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# Proposal of Development of Welding Health-Hazard Index (WHI) for Small and Medium Enterprises (SMEs)

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## ABSTRACT

In 2009, there were 28,840 small and medium enterprises (SMEs) which represented 94.2 % of the total establishments in the manufacturing sector in Malaysia. The SMEs have some setbacks such as poorer working conditions and worker's safety and health measures are more likely to be neglected. Welding fumes assessment in SMEs welding workplace is essential in order to ensure the minimum level of exposure is maintained as required by the prevailing standards. However, providing concentration or emission information alone is insufficient and meaningless to the non-expert/ workers. There is an urgent need to develop an index that can simplify the health and hazard issues of fumes to be comprehended easily by the workers and company management. Series of subjective measurement to investigate persistent symptom experience by the welder will be carried out along with spirometry test for verification purposes. Statistical method will be used to get the correlation between index value and persistent symptom experienced by the SMEs welders. This developed index will hopefully be able to harness preventive and voluntary risk control by the welder.

**Keyword:** *welding index, small and medium enterprises, welding hazard.*

## 1. INTRODUCTION

Welding is a common industrial process. Hazard that has both acute and long-term chronic effects is welding fume/particulate matters and toxic gases. Fumes are solid particles that originate from welding consumables, the base metal and any coatings present on the base metal. In welding, the intense heat of the arc or flame vaporizes the base metal and/or electrode coating. This vaporized metal condenses into tiny particles called fumes that can be inhaled. The thermal effects can cause agglomeration of the particles into particle chains and clusters that can be deposited in the human respiratory tract [1-3]. Toxic gases also produce from welding processes which include nitric oxide, nitrogen dioxide, carbon monoxide and ozone. These toxic gases can cause pulmonary oedema, headache and drowsiness. [4]

The hazards of welding depends on several factors, 1) type of welding being performed, 2) material the electrode being made, 3) type of material being welded, 4) presence of coatings on the metal, 5) voltage and current used and 6) type of ventilation [4, 5].

Epidemiological studies regarding the effect of weld fume constituent towards human being/ welders are enormous in quantity. Ironically these epidemiological studies finding are not sufficiently been aware by the welder itself resulting in a very poor practical of safety in welding practice. Indoor Air Quality investigator or an industrial hygienist providing emission and pollution concentration alone is meaningless to the non-expert (welders). This raises the question on how actually the effective way to give awareness to the welders and voluntary protect themselves from the hazardous welding emissions. There is an urgent need to develop a health-hazard index for welders because the index ranks the state of the environment in terms that the public and companies management can comprehend easily.

Factor such as chemical (gas, fumes) and biological (carcinogenic, toxicity) will be studied closely to characterize the welding exposure. Each welding

workplace should be indexed from acceptable to the extremely hazardous level and suggested countermeasure will also be proposed. As a result, welders would have a guideline to follow when dealing with certain job process and take appropriate countermeasure when dealing with hazardous welding process.

## 2. MOTIVATION

There is a growing trend in re-orienting occupational health research towards risk management. Such a trend is accelerated by the increasing attention to occupational safety and health management system [6]. Occupational Safety and Health Master Plan for Malaysian 2010-2015 had outline four keys strategies including the 'Inculcating Preventative Workplace Culture' emphasizes the proactive management of hazards to eliminate them wherever practicable and, if this is not possible, it then focuses on isolating and minimizing the hazard [7]. MS 31000:2010 for Risk Management had been published recently. While all organizations manage risk to some degree, this International Standard establishes a number of principles that need to be satisfied to make risk management effective. This International Standard recommends that organizations develop, implement and continuously improve a framework whose purpose is to integrate the process for managing risk into the organization's overall governance, strategy and planning, management, reporting processes, policies, values and culture [8]. Although Occupational Safety and Health Management System in Malaysia without nationally specific applied models, the Occupational Safety and Health Act of Malaysia 1994 facilitates the government action supporting self-regulation in OSH management.

According to Annual Survey of Manufacturing Enterprises conducted in 2010 for reference year 2009, majority of the Small and Medium Enterprises (SMEs) mainly involved in several industrial sectors such as manufacturing, agriculture, mining, services and construction. In 2009, there were 28,840 SME's which represented 94.2 per cent

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of the total establishments in the manufacturing sector, while the remaining were large establishments with total of 1, 767 establishments. The total numbers of employees engaged by SME's establishments were 648,458 workers or 38.3 per cent of total employment in manufacturing sector (1, 693, 154 workers). Of the total number of paid full-time employees in SME's, production / operative workers directly employed were the largest group with 56.6 per cent (348, 247 persons). In general, majority of the workers 1, 383, 334 persons or 81.7 per cent of total persons engaged in 2009 in this sector possessed qualification of SPM / SPMV or equivalent and below [9]. According to the Small Medium Enterprise Corporation, small enterprise is define as sales turnover between RM250, 000 and RM10 million or full time employees between 5 and 50. Meanwhile medium enterprise is define as sales turnover between RM10 million and RM25 million or full time employees between 51 and 150 [10]. Welders are not homogeneous group, the potential adverse effect of welding fumes exposures are oftentimes difficult to evaluate. Difference exist in welder populations, such as industrial setting, the type welding processes and materials used, ventilation and others occupational exposures beside welding fumes ( e.g solvents, asbestos, silica) [11]. From the stand point of industrial hygiene, the small and medium enterprises have vulnerability that must be recognized. This can attributes to a number of factors including the subordinate nature of smaller companies to larger ones, immaturity of management organizations, insufficient human resources, and delayed adoption of new technologies and equipment. As a consequences, in general, working conditions tend to be poorer, the work environment is worse, there is more hazardous work associated with higher rates of industrial accidents and occupational diseases, worker safety measures are more

