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Analysis of the Comprehensibility of Chemical Hazard Communication Tools at the Industrial Workplace

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Abstract: Chemical classification and labelling systems may be roughly similar from one country to another but there are significant differences too. In order to harmonize various chemical classification systems and ultimately provide consistent chemical hazard communication tools worldwide, the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) was endorsed by the United Nations Economic and Social Council (ECOSOC). Several countries, including Japan, Taiwan, Korea and Malaysia, are now in the process of implementing GHS. It is essential to ascertain the comprehensibility of chemical hazard communication tools that are described in the GHS documents, namely the chemical labels and Safety Data Sheets (SDS). Comprehensibility Testing (CT) was carried out with a mixed group of industrial workers in Malaysia (n=150) and factors that influence the comprehensibility were analysed using one-way ANOVA. The ability of the respondents to retrieve information from the SDS was also tested in this study. The findings show that almost all the GHS pictograms meet the ISO comprehension criteria and it is concluded that the underlying core elements that enhance comprehension of GHS pictograms and which are also essential in developing competent persons in the use of SDS are training and education.

Key words: Hazard communication, Comprehensibility, GHS, Malaysia, Industrial workplace

Introduction

In order to improve safety in the use and handling of chemicals, it must be understood that each chemical has its own potential hazards[1)]. Thus, every chemical must be labelled based on its hazardous properties, and this hazard information must be adequately communicated to various target audiences such as chemical transporters, store keepers, distributors, users and/or regulating authorities. This is what is known as chemical hazard communication. In general, chemical labels and Material Safety Data Sheets (MSDS) are the two main tools of chemical hazard communication[2)].

Before the hazards of a particular chemical can be communicated to the public, different degrees of hazards should be classified based on specific cut-off values or end points. Many countries already have their own systems and requirements for classifying chemicals. However, although these requirements may be similar from one country to another, the actual classification may not be the same due to different cut-off values or endpoints[3)]. For example, the same chemical can be labelled as ‘flammable’ in one country but ‘very flammable’ in another country, leading to confusion among users and possibly increasing the risks of using and handling the chemical[4)].

In order to harmonize various chemical classification systems and ultimately provide consistent chemical hazard communication tools worldwide, country delegates

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at the United Nations Conference on Environment and Development (UNCED), held from 3–14 June 1992, in Rio de Janeiro, Brazil, agreed to develop a globally harmonized classification system, if feasible, by the year 2000. This was stipulated in the Programme Area B in Chapter 19 of the conference report known as Agenda 21[5]. With the culmination of more than a decade of work by multidisciplinary experts, the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) was adopted in 2002 by the United Nations Economic and Social Council's Subcommittee of Experts on the GHS (UNSCEGHS) and endorsed by the United Nations Economic and Social Council (ECOSOC) in July 2003[6]. The technical information for chemical classification, such as the classification criteria, was stipulated in the GHS document (also known as the GHS purple book).

The GHS covers classification and hazard communication for chemical substances and mixtures. Under the GHS classification, three types of hazards are identified, i.e. physical hazards, health hazards and environmental hazards, and for each type of hazard, various hazard classes have been assigned (Table 1)[7]. The division of criteria within each hazard class is known as hazard category. Table 2 illustrates the GHS pictograms correlated with the hazard classes, while Table 3 illustrates information required by the Safety Data Sheets (SDS)[7]. The SDS is similar to the existing MSDS and the Chemical Safety Data Sheet (CSDS) recommended by the International Labour Organisation[8]; the only difference is in the sequencing of items.

The Asia-Pacific Economic Cooperation (APEC) member countries targeted GHS implementation within APEC member countries by 2006[9] while the World Summit on Sustainable Development[10] and Intergovernmental Forum on Chemical Safety[11] set 2008 to achieve worldwide GHS implementation. However, none of the countries have declared that they have successfully implemented GHS. Although the target dates recommended by the aforementioned organisations have come and gone, countries are progressing towards GHS implementation by incorporating GHS elements into their respective national chemical classification and labelling systems. In Japan, an inter-ministerial committee comprising seven government ministries and experts from national laboratories and industries has been set up to exchange and share information on the GHS, and activities carried out by Japan include translation of the GHS purple book into Japanese; identification of gaps between the GHS and current Japanese laws; amending existing Japanese laws (e.g. the Industrial Safety and Health Law) by incorporating GHS elements into the laws; classification of 1,400 chemicals which are regulated under current Japanese laws using GHS criteria; revision of the Japanese Industrial Standards (JIS) (e.g. JIS Z 7250); and preparation of the GHS classification manual and technical guidance[12].

