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Article

Knowledge and Practice of Health and Safety in Handling Organic Solvents among Automobile Industry Workers in Brunei Darussalam

Hazimah Hasylin[1], Khadizah H. Abdul-Mumin[1,2*], Pg-Khalifah Pg-Hj-Ismail[3], Ashish Trivedi[3] and Kyaw Naing Win[3]

[1] Universiti Brunei Darussalam, Pengiran Anak Puteri Rashidah Sa'adatul Bolkiah Institute of Health Sciences; hazimah.hasylin@moh.gov.bn; khadizah.mumin@ubd.edu.bn
[2] School of Nursing and Midwifery, La Trobe University, Bundoora, Victoria, Australia; K.Abdul-Mumin@latrobe.edu.au
[3] Ministry of Health, Bandar Seri Begawan, Brunei Darussalam; khalifah.ismail@moh.gov.bn; ashish.trivedi@moh.gov.bn; kyawnaing.win@moh.gov.bn
* Correspondence: khadizah.mumin@ubd.edu.bn, Tel.: +6732460922

Abstract: Automobile industries worldwide extensively use organic solvents. Yet, limited evidence examined the health and safety in handling these solvents, which can only be assured if workers have appropriate knowledge and demonstrate safe practices. A cross-sectional study was conducted to explore the knowledge and practice among workers who are involved with handling organic solvents in the automobile industry in the largest most urban district in Brunei Darussalam. Qualitative data were sought from open-ended questions; observations and pictorial evidence through still photographs. Quantitative analysis showed that 75% of the workers practice reading labels, 94.1% use fully covered clothes, 82.4% wear gloves and 98.5% practice proper hand washing as well as 98.5% cover container lids. The qualitative analysis illustrated workers have general knowledge of materials containing solvents but did not identify the exact solvents, the harmful effects of the solvents, pathophysiology and harmful effects on specific body systems. Health and safety were practiced albeit not consistent. Health and Safety Authorities in Brunei Darussalam must review and enforce specific policies on use of organic solvents so that they can be practiced consistently and safely in automobile industries. Cooperation and collaboration in adhering to the policies are mandatory to ensure health and safety at work.

Keywords: occupational; environmental; health; organic solvents; automobile; workshop; spray painting; Brunei

1. Introduction

Organic solvents are carbon-based solvents, which are substances that dissolve another substance to create a homogenous solution [1]. Common organic solvents include isopropanol, toluene, xylene, and solvents mixtures such as white spirits and chlorinated solvents [2]. Depending on the exposure and concentration, organic solvents have harmful effects on the respiratory system, integumentary system, digestive system primarily on the liver and kidney, cardiovascular system and central nervous systems such as cognitive and emotional deficits diseases or even death [3]. It has been reported worldwide that a deficit of health and safety procedure in handling these organic solvents lead to adverse health effects. Reducing exposure levels as well as safe practices on solvents use is important in reducing the risk of ill-health effects. Safe practices depend on having the appropriate knowledge towards the health risks associated with the exposure and harmful effects of the organic solvents [4].

Organic solvents are also extensively used in activities such as degreasing, cleaning and repairing of car engine in the automobile industry [5]. Repairing requires painting

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and coating using paint, varnish, and rustproofing, all which contain organic solvents [6]. N-hexane is mainly use in solvents, glues, spray paints, coatings, and silicones which is well known for its neurotoxicity, and increased risk of development for peripheral neuropathy. Many cases of N-hexane related neurotoxicity have reported in automotive repair industry in Asia, Europe, and the United States [7]. Other agents are toluene and acetone, which are found abundantly in commercial thinner and also well-known neurotoxic agents [8].

Road Traffic Accidents (RTA), requires major repairs which are mostly done in auto garages, typically include damaged body parts such as bumpers and hoods, hammering out and patching up dents, other minor or major body damages in automobile industry. In Brunei Darussalam (henceforth: Brunei), for the year 2016, the recorded number of vehicles were 182238 with 3375 road traffic accidents cases reported, giving a ratio of RTA to vehicles at 1:53 [9]. Despite the wide use of organic solvents in auto mobile industries, there are still limited studies that examine the knowledge and practice of these industries' workers on organic solvents.