likely to be neglected, and there is a greater dependence on unstable sources of labor such as part time workers than in case of larger companies [12]. There is critical need to develop a health-hazard index in SMEs for enhancing the safety and health of the welders.

### 3. RELATED WORKS

Environmental quality indices had been developed and applied for ambient air and water quality. However, indices for indoor air quality are limited and relatively novel. From 2000 till recently only a few indices on indoor air quality had been developed. Two of the worth mentioning pioneering indices are Indoor Air Pollution Index (IAPI) [13] and Indoor Pollutant Standard Index (IPSI) [14]. These indices had attracted attention argument and commentary from the Indoor Environment community. List of recommendation and further research needs on this area had been highlighted by several experts [15-17]. Comments and recommendation of the developed indices had also been reply by the designated author [18, 19] to answer the arguments and comments highlighted. The development of indoor air quality indices leaves an open ended question to be further investigated and study. Nevertheless the development of IAPI and IPSI can be regard as pioneering and creative effort by both author and co-authors in an area that have received insufficient attention. Unfortunately there seems no further investigation had been carried out to continue these efforts mainly due to the difficulty encounter when neither the health effect nor the causal exposure are well defined in building related syndrome. Table-1 shows the indoor environment indices that had been developed from 2000 until recently.

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**Table-1.** Indoor environment indices that had been developed.

No	Author	Index name	Purpose	Health based	Formulae	Aggregation model type
1	[20]	Indoor Air Pollution Index (IAPI)	Categorize work division for safety and hygiene	Yes	$EQI = \sum \text{individual IPU}$ Index value 1 -5 (good /healthy) to 20-25 (hazardous)	additive
2	[21]	Indoor Pollution Standard Index (IPSI)	Labeling of building in term of energy consumption by referring to Portuguese Guideline.	No	$IEI = (IAPI + IDI) / 2$ IAPI: Indoor Air Pollution Index IDI: Indoor Discomfort Index For IAPI 1 (lowest pollution level) to 10 (highest pollution level) For IDI 0 (low discomfort) to 10 (high discomfort)	additive (arithmetic mean)
3	[22]	Index of Comprehensive Percentage Dissatisfied (CPD)	Ranking a subject building relative to other building and relates with occupant symptom.	Yes	$IEI = (IAPI + IDI) / 2$ I API: Indoor Air Pollution Index For IAPI 1 (lowest pollution level) to 10 (highest pollution level) For IDI 0 (low discomfort) to 10 (high discomfort)	additive (arithmetic mean)
4	[13]	Indoor Air Pollution Index (IAPI)	Provides a relative measure of indoor air pollution for office building associate with occupant symptom and percentage of occupant with persistent symptoms.	Yes	Refer <i>Appendix A</i>	additive (arithmetic mean)
5	[14]	Indoor Pollution Standard Index (IPSI)	To express the quality of indoor air in different premises	No	$IPSI = \max(S1, S2, S3, \dots, S8)$ S: sub indices for each parameter 0 to 10 index value 2(guideline value), 10 (significant harm)	Logical (maximum operator)
6	[23]	Index of Comprehensive Percentage Dissatisfied (CPD)	To evaluate the comfort situations of indoor environment	No	$CPD = \alpha_1 TPD + \alpha_2 NPD + \alpha_3 QPD$ TPD: Thermal Percentage Dissatisfied NPD: Noise caused Percentage Dissatisfied QPD: Air Quality caused Percentage Dissatisfied $\alpha_1, \alpha_2, \alpha_3$ : respective coefficient CPD <20% (comfortable) CPD 80-100% (very uncomfortable)	additive (weighted arithmetic mean)

Development of indices to rank and provide a composite picture of an environmental condition derived from a series of observed measurements and parameters should benefit to the industrial field where the causal exposure are well defined such as on welding related process. The development of indoor air quality welding indices should benefited SMEs since larger companies would have sufficient resources for creating a safer and healthier workplace. Thus there is a need to development a welding

health-hazard index for SMEs in Malaysia. The index of environmental quality must satisfy three requirements [22]

- 1) Index must be understood easily by all involved in assessing the environment, including the consumer, the potential polluter, the scientist and the regulator.
- 2) Index must associate well with the measurement of impacts cause by the contaminant ranked by the index.