In Taiwan, prior to the introduction of GHS, the classification and labelling of chemicals broadly followed the United Nations Recommendations on the Transport of Dangerous Goods (UNRTDG) prepared by the United Nations Economic and Social Council's Sub-Committee of Experts on the Transport of Dangerous Goods (UNSCETDG)[13]. An inter-agencies coordination committee chaired by the Council of Labour Affairs, Executive Yuan, was set up to facilitate and catalyse GHS implementation in Taiwan. In February 2006, the inter-agencies coordination committee endorsed the

Table 1. GHS hazard classes

GHS Classification	
Physical Hazards:	**Health Hazards**:
1) Explosives	1) Acute toxicity
2) Flammable gases	2) Skin corrosion/irritation
3) Flammable aerosols	3) Serious eye damage/eye irritation
4) Oxidising gases	4) Respiratory or skin sensitization
5) Gases under pressure	5) Germ cell mutagenicity
6) Flammable liquids	6) Carcinogenicity
7) Flammable solids	7) Reproductive toxicity
8) Self-reactive substances and mixtures	8) Specific target organ toxicity – single exposure
9) Pyrophoric liquids	9) Specific target organ toxicity – repeated exposure
10) Pyrophoric solids	10) Aspiration hazard
11) Self-heating substances and mixtures	
12) Substances and mixtures which, in contact with water, emit flammable gases	**Environmental Hazards**:
13) Oxidising liquids	1) Hazardous to the aquatic environment (acute and chronic)
14) Oxidising solids	
15) Organic peroxides	
16) Corrosive to metals	

Table 2. GHS pictograms

GHS Pictogram	Symbol in the GHS pictogram	GHS hazard classes	To ease the discussion, the GHS pictogram in this paper means:
	Skull and crossbones	Acute toxicity (for oral, skin and inhalation)[a]	Toxic
	Flame	Flammable gases; flammable aerosols; flammable liquids; flammable solids; self-reactive substances and mixtures; pyrophoric liquids; pyrophoric solids; self-heating substances and mixtures; substances and mixtures which, in contact with water, emit flammable gases; organic peroxides	Flammable
	Flame over circle	Oxidising gases; oxidising liquids; oxidising solids	Oxidising
	Exploding bomb	Explosives; self-reactive substances and mixtures; organic peroxides	Explosive
	Corrosion	Corrosive to metals; skin corrosion; serious eye damage	Corrosive
	Gas cylinder	Compressed gas; liquefied gas; refrigerated liquefied gas; dissolved gas	Compressed gas
	Exclamation mark	Skin irritation; eye irritation; skin sensitizer	Harmful
	Environment	Acute and chronic hazards to the aquatic environment	Environmental hazards
	Health hazards	Germ cell mutagenicity; carcinogenicity; reproductive toxicity; specific target organ toxicity – single exposure[a]; specific target organ toxicity – repeated exposure; respiratory sensitizer	Health hazards

[a]the exclamation mark pictogram is used for less severe toxicity, for details please refer to GHS purple book.

Table 3. Information to be listed on SDS

No	Items
1.	Product, company identification
2.	Hazards identification
3.	Composition information on ingredient
4.	First aid measures
5.	Fire fighting measures
6.	Accidental release measures
7.	Handling and storage
8.	Exposure controls, personal protection
9.	Physical, chemical properties
10.	Stability and reactivity
11.	Toxicological information
12.	Ecological information
13.	Disposal considerations
14.	Transport information
15.	Regulatory information
16.	Other information

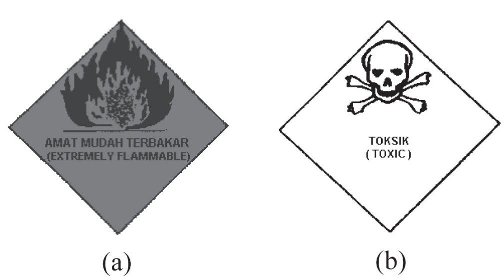
3-yr plan of GHS implementation (i.e. 2006–2008), with Executive Yuan's approval[14]. Under the three-year plan, Taiwan revised their Chinese National Standards CNS 6864 Z5071 Labels of Dangerous Materials based on the elements in the 14th revised edition of UNRTDG (that already incorporated GHS elements), and then incorporated those amendments into the Traffic Safety Rule Article 84.

