all measured health outcomes only asthma was marginally increased in the exposure group employees with 6.3% in the control group and 21.8% in the exposure group (p=0.057). No statistical significant differences were found in other diseases or disease groups. There were also no differences in family members with cancers and other medical conditions between the two group participants.

Further examination on health status among four job specific groups (mechanics, drivers, riggers and officers) indicated that sick leave was the highest (27.3%) in mechanics and 7.7% in rigger group (p=0.001). But no significant differences were found in disease distributions between these job titles.

Comparisons were then made by using personal diesel exhaust CEI, to semi-quantitatively assess the correlations between workplace diesel exhaust exposure and related chronic health conditions. The results are displayed in Table 3. Interestingly, for the category of “all cancers”, which include lung cancer and cancers from other sites, there was an increasing trend with increased cumulative time exposure to diesel exhaust (p=0.040). Other ill health effects, such as respiratory symptoms/diseases and cardiovascular disorders, had no statistical difference with various levels of cumulative exposure. Although the ratio of asthma, respiratory diseases and symptoms as well as sick leave seemed to have the trend of increasing with cumulative increased exposure, these results did not reach statistical difference (p>0.05).

Comparison of health status with smoking exposure

Table 2: Occupational history and working conditions in exposure group.

	Median	Range
Working years	4	2-41
Age of vehicle	15	2-27
Driving KM/month	2,000	20-18,000
Engine working hours/month	160	5-240
Cumulative exposure index (CEI)		
Low (n=29)	4.06	1.73-5.85
High (n=27)	13.41	6.50-66.63
	%	n
Current role		
Mechanic/fitter	20.8	11
Crane /truck driver	54.7	29
Rigger	24.5	13
Frequent work place		
Construction site	32.1	17
Workshop	22.6	12
On road	22.6	12
Other	22.6	12
Previous exposure to diesel		
No	7.3	4
Yes	80.0	44
Not sure	10.9	6
Capacity of cranes		
≤ 25t	17.4	8
30-75t	52.2	24
≥ 80t	15.2	7
All types	15.2	7
Fill tank by self		
No	17.4	8
Yes	82.6	38
Colour of smoke from vehicle		
Black	53.5	23
Blue/white	46.5	20
Risk control measures		
No	20.4	11
Yes	72.2	39
Not sure	7.4	4

ISSN: 2328-1723

Table 3: Comparisons of health status between different cumulative exposure levels.

	Non exposure (%)	Short term exposure (CEI 1.73-5.85) (%)	Long term exposure (CEI>5.85) (%)	Pearson Chi-Square (p)
Asthma No Yes	93.5 6.5	79.3 20.7	77.8 22.2	3.339 (0.188)
Respiratory diseases No Yes	87.1 12.9	79.3 20.7	70.4 27.5	2.460 (0.292)
Cough No Yes	96.8 3.2	96.3 3.7	96.0 4.0	0.025 (0.988)
Short of breath No Yes	93.5 6.5	89.7 10.3	92.0 8.0	0.303 (0.859)
Respiratory symptoms No Yes	78.1 21.9	75.9 24.1	69.2 30.8	0.631 (0.729)
Angina No Yes	96.9 3.1	92.9 7.1	92.6 7.4	0.644 (0.725)
Arrhythmia No Yes	96.9 3.1	96.4 3.6	92.6 7.4	0.711 (0.701)
High blood pressure No Yes	96.9 3.1	89.3 10.7	92.6 7.4	1.355 (0.508)
All cardiovascular disorders No Yes	93.8 6.2	85.7 14.3	85.2 14.8	1.372 (0.504)
Lung cancer No Yes	100 0	100 0	96.3 3.7	2.248 (0.325)
All cancers 0 1 2	96.9 3.1 0	82.1 17.9 0	96.3 0 3.7	10.055 (**0.040**)
Family history of respiratory diseases No Yes	93.3 6.7	96.3 3.7	100 0	1.836 (0.399)
Family history of cardiovascular diseases No Yes	86.7 13.3	85.2 14.8	92.6 7.4	0.797 (0.671)
Family history of cancers No Yes	80.0 20.0	70.4 29.6	77.8 22.2	0.782 (0.676)
Sick leave No Yes	100 0	96.4 3.6	88.9 11.1	4.032 (0.133)

Apart from the result displayed in Table 1 that showed no statistical significant difference between the exposure and the control group in initial assessment of smoking habit and SI, additional assessments by using job title and CEI also showed no statistical significant difference in smokers distributed in different job groups (p>0.05) and CEI groups (p>0.05). To further assess if smoking exposure was a confounding factor for health outcomes, comparisons of smoking exposure and health status of all participants, regardless of their exposure conditions, were performed. The results are displayed in Table 4 and 5.

