Conference Paper

Study on Potential of Occupational Exposure Limits Harmonization in ASEAN-5 Countries

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Abstract

Five countries within the Association of South East Asian Nation (ASEAN-5), which consists of Indonesia, Malaysia, Singapore, Thailand, and Philippines, use a variety of chemicals in their industries and set Occupational Exposure Limit (OEL) as a regulation or reference instrument to control chemical. This study is aimed to assess the potential of OEL harmonization amongst ASEAN-5 since there is extensive labor exchange between South East Asian Region. Seven OELs (three lists from Indonesia) were compared between each other; and also, with TLV ACGIH 2016 and PEL OSHA as references. The geometric similarity measure (GSM) and non-metric multidimensional scaling plots were used for OEL similarities evaluation. There were a total of 713 chemical substances in the list being compared; 40 common substances that were available in all OEL lists; and 73 unique substances that appear only in 1 list of OEL. In non-metric multidimensional scaling plots, it was found that 5 OEL have close similarities with both TLV ACGIH 2016 and PEL OSHA. Thailand-OEL and Regulation of Ministry of Health of Indonesia No. 70 of Year 2016 showed dissimilarity with TLV ACGIH 2016 and PEL OSHA 2016 due to having lesser number of substances. There was a potential of OEL harmonization within ASEAN-5 since some similarities in listed substances and concentration limit were found.

Keywords: chemical substances, harmonization study, occupational exposure limit, regulation

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Received: 15 May 2018
Accepted: 3 June 2018
Published: 19 June 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICOHS 2017 Conference Committee.

1. Introduction

Association of Southeast Asian Nations (ASEAN) was established in 1967. As if right now, the members of ASEAN are: Indonesia, Brunei Darussalam, Kamboja, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. ASEAN owns the world's seventh largest economic power with a population of 622 million and its working age comprises 50 percent of the total population [1].

The chemical industry is a huge contributor to the economy of ASEAN. In 2011, chemical exports per year in this region reached tens of trillions of USD [2]. Investment from other countries into ASEAN's chemical field is also very high. For example, the investment of South Korea (on the 2010) and US (on the 2014) into ASEAN's chemical industries were about 1,264 to 1,387 million dollars, respectively [3].

Amongst ASEAN country members, five countries have achieved the highest Gross Domestic Income in 2015 and are also predicted to reach the highest Gross Domestic Income in 2020, according to the International Monetary Fund [4]. They are Indonesia, Thailand, Malaysia, Singapore and the Philippines which is why they are now called the ASEAN-5. These countries were also included in the top 50 countries of the Global Competitive Index issued by the World Economic Forum [5]. IMF calls these five countries as 'ASEAN-5' [6].

The combination of high chemical usage and high labor force in the five ASEAN countries causes high risk of work related diseases and accidents due to intense chemical exposure. For example, there was a mercury contamination case in six villages of Minahasa Indonesia in 1997 [7]. In Thailand, there were 8 fatalities due to pyrogenous aerosols exposure in a basement of a bank building [8]. In Malaysia, occupational diseases caused by pesticides in 1997–1998 reached 239 cases [9]. In Singapore, cases of occupational diseases in 2001–2006 reached more than 194 cases [10]. In the Philippines, dermatitis and asthma in the workplace increased by more than 100 percent in 2013 compared to 2011 [11].

Several initiatives from various organizations have been proposed in order to reduce occupational diseases and accidents caused by chemical exposure in ASEAN. The ASEAN Secretariat in 2013 has developed a guideline for Occupational Health and Safety, consisting of OSH hazard assessment, OSH training, and labeling of chemicals using the Globally Harmonized System [12]. In 2014, the United Nations Environmental Program (UNEP) has conducted a study on Chemical Accident Prevention & Preparedness (CAPP) in the ASEAN Region. This study found out that the attention from governments in ASEAN regions toward industrial disasters were still limited compared to natural disasters, although some regulations were already in place. In 2015, the Economic Research Institute for ASEAN and East Asia has drafted plans for an ASEAN-wide chemical safety database [13]. In addition, the Singapore Chemical Industry Council had also made a cooperation plan in the field of chemical regulation in ASEAN [14].