In Korea, the GHS-related activities were carried out by several Korean ministries independently after the adoption and publication of the GHS purple book[15]. In order to consolidate these independent GHS-related activities, an inter-ministerial GHS Committee (IGC) was established in 2004. The IGC encompasses eight ministries, and is supported by an expert working group comprising nine experts from these ministries including one private consultant[16]. Korea has revised their Industrial Safety and Health Act (ISHA) and the criteria for chemical classification were increased from the existing 15 to 27 criteria. Basically the ISHA adopted most of the building blocks described in the GHS purple book except classification categories which have no labelling requirement, e.g. acute toxicity category 5[16].

Malaysia is also in the process of implementing the

GHS. One of the important milestones for the GHS implementation in Malaysia occurred on 17th January 2006 at a meeting on the proposal for the establishment of a National Coordinating Committee for the Implementation of GHS (NCCGHS) chaired by the Ministry of International Trade and Industry (MITI). During the meeting, members nominated MITI as the coordinator (i.e. MITI to serve as the national focal point for the GHS implementation in Malaysia) and also as the secretariat for the NCCGHS. In line with this role, MITI hosted the first NCCGHS on 3rd August 2006[17]. Respective lead agencies for GHS implementation were identified and the GHS implementation for the industrial workplace is now led by the Department of Occupational Safety and Health (DOSH). The industrial workplace is one of the most relevant sectors for the implementation of GHS. Chemicals are commonly handled by industrial workers in different ways, including using chemicals as raw materials for manufacturing or formulation processes, moving or carrying chemicals from one area to another within the same premises, and storing chemicals in appropriate locations. In order to convey or communicate hazard information to the industrial workers, DOSH gazetted the Occupational Safety and Health (Classification, Packaging and Labelling of Hazardous Chemicals) Regulations 1997 (also known as CPL 1997) to ensure chemicals are classified and labelled according to Malaysia's requirements. Hazard communication tools stipulated in the CPL 1997 include the danger symbols and CSDS. The danger symbols are similar to the GHS pictograms except that the hazard statement placed in the middle of the danger symbol (Fig. 1). The hazard statement is in both English and *Bahasa Malaysia* (the national language of Malaysia).

As the GHS is different from the CPL 1997, it is interesting to study the comprehensibility of the GHS hazard communication tools, namely, the GHS pictograms and SDS. It is also essential to ascertain responses from industrial workers on the comprehensibility of GHS pictograms, to see whether the 85% comprehension criterion set by the American National Standards Institute[18] and/or the requirement of the ISO criterion of at least 67% correct answers[19] are met. The possible factors influencing comprehension of the GHS pictograms among the industry workers will also be identified and analysed.



(a): Danger symbol for extremely flammable
(b): Danger symbol for toxic

Fig. 1. Example of danger symbols described in the CPL 1997.

Methods

Preparation of questionnaires

The rapid Comprehensibility Testing (CT) modules (or questionnaires) developed by the University of Cape Town[20] (UCT) were adapted to Malaysian conditions, needs and requirements. For example, awareness of Malaysian regulations such as the CPL 1997 was incorporated into the modules. As language is the key element for effective hazard communication survey[21], these modules were translated from English into *Bahasa Malaysia*.

All the questions were open-ended questions. Multiple-choice questions were not part of the study approach as past papers have expressed concern regarding the reliability of multiple-choice tests as the quality of the distractors can greatly influence comprehension[13] and hence affect analysis of the responses. The objectives for the six CT modules are stated in Table 4.

The CT survey comprised six modules, and the time needed for each survey was approximately 90 min, depending on the respondents. The same survey that was carried out in Nigeria took approximately 95 min[21]. The surveys were designed to be conducted face-to-face, and not via email, fax, phone call or mail. The reason is that interviewers had to record spontaneous responses from each respondent, such as recall of elements on a given dummy chemical label immediately after the chemical label was displayed and withdrawn, as well as respondents' ability to identify the appropriate SDS that illustrates the properties of the chemical stated on the dummy chemical label. Another reason why the questionnaire was administered to only one respondent at one time was to avoid influence by other respondents. Prior to the survey, all the interviewers were trained in two-day workshops organised by DOSH to ensure the quality of the survey. When Indonesia carried out the CT survey, the team of interviewers also underwent similar training[22].