There are several existing and related legislations under the purview of the Safety Health and Environment National Agency (SHENA) that regulates and oversees the health, safety and welfare of workers in Brunei. Under the Workplace Safety and Health Order (WSHO) 2009, there are special provisions for the hazardous substances and it specifies the duty of employer as well as suppliers and provides information for its safe use at the workplace [10]. These legislations provide to principally eliminate or control workplace hazards and risk; and protect the welfare of employees during employment. Although there is a specific clause that list chronic benzene poisoning in the WHSO, however, there are no other specific provisions concerning the handling of organic solvents, nor available data or evidences that determine whether workers are compliant with safe practices whilst handling organic solvents. The objective of this study is to explore the knowledge and practice amongst workers who are exposed to organic solvents in selected auto garages in Brunei.

2. Methods

2.1. Study Design, Setting and Sampling

Ethical clearance for this research was approved by the Pengiran Anak Puteri Rashidah Sa'adatul Bolkiah Institute of Health Sciences Research Ethics Committee (IHSREC) (Ethics Reference Number: UBD/IHS/B3/8). A cross-sectional, mixed-method study was conducted in four of the leading automobile workshop industries in the most populous and most urban districts in Brunei. Although all workers who are exposed to or associated with the handling of organic solvents in the automobile workshops were included in this study, Brunei is such a small country. Hence, a whole total of 91 workers works in the four workshops: thirteen were involved during the questionnaire pre-testing, 68 participated in the main study.

2.2. Data Collection and Analysis

2.2.1. Questionnaire

Data was collected using a pre-designed questionnaire derived from the questionnaire used for a study on "Knowledge, Attitude and Practices" (KAPs) regarding organic solvents among printing workers in Hong Kong [11]. The questionnaire was modified for appropriateness to the local setting that focuses on knowledge and practice with permission from the researchers. The research team act as an expert panel group (three experts in environmental health and two experts in public health) that evaluate the suitability of the questions. Following that, two focus groups (6 in one group and 7 in another) involving 13 automobile workers were conducted for test-retest that aimed for content validity. The words used in the questions were modified which are comprehensible to the respondents until there was a consistent understanding of the questionnaire from one to another respondents.

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The final instrument consisted of close-ended questions on current knowledge and practice of organic solvents in the automobile industry. Open-ended questions were also inserted that add qualitative value to the study. The questions aimed to acquire in-depth elaboration that assessed knowledge of adverse health effects of organic solvent exposure. Two researchers take turns in collecting data on each study site. The questionnaire was interviewer-assisted with the help of a professional translator who worked at the study site, as a large number of the workers are foreigners and do not speak English.

The questionnaire consists of question on education level which was classified based on the International Standard Classification of Education (ISCED)[12]. The best five safe practices were defined as reading chemical labels, using fully covered clothes, wearing gloves, hand washing and cover lids of containers after use. Participants were also categorized into direct and indirect exposure to organic solvents, based on their job descriptions. Painters who are directly exposed to organic solvents are those involved with body repair workers, mechanics, and panel beaters. Those workers who are not directly exposed include site supervisors and technicians who do not spent on handling the organic solvents [13]. The quantitative data was analyzed using Statistical Package for the Social Sciences (SPSS) 26.0. Frequencies and percentages were used to present categorical variables.

Qualitative data were tabulated using Microsoft EXCEL spreadsheet and analyzed using thematic analysis. The process of coding and themes formation until the finalization of themes were undertaken through constantly comparing data within the same questionnaire and with other questionnaires [14]. Numerous discussions were held and agreement was sought among the researchers on the final themes.

2.2.2. Observations (Pictorial evidence)

Additionally, on-site observations and pictorial evidence from still photographs were also undertaken to further compare and verify responses to the questionnaire. A different day was set for observations and taking still photographs of handling and storing of organic solvents in the automobile workshops. Photographs of observations of the auto-garages were interpreted and confirmed by all researchers. The photographs were used for corroborating results of the questionnaire.

3. Results

3.1. Quantitative Analysis

Figure 1, and Table 1 illustrated the quantitative findings of this study.