Table 4 shows that majority single and categorised health conditions were similar in participants with different smoking habits. However, one respiratory symptom, cough, was higher in smoking and ex-smoking group compared with non-smoking group (p=0.044). Some categorised diseases such as all cancers or family history of

Table 4: Health status and smoking habit.

	Non-smoker (%)	Smoker (%)	Ex-smoker (%)	Pearson Chi-Square (p)
Asthma No Yes	82.7 17.3	82.4 17.6	88.2 11.8	0.318 (0.853)
Respiratory diseases No Yes	82.7 17.3	70.6 29.4	70.6 29.4	1.750 (0.417)
Cough No Yes	100 0	93.8 6.2	86.7 13.3	6.225 (**0.044**)
Short of breath No Yes	92.3 7.7	100 0	78.6 21.4	4.521 (0.104)
Respiratory symptoms No Yes	80.8 19.2	64.7 35.3	64.7 35.3	2.786 (0.248)
Angina No Yes	94.2 5.8	100 0	88.2 11.8	2.149 (0.341)
Arrhythmia No Yes	94.2 5.8	100 0	94.1 5.9	1.034 (0.596)
High blood pressure No Yes	92.3 7.7	100 0	88.2 11.8	1.917 (0.384)
All cardiovascular disorders No Yes	86.5 13.5	100 0	82.4 17.6	3.006 (0.222)
Lung cancer No Yes	100 0	100 0	94.1 5.9	4.107 (0.128)
All cancers 0 1 2	88.5 11.5 0	100 0 0	94.1 0 5.9	8.179 (0.085)
Family history of respiratory diseases No Yes	96.2 3.8	94.1 5.9	100 0	0.831 (0.660)
Family history of cardiovascular diseases No Yes	84.6 15.4	94.1 5.9	93.3 6.7	1.581 (0.454)
Family history of cancers No Yes	84.6 15.4	64.7 35.3	60.0 40.0	5.438 (0.066)
Sick leave No Yes	98.0 2.0	94.1 5.9	87.5 12.5	3.042 (0.219)

ISSN: 2328-1723

cancers showed an increased trend, particularly in ex-smokers. But these changes did not reach statistical significant level (p=0.085 and 0.066, respectively).

Table 5 displays health assessment results using categorised cumulative smoking index. The results showed that heavy smokers had the highest rates of all respiratory diseases (p=0.013) and cough (p=0.008). While more heavy smokers reported having a family history of cancers (p=0.022) than mild and non-smoker groups, all cancers category showed a non-significant increase in the heavy smoking group (p=0.087).

Table 5: Cumulative smoking index and health effects.

	Non smoker (SI=0) (%)	Mild smoker (SI≤ 225) (%)	Heavy smoker (SI >225) (%)	Pearson Chi-Square (p)
Asthma				
No	82.7	93.8	75.0	2.065
Yes	17.3	6.2	25.0	(0.356)
Respiratory diseases				
No	82.7	87.5	50.0	8.628
Yes	17.3	12.5	50.0	(**0.013**)
Cough				
No	100	100	85.7	9.670
Yes	0	0	14.3	(**0.008**)
Short of breath				
No	92.3	100	78.6	4.521
Yes	7.7	0	24.1	(0.104)
Respiratory symptoms				
No	80.8	75.0	56.2	3.923
Yes	19.2	25.0	43.8	(0.141)
Angina				
No	94.2	100	87.5	2.241
Yes	5.8	0	12.5	(0.326)
Arrhythmia				
No	94.2	100	93.8	0.994
Yes	5.8	0	6.2	(0.608)
High blood pressure				
No	92.3	100	87.5	1.947
Yes	7.7	0	12.5	(0.378)
All cardiovascular disorders				
No	86.5	100	81.2	2.997
Yes	13.5	0	18.8	(0.223)
Lung cancer				
No	100	100	93.8	4.301
Yes	0	0	6.2	(0.116)
All cancers				
0	88.5	100	93.8	
1	11.5	0	0	8.129
2	0	0	6.2	(0.087)
Family history of respiratory diseases				
No	96.2	93.8	100	0.842
Yes	3.8	6.2	0	(0.656)
Family history of cardiovascular diseases				
No	84.6	100	92.9	3.218
Yes	15.4	0	7.1	(0.200)
Family history of cancers				
No	84.6	68.8	50.0	7.674
Yes	15.4	31.2	50.0	(**0.022**)
Sick leave				
No	98.0	93.3	87.5	3.042
Yes	2.0	6.7	12.5	(0.218)

Discussion

This research is the first study to use a semi-quantitative measurement to investigate the exposure patterns to diesel exhaust in a Western Australia logistic company, the distribution of chronic cardio-respiratory conditions presented in these employees in relation to cumulative diesel exhaust exposure and the influence of smoking habit on these health conditions.