Even though attention and implementation toward chemical safety in ASEAN regions were still limited, ASEAN-5 countries had set up their occupational exposure limit (OEL),

an important instrument regarding workers' health protection from the adverse effects of occupational chemical exposure [15]. In Indonesia particularly, there are three OELs that have been published, which are: the Regulation of the Minister of Manpower of Indonesia No. 13 year 2011 on Threshold Limits of Physical and Chemical Agents in the Workplace; Regulation of the Minister of Health of Indonesia No. 70 year 2016 about the Standard and Requirements of Industrial Environment Health; and Indonesian National Standard number 19-0232-2005 on the threshold value of chemicals in the workplace air. In other ASEAN countries they have ACT 514 in Malaysia; Factories ACT (Chapter 104) in Singapore; Ministerial Regulation on the prescribing of standard for administration, management and operation of Occupational Safety, Health and Work Environment in relation to hazardous chemicals B.E. 2556 in Thailand; and Rule number 1070 in Philippines.

Since 2015, ASEAN countries has established a partnership called ASEAN Economic Community (AEC). The cooperation has four pillars, namely: single market and production base; competitive economic region, equitable economic development, and global economic integration (integration into global economy) [3]. These collaborations allow labor exchange across ASEAN countries, as well as product and materials. Regarding worker health protection, this study aimed to evaluate possibilities of OEL harmonization in ASEAN region, especially ASEAN-5. OEL from ASEAN-5 will be compared and analyzed to investigate their common and unique chemicals that are controlled, as well as OEL value compared to TLV-TWA ACGIH and OSHA PEL standard.

2. Methods

2.1. OELs database

The OEL from ASEAN-5 was collected from government's website and correspondence via electronic mail to relevant institutions. Seven OELs in ASEAN-5 Country were collected, including 3 OELs from Indonesia and 1 OEL from each Malaysia, Singapore, Thailand and Philippines.

The chemical lists from each OEL were compared side by side in an excel table. Only 'Time weighted average (TWA)', a concentration limit for 8 hours per day or 40 hours per week exposure duration in ppm was compared. Equation 1 was used to convert mg/m^3 unit into ppm. If TWA concentration was missing but STEL value was available,

TWA was gathered by dividing the STEL concentration with multiplicative factors (Table 1) [16].

$$\text{OEL in ppm} = \frac{(\text{OEL in mg/m3})(24.45)}{\text{molecular weight from substance}} \quad (1)$$

Table 1: Multiplicative factor to adjust concentration in STEL to be in TWA (Hansson 1998 in Schenk 2008).

TWA (ppm or mg/m^3)	Multiplicative factors
$X \leq 1$	3
$1 < X \leq 10$	2
$10 < X \leq 100$	1.5
$100 < X \leq 1000$	1.25
$1000 < X$	1

2.2. Common and unique substance

From the OEL database, common substances that appeared in all 7 OELs under reviewed were recognized. Unique substances which listed in one particular OEL was also identified.

2.3. Closeness of OEL ASEAN-5 with TLV-TWA ACGIH 2016 and PEL OSHA

In term of similarity of each OEL with TLV-TWA ACGIH 2016 and PEL-OSHA, geometric similarity measure (GSM) and non-metric multidimensional scaling plot were used. In GSM, concentration of each chemicals was divided by corresponding standard resulting list of ratios. Geometric mean for each OEL was then calculated from this ratio list (equation 2). Simple example of geometric similarity calculation is provided in Table 2 [17]. If GSM is higher than 1, means that the concentration limit is higher than standard OEL [16, 18]. In contrast, if GSM is smaller than 1, the concentration limit is lower than standard OEL. The closer the GSM to 1, the more similar the concentration limit to the OEL standard.

$$G_m = \left(\prod_{i=1}^{n} a_i\right)^{1/n} - 1 = \sqrt[n]{a_1 * a_2 * \cdots a_n} - 1 \quad (2)$$

Non-metric multidimensional scaling plot using R version 3.3.3 software was used to visualize proximity of all OEL being compared. Similarity of each OEL was seen from the closeness of corresponding plot in the multidimensional scaling figure [19, 20].