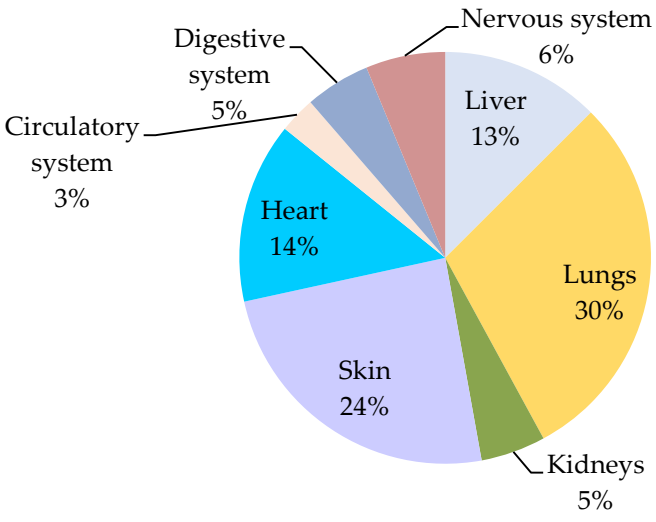

Figure 1. Participants opinion about organ affected by solvents exposure.

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In Figure 1, most workers (30%) cited lungs as the organ affected by exposure to organic solvents, followed by skin (24%), heart (14%), and liver (13%).

Table 1. Socio-demographic and Work Characteristics of Study Participants.

Characteristics	Number (%)
Age Groups (years)	
< 30	8 (11.8%)
30-40	21 (30.8%)
41-50	24 (35.3%)
≥ 50	15(22.1%)
Gender	
Male	67 (98.5%)
Female	1 (1.5%)
Nationality	
Malay	9 (13.2%)
Chinese	19 (27.9%)
Others	40 (58.8%)
Education	
Primary	38 (55.9%)
Secondary	24 (35.3%)
Tertiary	6 (8.8%)
Smoking	
Current Smoker	27 (39.7%)
Ex-Smoker	09 (13.2%)
Non-Smoker	32 (47.1%)
Alcohol	
Consumes alcohol	27 (39.7%)
Past alcohol consumption	09 (13.2%)
No alcohol	32 (47.1%)
Work Activity	
Painter	24 (35.3%)
Body repair	12 (17.6%)
Mechanic	14 (20.6%)
Panel beater	5 (7.4%)
Others	13 (19.1%)

Table 1 illustrated that there were 68 workers who participated in this study which is 100% response rate of the respondents who are not involved during the test-retest. The mean age of workers was 41 years (range: 22-62 years old). The highest age group was 41-50 years (35.3%). 55.9% of the workers have primary-level education, and only 8.8% had tertiary education level. The majority of the workers were expatriates (58.8%). Expatriates were from Indonesia (15.4%), the Philippines (38.5%), Thailand (28.2%) and others (17.9%) including India and Sri Lanka and Bangladesh. There were 39.7% of current smokers, and 39.7% consume alcohol. 35.3 % of workers were painters who were directly exposed to organic solvents, 17.6% body repair workers, 20.6% mechanics, 7.4% panel beaters and 19.1 % site supervisors and technicians who are only indirectly exposed.

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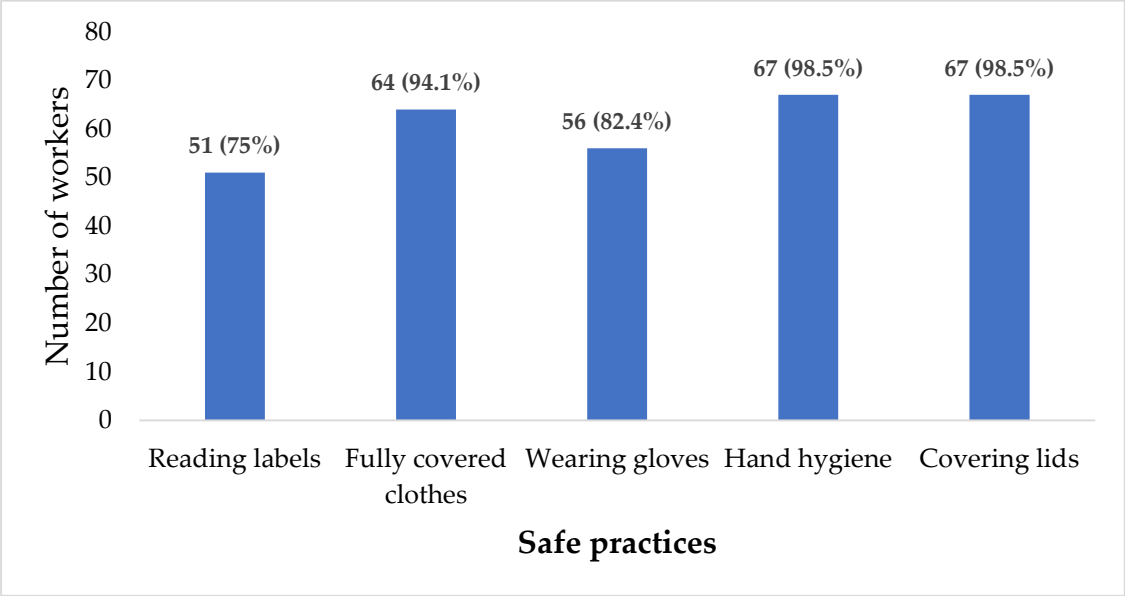