Sampling

A total number of 150 respondents were selected from 25 companies on different scales, i.e. multi-national, national, and small and medium enterprises (SMEs)

Table 4. Objective of the CT modules

Module	Objectives
Module 1: General interview	To ascertain demographic and other related data as basis for analysis of CT. To ascertain competence in visual acuity that is necessary for some of the subsequent tests.
Module 2: Recall, reading, and comprehensibility of labels and SDS	To evaluate respondent's familiarity with labels and SDS. To test respondent's ability to recall elements on label. To test the comprehensibility of the label and SDS. To assess whether respondents can correctly identify appropriate SDS, as well as appropriate sections in the SDS, for a given chemical label.
Module 3: Understanding pictograms	To test whether respondent understands the meanings of pictograms.
Module 4: Comprehension of hazard symbols	To test ability of respondent in identifying appropriate pictograms accordingly to respective chemical hazards.
Module 5: Comprehensibility of SDS	To test respondent's ability to identify appropriate information from SDS. To assess type of information in SDS that the respondent finds to be useful, appropriate and comprehensible.
Module 6: Knowledge of chemical safety	To ascertain whether respondents have had any training related to chemical safety. To ascertain if respondents are aware of CPL and GHS.

Table 5. Definition of company scales and respective number of participating companies

Company Scale	Definition	Number of participating companies
Multi-national company	• The company is a branch company that is registered in Malaysia; and • The company does not have its head office or principal place of business in Malaysia.	8
National company	• The company is the head office that is registered in Malaysia; or • The company is a branch company and its head office is already registered in Malaysia; or • The company that is registered in Malaysia does not have any branch; and • The company is not classified as SME or Multi-national company	11
SME	• The National SME Development Council has evolved a definition of SMEs based on two criteria, namely full-time employees and annual sales turnover[23]: For manufacturing SMEs: ➢ Micro scale: less than 5 employees, or less than RM 250,000 annual sales turnover; ➢ Small scale: between 5 & 50 employees, or the annual sales turnover is between RM 250,000 & less than RM 10 million; ➢ Medium scale: between 51 & 150 employees, or the annual sales turnover is between RM 10 million & RM 25 million For services and agricultural SMEs: ➢ Micro scale: less than 5 employees, or less than RM 200,000 annual sales turnover; ➢ Small scale: between 5 & 19 employees, or the annual sales turnover is between RM 200,000 & less than RM 1 million; ➢ Medium scale: between 20 & 50 employees, or the annual sales turnover is between RM 1 million & RM 5 million	6

located throughout 13 states of Malaysia. Table 5 shows the criteria used in this study to define different company scales, as well as the number of companies in each scale that participated in the study. The participating companies were in various businesses, including electrical and electronics, polymers, pharmaceuticals, rubber, chemicals, stamping, steel, toys, roofing, petrochemicals, consumer products, pewter/silver, food and printing.

Procedures and methods of analysis

General information about respondents

General information about respondents such as gender, level of education and current position in the company were collected.

Respondents' use of information from hazard communication tools

Information on the frequency of utilising information on chemical labels and SDS according to the respondents' recollection was recorded. In addition, respondents' reasons for using information on chemical labels and SDS were noted.

Analysis of the comprehensibility of hazard communication tools

In order to ascertain which elements on chemical labels were most easily recalled by the respondents, a dummy chemical label was handed to each participant and then the label was withdrawn after some time was given for scrutiny. The elements recalled by respondents were recorded.

For the GHS pictograms comprehensibility testing, all the GHS pictograms (Table 2) were shown to the respondents and 1 point was awarded for each correct interpretation of a GHS pictogram. Thus, the maximum possible score for each respondent was 9 points. Factors that could have influenced the scores, such as company scale, current position in the company, education levels and awareness of CPL 1997 were analysed using one-way ANOVA via the SPSS version 15.0.