Table 2: Comparison of arithmetic mean and geometric mean.

Substance	OEL standard (ACGIH-TWA or PEL-OSHA)	OEL value	Comparison Ratio (OEL value/OEL comparison value)
A	10	1	0.1
B	1	1	1
C	0.1	1	10
Arithmetic Mean			3.7
Geometric Mean			1

3. Results and Discussion

3.1. Comparison of OEL characteristics

Seven OEL list from ASEAN-5 countries were compared. They were:

1. Regulation of the Minister of Manpower Indonesia No. 13 year 2011
2. Regulation of the Minister of Health Indonesia No. 70 year 2016
3. Indonesian National Standard (SNI) 19-0232-2005
4. ACT 514 Malaysia
5. Chapter 104 Factories Act Singapore
6. Thailand's OEL
7. Rule 1070 of the Philippines

Characteristics of each OEL is provided in Table 3.

Table 3: OEL list characteristic in ASEAN-5 countries.

Country	Regulation Concerning OELs	Legal Status[a]	Organization responsible for setting OEL	No. of Substance	Regular update	Last update	Base of Legislation	Factor[b]	Authority of Supervisior	Main Source of Influence
Indonesia	Regulation of the Minister of Manpower No. 13/2011 on Threshold Limits of Physical and Chemical Factors in the Workplace	M	Ministry of Manpower Indonesia	581	No	No	Law Number 1 Year 1970 on Occupational Safety; Act No. 13 of 2003 on Manpower	P	Ministry of Manpower, General Safety Expert, SMK3 Auditor	TLV ACGIH 2010
Indonesia	Regulation of the Minister of Health No. 70 of 2016 on the Requirements of the Office and Industrial Work Environmer	M	Directorate of Occupational Health and Sport Ministry of Health Republic of Indonesia	255	No	No	Law Number 1 Year 1970 on Occupational Safety; Act No. 13 of 2003 on Manpower	P	Minister, head of related institution, head of department provincial health, and heads of departments district/city health	ACGIH, NIOSH, OSHA, JSOH, Worksafe BC, HSE UK, Regulation of the Minister of Manpower No. 13/2011, SNI 19-0232-2005
Indonesia	Indonesian National Standard 19-0232-2005 on the threshold value (NAB) of chemicals in the workplace air	R	Health and Safety Technical Sub-Committee on the Committee Technical 94S, Occupational Safety and Health	618	No	No	Circular Letter of the Minister of Manpower Number: SE-01/MEN/19 on Threshold Value Chemical factors in the air of the working environmer	P	No	Research from Center for Safety and Industrial hygiene development, Department Labor and Transmigration

Country	Regulation Concerning OELs	Legal Status[a]	Organization responsible for setting OEL	No. of Substance	Regular update	Last update	Base of Legislation	Factor[b]	Authority of Supervisior	Main Source of Influence
Malaysia	Occupationa Health and Safety Act 1994 (ACT 514) Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulations	M	Department of Occupational Safety and Health, Ministry of Human Resources	556	Yes	2000	The Occupational Safety and HealthAct-The Factories and Machinery Act	P	Health and Safety Departmen	ACGIH
Singapore	Factories Act (Chapter 104) Factories (Permissible Exposure Levels of Toxic Substances) Order 1996	M	The Chemical Hazard Management Committee The Occupational Health Department Minister of Manpower	569	Yes	2004	The Factories Act	P	the Chief Inspector of Factories	ACGIHEU Australia, Canada Japan