Figure 2. Five best safety practices of automobile workers at their workplaces in Brunei Darussalam.

Figure 2 shows 75% of the workers practice reading chemical labels, 94.1% practice using fully covered clothes, 82.4% practice wearing gloves, 98.5% practice hand hygiene and 98.5% practice covering lids of the containers while handling the organic solvents.

3.2. Qualitative Analysis

Open-ended questions elaborate on respondents' "Knowledge and Practice" towards Health and Safety in the handling of organic solvents before, during and after spray painting and handling car repairs. Qualitative analyses of the respondents' answers to the open-ended questions indicated three common themes: Theme 1: Awareness of materials containing organic solvents; Theme 2: Harmful effects of organic solvents; and Theme 3: Safety practice and precautions. The themes formulated from the open-ended questions in the questionnaire and findings from the pictorial evidence are described below.

3.2.1. Theme 1: Materials Containing Organic Solvents

This theme represents the participants' ability to identify organic solvents that they use at their workplace. The majority of them had limited knowledge of the exact organic solvents that they dealt with in their workplace, but, managed to identify materials/chemicals that contain organic solvents. Thinner was the most commonly reported material containing organic solvents that they use for mixing with spray paints or for cleaning spray paints or for use after car repair. Degreaser and other paints materials were other material identified that contains organic solvents, especially by spray painters.

"Most of the organic solvents we are using now is inside Lacquer thinner that we mix with the spray paints"

(Participant 52)

"I use thinner either to clear paints or to mix with paints; and clear and hardener (to make car paints appear glossy). They contain organic solvents."

(Participant 5)

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"The organic solvents are in some of the chemicals that I dealt with, such as thinner, degreaser, colour paints materials, and other volatile organic compounds such as engine oil and gases."

(Participant 56)

Some participants specifically highlighted benzene, greases, synthetic oil, engine oil, brake fluids and gearbox oils as the chemical that contains organic solvents that they used in repairing cars.

"I work in repairing engine. Some solvents that I used during working include that is in the ingredients of greases, synthetic oil, engine oil, brake fluids, and gearbox oil. I also use benzene to clean engine parts so that it is shiny."

(Participant 2)

3.2.2. Theme 2: Knowledge on Harmful Effects of Organic Solvents

This theme illustrated the participants' knowledge on the harmful effects of organic solvents. Participants were able to report the generalized effects but were not able to identify the specific harmful effects of the organic solvents on health. Majority of them reported the effects on skin and lungs such as skin irritation and lung disease or cancer. They also mentioned the mode of contact such as skin contact or inhalation that may lead to harmful effects.

"It causes skin irritation if spilled over or in contact with organic solvents and lungs defects if inhaled."

(Participant 53)

"Organic solvents caused skin irritation through direct contact. Leading to lungs problem due to inhalation."

(Participant 5)

There were also participants who identified the effects of organic solvents on the liver, kidney as well as the psychological effects. However, they were not able to identify the specific organic solvents that may cause the harmful effects on the particular organ, system or body part.

"The solvents may possibly be inhaled through the nose going to the lungs. Hand chemical such as thinner also can affect the skin causing skin diseases. The long term used of organic solvents may affects the liver."