Most epidemiological studies have inferred diesel exhaust exposure from job title in the absence of any information on quantitative assessment of diesel exhaust levels [18]. Some other resources (if available) that may help in estimation of past exposure also including past hygiene surveys, the company's records and historical carbon monoxide (CO) concentrations (to model and predict past element carbon exposure), which was used in a recent USA miners' study [19,20]. In this study, job titles were initially used and the cardio-respiratory health conditions in relation to job titles are presented in Table 3. Except for the proportion of sick leave, which was higher in mechanics (p=0.001) than other job roles, there were no statistical significant difference between different job groups and related health conditions.

In order to accurately assess workplace exposure to diesel exhaust, a cumulative exposure index, CEI, was introduced and used in this study, and categorised as non-exposure, low and long term exposure groups. The results presented in Table 3 showed that there were more employees in long term exposure group who reported having family members with all types of cancers (p=0.04). The results demonstrate that CEI is a better surrogate exposure indicator than job titles for assessing cumulative exposure to diesel exhaust and its value in semi-quantitative assessment of long term exposure related ill health effects is promising. With limited resources, the CEI is considered a better exposure index than job titles in this study. The CEI is especially useful when environmental diesel exhaust monitoring data was not available. However, we have to acknowledge that although the result achieved statistical significant level, the possibility that the significance resulted by random error cannot be fully excluded. Considering the design and the scope of this preliminary study, meaningful conclusion can only be achieved after reassessment in large scale analytical epidemiological studies. Because diesel exhaust exposure level varies significantly in chemical composition and particle size between different engine types (heavy duty vs. light duty), engine operating conditions (idle, accelerate, decelerate), fuel types (high/low sulfur fuels) and emission control systems, the variables assessed in Table 2 (type of engine and capacity, the colour of smoke from vehicles and risk control measures in the workplace, etc.) can provide additional useful information for assessing exposure conditions in the workplace [21].

Even though no statistical significant difference was found between exposure and control groups in smoking habit and SI (Table 1), more employees reported having cough in the ex-smoker group than did in the current smoking and non-smoking groups (p<0.05)

ISSN: 2328-1723

(Table 4). While using SI (Table 5), more heavy smoking workers reported having respiratory symptom, cough, all respiratory diseases and family members with cancers than did non-smokers and mild smokers, and the differences achieved statistically significant levels ($p<0.05$). These results indicated that semi-quantities measurement cumulative smoking exposure by using SI may be a better indicator for assessing smoking related health effects. In addition, ill-health respiratory effects in ex-smokers should not be ignored.

Apart from diesel exhaust exposure and smoking exposure, the research also identified some other characteristics which were different between the exposure and control groups including educational level and other lifestyle habits (drinking beer and eating tomato or smoked food). Those identified significant factors summarised in Table 1 suggest that more employees in the control group tend to consume healthy food such as tomato but drink less beer compared with the exposure group. Considering the likelihood of residual confounding effects from various social-economic status groups, such variables (educational levels and lifestyle factors) should be considered in planning epidemiological studies as potential confounding factors that may influent the outcomes.

Although cross-section study is considered the best to initiate a descriptive study in a place where the distribution of a concerned problem is unknown, the main limitation of a cross-sectional study is that it may not necessarily confirm causal relationship due to the nature of the study design. In addition, cases with ill health conditions may be underestimated because of ceased employment or changed jobs owing to diseases. As such, further case-control studies of a large scale are necessary to confirm the association of exposure to environmental hazards (diesel exhaust & smoking in particular) and ill health effects identified in this study.

Conclusion

Results from this study have provided first-hand information about the cardio-respiratory effects experienced by Australian employees who receive work-related diesel exhaust exposure. This research has demonstrated the promising application value of the questionnaire and related semi-quantitative assessments for cumulative diesel exhaust exposure and smoking exposure. The study identifies opportunities, by using semi-quantitative approach introduced in this initial study where historical air monitoring data were not available, for further large scale studies by health and safety professionals to build on the findings of this initial study. However, it is necessary to adjust for the confounding influence of smoking and other life style factors to allow accurate health effects assessment. In addition, ill health effects related to ex-smokers should be separately assessed. Future large scale studies are necessary to reassess and confirm the dose-response relationship between diesel exhaust exposure and related health effects.