The ability of the respondents to retrieve information from the SDS was also tested. For this purpose, one dummy chemical label and three SDS were handed to each respondent. Only one of the three SDS had the correct information related to the chemical label. Respondents were required to provide information pertaining to health hazards, physical hazards, spillage, protective clothing and storage. Respondents' perspectives on the comprehensibility of SDS were recorded, as well as their suggestions on how to make the SDS easier to understand.

Results and Discussion

General information about respondents

From the survey, it was found that more than 95% of the total respondents had completed secondary school or attained a tertiary degree. Besides that, distribution of the types of positions was almost equally divided among managers, supervisors and workers. The background of the respondents is illustrated in Table 6. It was found that awareness among the respondents of the CPL 1997 was only 64.7%, despite the fact that it was a mandatory element.

Respondents' use of information from hazard communication tools

The GHS purple book has identified chemical labels and SDS as hazard communication tools in the context of GHS[7]. The chemical label consists of essential information of the intrinsic hazardous properties of chemicals, and this information is conveyed to the target audience via pictograms, hazard statements, signal words and/or precautionary statements. Additional/supplementary information such as toxicity, storage, ecotoxicity and disposal can be found throughout the SDS.

Approximately 82% of the respondents obtained

Table 6. General information about respondents

Aspects	Description	Percentage (%)
Gender	Male	92.0
	Female	8.0
Age distribution	20–29	20.7
	30–39	40.7
	40–49	30.0
	50–59	8.0
	60–69	0.7
Education level	Formal schooling but never completed primary school	0.7
	Formal schooling, completed primary school but never completed secondary/high school	2.7
	Completed secondary/high school	55.3
	Has a tertiary degree	41.3
Company scale	Multi-National Company	32.0
	National Company	44.0
	SMEs	24.0
Current position	Manager	32.0
	Supervisor	31.3
	Worker	36.7
Awareness of CPL 1997	Yes	64.7
	No	35.3

Table 7. Frequencies of respondents reading the information on chemical label and SDS

Frequency	Often (>10) (%)	Sometimes (<10) (%)	Never
of reading information on chemical label	64.0	34.0	2.0
reading information on SDS	38.7	50.4	10.9

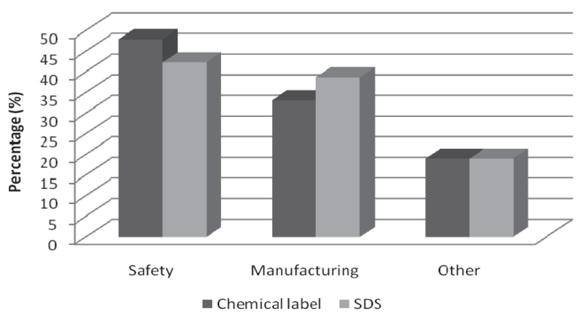


Fig. 2. Purpose of using information on chemical label and SDS.

chemical hazard information via chemical labels and SDS, and the frequencies of respondents reading the information on chemical labels and SDS are shown in Table 7. Respondents used the information for different purposes, particularly for safety and manufacturing purposes (Fig. 2). Safety purpose means obtaining safety information such as appropriate personal protective equipment and/or precautionary measures needed while handling the chemical; while manufacturing purpose means finding out, for instance, the chemical trade name and its ingredients. Other reasons for using information on chemical labels and SDS include recall of the product information, audit and/or upon instruction by supervisors.

Analysis of the comprehensibility of hazard communication tools

Comprehension of GHS pictograms

The most frequently recalled element on the chemical label was the pictogram (i.e. 86.0%), followed by the hazard information (i.e. 53.3%) and precautionary statements (i.e. 50.7%). Each respondent may recall more than one element from the chemical label.

As the pictograms were the most frequently recalled element, it was essential to ascertain whether respondents understood the meaning of pictograms, particularly the GHS pictograms. Hence, all the nine GHS pictograms were shown to respondents and they were requested to identify the meaning of each GHS pictogram. As mentioned earlier, although several danger symbols in the CPL 1997 were similar to the GHS pictograms, those CPL danger symbols were not part of the questionnaire because (i) the hazard statement in the CPL danger symbols (Fig. 1) might either directly or indirectly influence respondents' answers for the meanings of GHS pictograms (because there are no hazard statements in GHS pictograms); and (ii) since Malaysia is in the process of implementing GHS, the pictograms in the CPL 1997 will be replaced by the GHS pictograms when the CPL 1997 is amended.