Country	Regulation Concerning OELs	Legal Status[a]	Organization responsible for setting OEL	No. of Substance	Regular update	Last update	Base of Legislation	Factor[b]	Authority of Supervisior	Main Source of Influence
Thailand	Ministerial Regulation on the prescribing of standard for administration, management and operation of Occupational Safety, Health and Work Environment in relation to hazardous chemicals B.E. 2556	M	Ministry of Interior	106	Yes	2017 (currently in draft)	Occupationa Safety, Health and Environment Act B.E 2554 (A.D 2011)	P	Ministry of Labour Thailand	PEL US OSHA, TLV ACGIH, OSHA (Malaysia)
Philippines	RULE 1070 OCUPATIONAL HEALTH AND ENVIRONMENTAL CONTROL Occupational Safety and Health Standards (As amended, 1989)	M	Department of Labor and Employment	381	Yes	1998	Article 162 of the Labor Code of the Philippines	P	Departmen of Labor and Employmer	PEL OSHA, TLV ACGIH

Abbreviations: ACGIH, the American Conference of Industrial Hygienists; US NIOSH, the National Institute for Occupational Safety and Health h of the US; US OSHA, the Occupational Safety and Health Administration of the US.

[a]M, Mandatory; R, Recommendation

[b]P, Pragmatic; and H, Health based

There are similarities between those 7 OELs. All of the OELs referred to TLV ACGIH as main reference, as also found in European Countries [21]. The Ministry of Manpower is the main regulator of OEL development in most of ASEAN-5 countries. Except in Philippines where there is no enforcement of OEL regulations through fines and criminal penalties [22], the legal aspect of OEL in other ASEAN-4 is mandatory.

The main differences amongst ASEAN-5 OEL was the number of listed substances. SNI 19-0232-2005 has the most regulated substances, 618 in number; and Thailand's OEL has the least regulated substances, which only has 105. ASEAN-5 countries update their OEL in regular basis [21] with the exception of Indonesia. Up-dating the OELs is essential to ensure that exposure risk assessments match current scientific and industrial developments.

The list of common and unique substances available in 7 ASEAN-5 OELs can be found in Table 4 and 5, respectively. There were 40 substances that always appear in all OEL list, and the majority of those substances are in liquid or gas phase at normal room temperature and pressure. Consequently, many chemical hazards are associated with inhalation route of entry, as has been going on since the early development of the industrial world [21]. Only a few number of substances are deemed as unique substances. Interestingly, more unique substances are found in Rule 1070 of the Philippines, Chapter 104 Factories Act of Singapore, and Regulation of the Minister of Manpower Indonesia No. 13/2011 than other OELs (Table 5).

3.2. Similarities of each OEL with TLV-TWA ACGIH 2016 and PEL-OSHA

Similarities of each OEL are represented by geometric similarity measure (GSM) and are visualized in non-metric multidimensional scaling plot. GSMs of 7 OELs from ASEAN-5 countries in regard to TLV-TWA ACGIH 2016 and PEL OSHA were calculated and the results are presented in Table 6 and 7. It was found that all 7-OELs has GSM above 1 when compared to TLV-TWA ACGIH 2016, which means that generally the concentration limit for most substances in those 7-OELs were higher than TLV-TWA ACGIH 2016. Regulation of the Minister of Health Indonesia No. 70 year 2016 has the most similar concentration limit with TWA-ACGIH 2016 since the GSM is the closest to 1, followed by the Regulation of the Minister of Manpower Indonesia No. 13 year 2011; ACT 514 Malaysia; SNI 19-0232-2005; Chapter 104 Factories Act Singapura; Rule 1070 Filipina and Thailand OEL.

On the other hand, the comparison between 7 OEL of ASEAN-5' with PEL-OSHA shows a slightly different trend. Only Rule 1070 of the Philippines has a higher concentration limit than PEL-OSHA. Thailand's OEL is the most similar to PEL-OSHA, while Regulation of the Minister of Health Indonesia No. 70 year 2016 is the most dissimilar from PEL-OSHA.

Table 4: Common substances available in 7 ASEAN-5 OELs list.