References

1. IARC (2012) IARC: Diesel engine exhaust carcinogenic.
2. Wichmann HE (2007) Diesel exhaust particles. Inhal Toxicol 19: 241-244.
3. U.S. Environmental Protection Agency (2002) Health Assessment Document for Diesel Engine Exhaust. Washington, DC: the National Center for Environmental Assessment.
4. Hesterberg TW, Long CM, Bunn WB, Sax SN, Lapin CA, et al. (2009) Non-cancer health effects of diesel exhaust: a critical assessment of recent human and animal toxicological literature. Crit Rev Toxicol 39: 195-227.
5. Hesterberg TW, Bunn WB 3rd, Chase GR, Valberg PA, Slavin TJ, et al. (2006) A critical assessment of studies on the carcinogenic potential of diesel exhaust. Crit Rev Toxicol 36: 727-776.
6. Pronk A, Coble J, Stewart PA (2009) Occupational exposure to diesel engine exhaust: A literature review. J Expo Sci Environ Epidemiol 19: 443-457.
7. Dai YF, Zhang X, Zhang R, Zhao XZ, Duan HW, et al. (2016) Long-term exposure to diesel engine exhaust affects cytokine expression among occupational population. Toxicol Res 5: 674-681.
8. Larkin EK, Smith TJ, Stayner L, Rosner B, Speizer FE, et al. (2000) Diesel exhaust exposure and lung cancer: adjustment for the effect of smoking in a retrospective cohort study. Am J Ind Med 38: 399-409.
9. Tual S, Silverman DT, Koutros S, Blair A, Sandler DP, et al. (2016) Use of Dieselized Farm Equipment and Incident Lung Cancer: Findings from the Agricultural Health Study Cohort. Environ Health Perspect 124: 611-618.
10. Pintos J, Parent ME, Richardson L, Siemiatycki J (2012) Occupational exposure to diesel engine emissions and risk of lung cancer: evidence from two case-control studies in Montreal, Canada. Occup Environ Med 69: 787-792.
11. Pamphlett R, Rikard-Bell A (2013) Different occupations associated with amyotrophic lateral sclerosis: is diesel exhaust the link? PloS One 8: e80993.
12. NIOSH (2009) Diesel Exhaust.
13. Jian L, Binns CW, Lee AH (2006) Validity of a food-frequency questionnaire for elderly men in southeast China. Public Health Nutr 9: 928-933.
14. Jian L, Meyerkort P, Janisz J (2010) Reliability of a questionnaire assessing occupational exposure to diesel exhaust and health effects. The 42nd APACPH Conference.
15. Garshick E, Laden F, Hart JE, Smith TJ, Rosner B (2006) Smoking imputation and lung cancer in railroad workers exposed to diesel exhaust. Am J Ind Med 49: 709-718.
16. Kellen E, Zeegers M, Paulussen A, Vlietinck R, Vlem EV, et al. (2007) Does occupational exposure to PAHs, diesel and aromatic amines interact with smoking and metabolic genetic polymorphisms to increase the risk on bladder cancer?; The Belgian case control study on bladder cancer risk. Cancer Lett 245: 51-60.
17. Chang CH, Hsiao CF, Chang GC, Tsai YH, Chen YM, et al. (2009) Interactive effect of cigarette smoking with human 8-oxoguanine DNA N-glycosylase 1 (hOGG1) polymorphisms on the risk of lung cancer: a case-control study in Taiwan. Am J Epidemiol 170: 695-702.
18. Silverman DT, Samanic CM, Lubin JH, Blair AE, Stewart PA, et al. (2012) The Diesel Exhaust in Miners study: a nested case-control study of lung cancer and diesel exhaust. J Natl Cancer Inst 104: 855-868.
19. Attfield MD, Schleiff PL, Lubin JH, Blair A, Stewart PA, et al. (2012) The diesel exhaust in miners study: a cohort mortality study with emphasis on lung cancer. J Natl Cancer Inst 104: 869-883.
20. Stewart PA, Vermeulen R, Coble JB, Blair A, Schleiff P, et al. (2012) The Diesel Exhaust in Miners Study: V. Evaluation of the Exposure Assessment Methods. Ann Occup Hyg 56: 389-400.
21. Wheatley AD, Sadhra S (2004) Occupational exposure to diesel exhaust fumes. Ann Occup Hyg 48: 369-376.

Acknowledgements

This project was sponsored by the Cancer Council of Western Australia and Curtin University. The authors would also thank all participants and the safety adviser of the company.