Table 8 shows the percentage of the respondents that gave the correct meanings for the given GHS pictograms. The 'flammable' pictogram was the one understood by most respondents (i.e. 99.3%) followed by the 'toxic' pictogram (94.7%). Other studies have also shown that both the 'flammable' pictogram and the 'toxic' pictogram were the most easily identifiable GHS pictograms[1, 21, 22]. The 'compressed gas' pictogram was the least understood pictogram (i.e. 27.3%). The 'oxidising' pictogram had a low percentage of correct answers

Table 8. Results of LSD Test on comprehension of GHS pictograms

GHS pictogram[a]	Percentage of respondents who gave correct answers (%)	LSD grouping[b]					
Toxic	94.7	A					
Flammable	99.3	A					
Environmental hazards	78.0		B				
Corrosive	76.7		B	C			
Explosive	69.3		B	C	D		
Oxidising	28.0					E	
Harmful	73.3		B	C	D		F
Health hazards	76.0		B	C	D		F
Compressed gas	27.3					E	

[a]Significant at α=0.001.
[b]Values with the same letter are not significantly different.

Table 9. Results of factors influencing comprehension of GHS pictograms

Factor[a]	Average total score	LSD's grouping[b]		
Education level				
Formal schooling but never completed primary school[c]	4.00			
Formal schooling, completed primary school but never completed secondary/high school	4.00	A		
Completed secondary/high school	5.60		B	
Has a tertiary degree	7.24			C
Current position				
Manager	6.90	A		
Supervisor	6.06		B	
Worker	5.78		B	
Company scale				
Multi-National Company	6.04		B	
National Company	6.71	A		
SMEs	5.62		B	
Awareness of CPL 1997[d]				
Yes	6.60			
No	5.55			

[a]Significant at α=0.05.
[b]Values with the same letter are not significantly different.
[c]This variable was not considered in the Fisher's LSD tests due to its small sample size (n=1).
[d]t-test analysis.

(i.e. 28.0%) because almost half of the total respondents said that it had the same meaning as the 'flammable' pictogram. A similar confusion was also found in Japan where many respondents could not distinguish between the 'flammable' pictogram and the 'oxidising' pictogram[1].

ANOVA showed that the GHS pictograms had a statistically significant effect on comprehension ($F(8, 1341)=62.37$, $p<0.001$). The results of a Fisher's Least Significant Difference (LSD) Test demonstrated that comprehension of both the 'toxic' pictogram and the 'flammable' pictogram was significantly higher than that of all the other seven GHS pictograms (Table 8).

Comprehension of the nine GHS pictograms differed significantly. Only the 'toxic' and 'flammable' pictograms reached the 85% comprehension criterion set by the American National Standards Institute[18]. However, all the other pictograms, except the 'oxidising' and 'compressed gas' pictograms, met the requirement of the ISO standard with the criterion of at least 67% correct answers[19]. These results show that most of the GHS pictograms fulfil international requirements.

Factors influencing comprehension of GHS pictograms

Factors influencing respondents on the GHS pictogram comprehensibility tests were identified: these include respondents' education level, current positions, and company scales. Table 9 shows the average total scores for different variables under each factor. Factors on gender and age were analysed and the results showed no significant differences in influencing comprehension of GHS pictogram. This is similar to the finding of Hara *et al.*[1] that gender and age did not contribute to the understanding of GHS pictograms. Banda & Sichilongo[24] concluded that other factors such as literacy level, level of education attained and type of employment also did not influence the comprehension of chemical hazard labels.

The results of this study, however, show that education level, current position, company scale and awareness of CPL 1997 had some influence on the comprehension of GHS pictograms. The results of ANOVA show that educational level generated a significant effect on the GHS pictograms comprehension ($F(2, 146)=24.12$, $p<0.001$). The Fisher's LSD test reveals that respondents with a tertiary degree obtained better scores (7.24) compared to respondents who had completed secondary school (5.60) and primary school (4.00). In fact, respondents with a tertiary degree gained the highest score amongst other variables under different factors (Table 9). This finding highlights the fact that education level could enhance employees' capabilities in identifying hazards associated with the chemicals via the GHS pictograms. While this does not imply that employers should only recruit personnel with a tertiary degree, it does underscore the importance of employers' taking proactive efforts to educate and train those of their employees whose education is only up to secondary school or below.