Chemical name	CAS number	Physical Form (in 25 Celsius and pressure 100kPa)
Acetic acid (cuka)	64-19-7	Liquid
Ammonia	7664-41-7	Gas
Arsine	7784-42-1	Gas
Boron trifluoride	7/2/7637	Gas
Carbon dioxide	124-38-9	Gas
Carbon monoxide	630-08-0	Gas
Chlorine	7782-50-5	Gas
Chlorine dioxide	10049-04-4	Gas
Chlorine trifluoride	7790-91-2	Gas
Chloroform (Trichloromethane)	67-66-3	Liquid
DDT (Dichlorodiphenyltrichloroethane)	50-29-3	Liquid
o-Dichlorobenzene	95-50-1	Liquid
Ethyl mercaptan	75-08-1	Liquid
Ethylene glycol dinitrate	628-96-6	Liquid
Hydrogen cyanide	74-90-8	Gas
Iodine	7553-56-2	Liquid
Iron oxide	1309-37-1	Solid
Lindane	58-89-9	Liquid
Methanol (Methyl Alcohol)	67-56-1	Solid
Methyl chloride	74-87-3	Gas
Methylene bisphenyl isocyanate	101-68-8	Solid
Methyl mercaptan	74-93-1	Gas
Nickel carbonyl (as Ni)	13463-39-3	Liquid
Nicotine	54-11-5	Solid
Nitric acid	7697-37-2	Liquid
Nitric oxide	10102-43-9	Gas
Nitrogen dioxide	10102-44-0	Gas
Parathion	56-38-2	Solid
Phosgene (Carbonyl chloride)	75-44-5	Gas
Phosphorus (yellow)	12185-10-13	Solid
Styrene, monomer	100-42-5	Liquid
Sulfur dioxide	9/5/7446	Gas
Tetraethyl lead (as Pb)	78-00-2	Liquid
Thallium, soluble compounds (as Tl)	7440-28-0	Solid
Tin, organic compounds (as Sn)	7440-31-5	Solid
Toluene	108-88-3	Liquid
Toluene-2,4-diisocyanate (TDI)	584-84-9	Liquid
Trichloroethylene	79-01-6	Liquid
Xylenes (o-, m-, p-isomers)	1330-20-7	Liquid
Zinc oxide	1314-13-2	Solid

Table 5: Unique substances that are only available at particular OEL list.

OEL list	Number of unique substance	Unique substance list
Thailand's OEL	7	Amorphous Bisphenol Chrome and its compound Dimethyl 1,2-dibromo 2,2 dichloroethyl phosphate (dibrom) Iodine Tiram Tremolite
Regulation of the Minister of Health Indonesia No. 70 year 2016	2	Calcium carbonate Dimethyl disulphide
Chapter 104 Factories Act Singapura	11	Aluminum Welding Fume as Al; Aluminum soluble salt as Al; Aluminum alkyl as Al; Ammonium perfluorooctanoate; Borates, tetra sodium salts; Calcium cyanide; Coal respirable dust; Potassium cyanide; Silica-amorphous; Tin metal; Zinc oxide dust
Rule 1070 of the Philippines	29	Calcium arsenate Chloroethylene Chloroprene Chromic acid and chromate 1,2-dichloroethane Dichloromethane 1,2-dichloropropane Diethylether Dihydroxybenzene Dimethoxymethane Dimethylaminobenzene 2,6-Dimethyl-4-Heptanone Dipropylene Glycol Methyl Ether Ethyl Sec-Amyl Ketone Furtural Furiaryl alcohol Guthion Hydrogen Fluoride Methyl Cellosolve Methyl Cellosolve acetate Methyl Styrene Monomethyl hydrazine Phenothiazine Phosphorus Pentachloride Polytetrafluoroethylene decomposition RDX Systox Teffon Vinyl Cyanide
Regulation of the Minister of Manpower Indonesia No. 13/2011	12	Aliphatic hydrocarbon 3-amino 1,2,4-triazole 2-aminoethanol Aseton sianohidrin Disiston Epoxypropane 2,3 epoxy-1-propanol Ethantyol Metantiol Phenythylene Silica gel Weld fume
SNI 19-0232-2005	6	4-aminodifenil Amosite asbestos Krisotil asbestos Krisodolit asbestos Methyl Carbomyl chlor rosin
ACT 514 Malaysia	6	coal tar pitch volatiles as benzene soluble rubber fume rubber process dust precipitated silica triphenyl amine m-xylene alpha diamine

Table 6: Geometric similarity measure of ASEAN-5 OELs compared to TLV-TWA ACGIH 2016.