(Participant 55)

"Organic solvents damage the kidney, lungs and skin. Skin can be very itchy and dry if in contact with the solvents. Small particles from solvents may be inhaled that can either damaged the lungs or cause diseases such as cancer in long-term."

(Participant 9)

"Organic solvents can cause hallucination if exposed in long-term, lung cancer and suffocation if inhaled in the case of working without protection of respirator."

(Participant 21)

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3.2.3. Theme 3: Safety Practice and Precautions

This theme outlines the participants attitude and practice on safety and precautions at the workplace. Majority identified the safe practices and precautions as the most important step while working in the auto-garage with the wearing of PPE was the commonest safety practice reported by them, in spite of it being low on the scale of hierarchy of control measures.

"Safety is the first thing before we do work in painting. It is better to know first the safety procedure; like wearing PPE before doing painting, such as safety goggle, safety boot, gloves, mask (half face for preparation stage and full-face during painting."

(Participant 2)

"We use disposable mask for daily car repairs so that we will prevent our self from inhaling dangerous chemicals from solvents used in car repair. We also use full face respirator (half face with gas canister) so it will minimize the paint materials coming to us. We check the gas canister every 3 days in a week."

(Participant 50)

Participants especially in the supervisory role also mentioned the importance of reading the material safety data sheet (MSDS) for the proper handlings of the materials. Similarly, they also identified the safe practices such as the use of local exhaust ventilation as well as carrying out the spray painting in a properly designated / isolated area.

"Every time we work in automotive industry and using the chemical materials, we need to follow the instruction of each item."

(Participant 52)

"The Local Exhaust Ventilation (LEV) must be switch on during spray painting to prevent inhalation of the dusts from spray paints. Also need to wear rubber gloves, respirator and safety shoes."

(Participant 6)

"Make sure surrounding places are clear and working must not be in open place. Painting room must be well ventilated. There is equal air in and air out. Wear safety goggles and mask. Painting should be done inside spray booth. All doors must be locked and exhaust ventilation switched on, prepare air breathing system and painting booth ventilation equipment, organize the requisition of paint and solvents."

(Participant 39)

"No entry sign must be switched on while performing spray painting and heating car using oven. This is to prevent other people to come in during the procedure and to prevent inhaled dust from the spray paint that contains harmful organic solvents."

(Participant 11)

Some of the participants also pointed out the importance of cleaning and hygiene measures after the spray painting and repair activities, including dealing with the paint/chemical spillage. However, improper practices of using thinner as a cleaning agent

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for hands during and after work, as well as removing their gloves for better grip during the work was also mentioned by some of the participants.

"Prepare sand to clear up any oil spill. Use soil to absorb all chemicals. Paint sticking on paint brush are all clean using lacquer."

(Participant 39)

"Wash hand with usual soap because if we use thinner, then it can cause irritation to the skin of the hands. Throw the used oil after car repair on a proper disposal."

(Participant 57)

"PPE are cleaned. Disposed one time used item. Clean the workshop area. Wash hands after finish working. Tidy up things, and keep all tools and chemicals in cabinet. For painting room, it also needs to be cleaned and unwanted chemicals need to be cleared and disposed. Segregate the chemicals, plastic, paper and used oil properly and disposed properly."

(Participant 35)

"Use special soap provided by company to wash hands. Occasionally, we also use thinner to clean the paints and grease from the hands."

(Participant 48)

"If difficult to perform my work, I will remove my gloves."

(Participant 2)

3.3. Pictorial Evidences

Observation and pictorial evidences in the next page identified some of the chemicals used in the workshops had product labels with detailed information about its contents including the organic solvents as well as their harmful effects. However, participants were able to mention only the name of material used and general health hazards and were not aware about the organic solvent in that material and specific health hazards caused by them, shown in (Figure 3.1 and Figure 3.2). Pictorial evidence in the workshops also identified a designated /isolated area for spray painting activity with an exhaust ventilation system installed, in (Figure 3.3). However, in two of the workshops, pictorial evidences had shown inconsistencies in the appropriate or accurate usage as well as choice of PPE; i.e. spray painters were not using fully covered clothes as well as the mask/respirator were inappropriate, i.e. wearing of surgical face mask instead of using proper chemical respirator in (Figure 3.4). Pictorial evidence also indicated an improper procedure for dealing with paint spillage on the floor, i.e; spilled paint was being washed into the drain that led to the public drainage outside the workshop building as well as improper storage of chemicals after been used in (Figure 3.5).