The type of positions respondents held also influenced the comprehension of GHS pictograms. Managers were expected to have higher scores compared to supervisors and workers as they would have gained experience from the time they started as a worker before being promoted to supervisor, and then to manager. They might also have had working experience in other companies before their appointment as manager in a particular company. This hypothesis was proven correct as the managers had better scores (6.90) compared to supervisors (6.06) and workers (5.78) (ANOVA test result: $F(2, 147)=5.63$, $p<0.01$). In other words, managers selected in this study showed their capabilities in recognising GHS pictograms.

Respondents from multi-national companies were expected to have better scores compared to respondents from national companies and SMEs in this study. The rationale is that multi-national companies have to comply with different national regulations for chemical classification systems such as CPL 1997, thus employees should be familiar with different kinds of pictograms required by local authorities across country borders. However, this hypothesis was rejected as the respondents from national companies actually scored better than the respondents from multi-national companies and SMEs (ANOVA test result: $F(2, 147)=15.11$, $p<0.01$).

The results of the *t*-test showed that awareness of CPL 1997 demonstrated a significant effect on the comprehension of GHS pictograms ($t(148)=5.829$, $p<0.1$). The finding illustrates that awareness of CPL 1997 seems to have enabled respondents in obtaining higher scores on the GHS pictogram comprehensibility test.

Based on the results above, we might be led to summarise that a respondent with a tertiary degree, with a current position as a manager, working in a national company and is aware of the CPL 1997 will obtain a higher score on the comprehension of GHS pictograms. We must bear in mind, however, that those factors are inter-related and it is impossible to isolate them. A study of college students in Taiwan using GHS pictograms[25] used a logistic regression model to ascertain factors influencing perception towards chemical labelling where the logistic model is based on the *p*-value of Hosmer-Lemeshow index[26], but that logistic regression model is not suitable for this study due to the behaviour of certain factors. For example, for the position and company scale factors, the respondent might have just been promoted from supervisor to manager; or might have just moved from a multi-national company to a national company. Hence, the factors influencing comprehension of GHS pictograms should not be integrated or merged. With that in mind, we can then summarise that education level and awareness of CPL 1997 are two factors that influence comprehension of GHS pictograms, and that the underlying core elements for these two factors are training and education.

Comprehension of SDS

In order to test the comprehension of the SDS, one chemical label and three SDS were handed to each respondent. Of the three SDS, only one SDS describes properties of the chemical stated on the chemical label and respondents were requested to ascertain information of that particular chemical from the correct SDS. The purpose of this was to see if respondents could (i) identify the correct SDS for a particular chemical; and (ii) retrieve appropriate information within the correct SDS. Based on the chemical label, respondents were requested to provide information pertaining to health hazards, physical hazards, spillage, protective clothing and storage from the three SDS.

It was found that almost half of the respondents were able to provide appropriate information from the correct SDS: (in descending order) health hazards (44.4%), spillage (41.9%), storage (40.6%), protective clothing (39.7%) and physical hazards (34.1%). When the respondents were asked to suggest how comprehensibility of the SDS could be improved, 34.4% of the total respondents suggested using more pictograms or symbols in the SDS while reducing the number of words; while 33.3% of the respondents suggested highlighting important points in the SDS or re-arranging the information as a list of brief points. The latter suggestion seems to be more salient because the main purpose of the SDS is to illustrate in detail the information associated with the chemicals. For example, the skull and crossbones pictogram accompanied with the hazard statement – 'toxic if inhaled' - depicted on the chemical label do not describe the type of appropriate respiratory equipment needed while handling the chemical. However, this information can be found in the SDS. As the SDS is a technical guide, only competent persons can fully understand the information[2]. One effective method to develop competent persons is through training and education.

Conclusion

The result of this study illustrates that almost all the GHS pictograms meet the ISO comprehension criteria. Notably, the comprehension of the 'toxic' and 'flammable' pictograms exceeded 90%. However, respondents demonstrated uncertainty on the 'oxidising' and 'compressed gas' pictograms and this finding has highlighted which GHS pictograms should be emphasized when the authorities carry out GHS training. Various factors that influence comprehension of GHS pictograms were analysed. It was found that the underlying core elements that enhance comprehension of GHS pictograms, and which are also essential in developing competent persons in the use of SDS, are training and education.

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