OEL list	Geometric similarity measure (GSM)
Thailand OEL	2.85
Regulation of the Minister of Health Indonesia No. 70 year 2016	1.245
Chapter 104 Factories Act Singapore	1.634
Rule 1070 Philippines	2.578
Regulation of the Minister of Manpower Indonesia No. 13 year 2011	1.323
SNI 19-0232-2005	1.468
ACT 514 Malaysia	1.405

Table 7: Geometric similarity measures of ASEAN-5 OELs compared to PEL OSHA.

OEL list	Geometric means
Thailand OEL	0.980
Regulation of the Minister of Health Indonesia No. 70 year 2016	0.505
Chapter 104 Factories Act Singapore	0.689
Rule 1070 Philippines	1.049
Permenaker 13 tahun 201 Regulation of the Minister of Manpower Indonesia No. 13 year 2011	0.936
SNI 2015	0.585
ACT 514 Malaysia	0.638

Using a non-metric multidimensional scaling plot, similarities of each OEL can be visualized. Figure 1 shows the distribution of each OEL. It shows that TLV ACGIH 2016, SNI 19-0232-2005, ACT 514 Malaysia, Regulation of Ministry of Manpower Indonesia number 13 Year 2011, and Chapter 104 Singapore are very similar, compared to other 4 OELs (PEL-OSHA; Thailand OEL; Rule 1070 of the Philippines; and Regulation of the Minister of Health No. 70 of 2016). In addition, the position of Thailand's OEL list and Regulation of the Minister of Health No. 70 of 2016 in the scaling plot is relatively far from other OELs lists. This difference is because of those two OELs have less number of chemical substance, which are 106 substances in Thailand's OEL and 255 in Regulation of the Minister of Health Indonesia No. 70 of 2016. This number is much smaller than other OEL lists that are having 313 to 713 chemical substances.

According to these findings, there is potential in harmonizing the OELs because of their similarities from both type of substances and concentration limit. However, more studies are needed to explore the challenges and opportunities regarding harmonizing the OELs.

Conflict of Interest

Authors declare that they have no competing interest.

Funding

The authors thank the Indonesia Endowment Fund for funding this research.

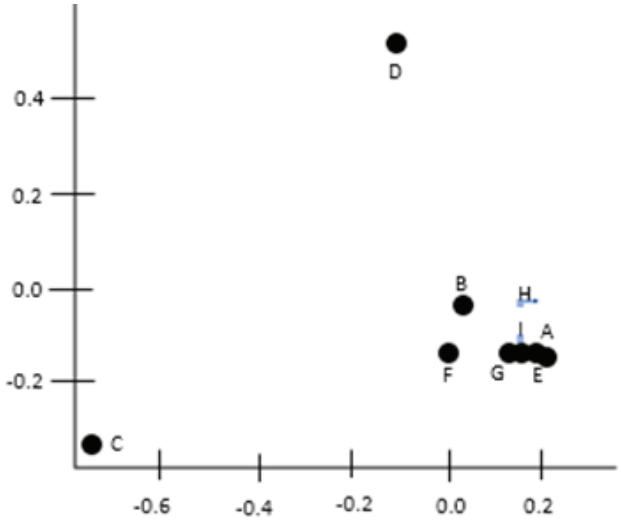

Figure 1: Graphic *scaling plot non-metric multidimensional* in comparing ASEAN-5's OEL list with PEL OSHA 2016 and TLV ACGIH 2016 with using *software* R. A = TLV ACGIH 2016, B = PEL OSHA 2016, C = OEL Thailand, D = Regulation of the Minister of Health No. 70 of 2016, E = Chapter 104 Factories Act Singapura, F = Rule 1070 Filipina, G = Regulation of the Minister of Manpower Indonesia No. 13/2011, H = SNI 19-0232-2005, I = ACT 514 Malaysia.

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