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Figure 3.1. Product details with ingrediant (organic solvents) and harmful effects.

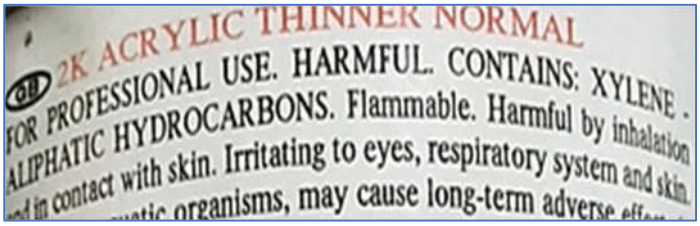

Figure 3.2. Product details with ingrediant (solvents) and harmful effects.

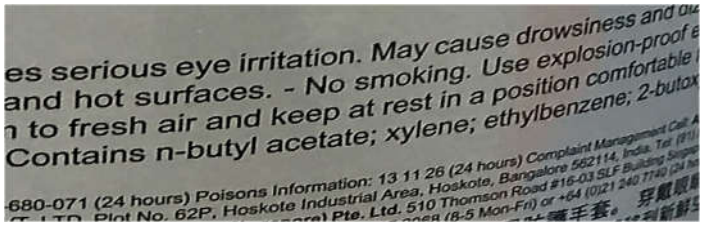

Figure 3.3. Designated spray paint area with an Local Exhaust Ventilation System(LEV).

Figure 3.4. Improper PPE practices at the workplaces.

Figure 3.5. Improper storage and poor spillage management.

3. Discussion

Lack of health and safety controls and measures while working with organic solvents can adversely affect the multiple body organs and systems. This study was conducted to

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assess awareness as well as work practices among automobile workers while handling organic solvents at their workplaces. 98.5% of participating workers were male, as male workers dominate at automobile workshops in Brunei Darussalam, which is similar to automobile industries in other countries such as Australia, Japan, and Europe [15–17]. More than half of the workers in this study are of primary level education (55.9%), and expatriates (58.8%) from Indonesia, Philippines, Thailand, India, Sri Lanka and Bangladesh. It is not unusual to have diverse expatriates' workers in many different parts of the world. This is attributed by globalization where the world become interconnected to each other attributing to workers migrated to work in another country due to overpopulation of workplace at their home countries or no opportunities available for working in the workplace desired. In 2017, the number of international migrants was estimated to be 258 million. According to the ILO, about 63% (164 million) of international migrants are migrant workers, of whom 58.4% are men. 61% of all international migrant workers reside in North America (23%), northern, southern, and western Europe (24%), and the Arab States (14%)[18]. The diversity in nationalities and background experience may also has an impact on the respective workers understanding, knowledge and safety practices on organic solvents use.

The quantitative findings indicated that automobile workers' knowledge about harmful effects of organic solvents was superficial and general, where only 30% and 24% respectively were able to mention the lung and skin as the organs affected by exposure to organic solvents. They were unable to identify the exact organic solvents that can cause the specific harmful effects on different body organs and systems. However, with regards to following the safe practices, more than 94% of participants wear fully covered clothes, practice hand hygiene and cover the lids of containers, while 82.4% wear gloves and 75% read chemical labels, while handling organic solvents at their workplace. The PPE practice, hand hygiene and reading the safety data sheets (SDS) at work were also mentioned by participants in the qualitative part of the study. However, improper safety practices like using thinner for cleaning hands as well as removing gloves for better grip during the work were also mentioned. Moreover, the site visit and pictorial evidences were also not congruent with the participants responses and were evident of improper use and choice of PPE as well as not using the fully protecting body coveralls. As per ILO recommendations, depending on the job tasks and exposures, workers should be provided with proper protective overalls, footwear, respiratory protection which filters out the chemical vapors, and equipment to protect face, eye and hands, while handling chemicals including spraying operations [19]. As mentioned by participants in this study, use of solvent for washing paints was also observed among painters in a study conducted in Ghana [4]. As part of health and safety precautions, it is always important to ensure that the right equipment's, tools were used, and in a good condition. Effective control of chemicals exposure during spray painting include proper selection of spray-painting equipment, properly designed and ventilated spray-painting booth with using of correct PPEs [20]. In Brunei, safety practices and procedures relating to work are provided under the Workplace Safety and Health Order [10]. In this legislation, it stated that general duties of employer include provision of PPE, providing equipment for the convenience of employees, ensure that all machineries, equipment's and working environments are safe at all times, providing information and procedures that is necessary before carrying out any work as well as responsible for repair and maintenance of the working environments that may pose to injuries at work.