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- 3) Index must enable those concerned to manage the environment efficiently.

From a regulatory compliances perspective, threshold levels of parameters are established in the context of possible adverse human health impacts. These thresholds values can be standard, guidelines, self imposed limits or best practice. As a result, it is useful to relate the index to some sort of acceptability measures. Development of environmental index involves following four basic steps [24].

- 1) Selection of relevant factors and parameters.
- 2) Transformation of selected parameters into sub indices
- 3) Derivation of weights
- 4) Aggregation of sub indices to determine the value model using a specific model

There is a few issues that should be highlighted here and consider in developing an index [24-27]

- 1) Ambiguity: index exceeds the critical level (unacceptable value) without any of the sub indices exceeding the critical level.
- 2) Eclipsing: index does not exceed the critical level (unacceptable value) despite one or more of the sub indices exceeding critical level.
- 3) Compensation: this property helps to account for the contribution of all sub-indices to not be biased to the extremes (highest or lowest sub index value).
- 4) Rigidity: this property helps to account new sub indices added in the aggregation model will not reduce the index value irrespective of the magnitude of sub indices.

#### 4. PROPOSED METHODOLOGY

Process flow to describe the methodology of the study is shown as in *Appendix B*. The study will be carried out in the following main three phases; Subjective and Physical measurement, Development of Welding Health-Hazard Index and Validation of the Developed Index. The followings will explain in detail each phases accordingly.

##### Phase 1: Subjective and Physical Measurement

The first phase is to conduct data collection. Two type of measurement will be carried out;

- i. Subjective measurement
  - a. System development (using QFD approach)
  - b. Welders persistent symptom
- ii. Physical measurement
  - a. Spirometry test for welders
  - b. Welding fumes concentration

The first questionnaire will be use to collect information on what type of health risk should the developed index portray as preferred by the welders by using Quality Function Deployment (QFD) approach. It is important that the survey question must be valid and reliable before distributed to the welders. Step to reserve the confidentiality of the information obtained will be taken.

The second questionnaire gathers the information of persistent symptom that had been experienced by the welders. Persistent symptom refer to symptoms that been experienced by the welder 'Yes, each time after conducting welding works', 'Yes, frequently' and 'Yes, occasionally' for the past 3 months. The symptom investigated should reflect the symptom caused by welding metal fumes.

In order to validate the persistent symptom experience by the welders, physical measurement of spirometry test to detect lung deterioration symptom in welders must be conducted. Series of on-site welding metal fumes measurement will also be carried out. The sample taken should be analyzed statistically to represent true population in normally distributed data. A standardize method for the welding exposure sampling and analysis will be used to maximize the validity and reliability of the data.

##### Phase 2: Development of Welding Health-Hazard Index

In this phase, welding health-hazard index will be developed by using information acquire from the QFD approach and the concentration of the welding metal fumes. Issues on development of index such as chemical mixture, transformation to sub indices, derivation of weights of sub indices, suitable aggregation models, ambiguity, eclipsing, compensation and rigidity issues will be analyze. The index will be formulate for easy understanding and relates with occupant symptom.

##### Phase 3: Verification of Developed Index

The developed index will be verified with a correlation between index value and persistent symptom. Using a suitable statistical approach, a strong relationship between persistent symptom and value index should be established. Index must associate well with the measurement of impacts cause by the contaminant ranked by the index.

#### 5. EXPECTED RESULT

Potential contributions of this study are as follow;

- i It is expected that better understanding of welding exposure in Malaysia welding related small and medium industry will be obtained in order to promote protection through legislation, health communications strategies or behavioral intervention where such data are needed.
- ii Development of a welding health-hazard index as a guideline and to harness awareness and voluntary preventative workplace culture on exposure of weld fume related with welders in small and medium industry.

#### 6. LIMITATIONS

In general the index will be developed according to multiple measured pollutant concentration. There are limitations on the available analytical method for welding fumes and toxic gas provided by the government accredited laboratory in Malaysia. Due to this limitations, only a shortlisted analytical method can be conducted and consider in the development index.

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Appendix A

$$IAPL = \frac{1}{I} \sum_{i=1}^I \frac{1}{J} \sum_{j=1}^J \frac{1}{K} \sum_{k=1}^K 10 \left( 1 - \frac{C_{ijk}^{max} - C_{ijk}^{obs}}{C_{ijk}^{max} - C_{ijk}^{min}} \left( \frac{C_{ijk}^{dmc} - C_{ijk}^{obs}}{C_{ijk}^{dmc}} \right) \right) \text{ For } C^{max} > C^{obs} \text{ and } C^{dmc} > C^{obs} > C^{min}$$

Where I: number of level 3 group (I=2)  
 J: number of level 2 group in each level 3 group (J=2)  
 K: number of level 1 pollutant variables in each level 2 groups (K=2)  
 max: maximum measured concentration  
 min: minimum measured concentration  
 dmc: demarcation concentration  
 obs: measured concentration in the subject building

Appendix B  
 Flow Chart of Research Activities