The uniqueness of this research is, additional to the quantitative descriptive cross-sectional research, it also employed open-ended questions and pictorial evidence. From the open-ended questions showed that auto-garage workers had good knowledge on the material/chemical used at their workplace that contains organic solvents, however majority had a very limited awareness about the actual solvents they were dealing with at the workplace. Similarly, participants were able to mention the generalized harmful effects of organic solvents, such as damage to lungs or skin following inhalation or skin exposure with some respondents also mentioning the harmful effects on kidney, liver as well as on

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mental health. However, they had a poor awareness regarding specific solvent affecting particular body organ or system.

By contrast, during the site observations and in the pictorial evidences, it was observed that product labels on the material/chemical containers/bottles had a detailed information about its ingredients including the organic solvents as well as its harmful effects. There is discrepancy in the quantitative and qualitative analysis with the pictorial evidences. This indicate that although a person may have the knowledge and stated that they employed safety practice, what they said may not necessarily be the case in actual situation [18, 21]. Qualitative analysis of the open-ended questions further indicated the importance of cleaning the workplace area, disposal of used paints, and hand washing after their work activities. Hand washing after work especially before eating or drinking, is considered an important measure for preventing chemical exposure at work [19].

There is study a small sample size in this study, but this is generally acceptable for Brunei setting, being a mal country. There was a challenge of language barrier as well as the literacy levels of participants as a barrier for data collection but these were addressed by the presence of professional translator at the respective study sites for the translation and transliteration. Alongside with the use of mixed-methods through cross-sectional design, responses from the open-ended questions and pictorial evidence through site observations ensure data triangulation that complemented and strengthen the quantitative findings.

5. Conclusions

This study is the first of its kind to explore knowledge and practice of health and safety while handling organic solvents amongst automobile workshop workers in Brunei. The results provided a base line information regarding prevailing awareness on harmful effects of solvents as well as their safety practices of automobile workers, for improving health and safety at work, as well as developing policies that benchmarks handling of organic solvents at automobile workshop. Training sessions and seminar should be held regularly for the workers to refresh knowledge and practice, and raise awareness on the health and safety measures in handling organic solvents. Provision of necessary information are deemed imperative /such as providing the Material Safety Data Sheet (MSDS) for the chemicals which can help to improve safety practices among the workers. Health and Safety authorities in Brunei Darussalam must review and enforce specific policies on organic solvents so that they can be practiced consistently at auto-garage industries and with the existing legislations and a designated national agency, cooperation and collaboration in adhering to these policies can be ensured to enhance the health and safety measures at such workplaces.

Author Contributions: Conceptualization, H.H., K.H.A. and P.P.; methodology, H.H., K.H.A. and P.P; software, H.H. and K.N.W.; validation, H.H., K.H.A., P.P. and K.N.W.; formal analysis, H.H., K.H.A., P.P. and K.N.W.; investigation, H.H., K.H.A. and P.P.; resources, H.H. and K.N.W.; data curation, H.H., K.H.A., P.P. and K.N.W.; writing—original draft preparation, H.H., K.H.A. and P.P.; writing—review and editing, H.H., K.H.A., P.P., A.T., and K.N.W.; visualization, , H.H., K.H.A., P.P., A.T., and K.N.W.; supervision, K.H.A. and P.P.; project administration, H.H., K.H.A. and P.P. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Pengiran Anak Puteri Rashidah Sa'adatul Bolkiah Institute of Health Sciences Research Ethics Committee (IHSREC) (Ethics Reference Number: UBD/IHS/B3/8) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the participant(s) to publish this paper.

Data Availability Statement: The datasets generated and/or analyzed during the current study are not publicly available due to restrictions on intellectual property regulations of the Research Ethics Committee.

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Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, interpretation of data; in the writing of the manuscript; and in the decision to publish the results.

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