International Journal of Automotive and Mechanical Engineering (IJAME)
ISSN: 2229-8649 (Print); ISSN: 2180-1606 (Online); Volume 9, pp. 1609-1619, January-June 2014

DOI: http://dx.doi.org/10.15282/ijame.9.2013.11.0133

DETERMINATION OF CUSTOMER REQUIREMENT FOR WELDING FUMES INDEX DEVELOPMENT IN AUTOMOTIVE INDUSTRIES BY USING QUALITY FUNCTION DEPLOYMENT APPROACH

Azian Hariri[1*], N. Azreen P.[1] , Norhidayah Abdull[3], A. M Leman[2] and M. Z. M Yusof[1]

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
*Email: azian@uthm.edu.my
Phone : +6074537880; Fax : +6074536080
[2]Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia
[3]Faculty of Technology Management, Universiti Malaysia Pahang,
Lebuhraya Tun Razak, 26300 Kuantan, Pahang, Malaysia

ABSTRACT

This paper discusses the determination of customer requirements for the development of a welding fumes index by using a Quality Function Deployment (QFD) approach. A welding fumes index is developed with the objective of enhancing welding workplace safety and health. The index simplifies complex health-hazard issues of welding fumes so that they can be comprehended easily by employees and administrators. Likert scale questionnaires on welders' desire to know about the health effects of the various welding fumes that exist in their workplace were distributed among welders in the automotive assembly industry in the state of Pahang, Malaysia. A pilot test of the QFD questionnaire was done (n=11) and Cronbach Alpha's analysis is 0.967, which indicates a high level of internal consistency of the questionnaire scale. In the actual sampling (n=32), the results of the questionnaires show that all the customer requirements (irritant effect, sensitizer effects, respiratory system effect, systemic toxin effect, reproductive toxins effect, carcinogen effect, mixture effect) were equally important to the welders. The relationship between the customer (welder) requirement and technical characteristics was established, whereby important technical characteristics were shortlisted (personal sampling 23.0%, multi chemical analysis 20.8%, exposure limit 19.7%, health questionnaire 17.6% and lung function test 14.7%). Development of welding fumes indices according to employee demand will increase knowledge and awareness of occupational safety and health among employees (welders).

Keywords**:** Welding fumes; welding health effect; quality function deployment.

INTRODUCTION

Hundreds of millions of people throughout the world work in circumstances that foster ill health or are unsafe. It is estimated that over two million people worldwide die annually of occupational injuries and work-related diseases. In fact, more people die from diseases caused by work than are killed in industrial accidents (Hassim & Hurme, 2010). There are two main acts in Malaysia covering occupational and safety; the Factories and Machinery Act (Act 139) (Malaysia, 2010a) and the Malaysian Occupational Safety and Health Act (Act 514) (Malaysia, 2010b). The Department of Occupational Safety and Health (DOSH) is the only government agency responsible for administering, managing and enforcing legislation pertaining to occupational safety and health in Malaysia. An effective approach to health and safety at work needs a suitable risk assessment phase. However, little attention has been paid to this phase of the practice, and inappropriate tools and methodologies have been used which are either too complex to manage or too simple and subjective, and are thus unsuitable for recognizing hazards and reducing the corresponding risks (Fera & Macchiaroli, 2010). Difficulty exists in measuring the two quantities with which risk assessment is concerned, which are the potential loss and the probability of occurrence. The chance of error in measuring these two quantities is large. A risk involving a large potential loss and a low probability of occurrence is often treated differently from a risk with a low potential loss and a high likelihood of occurrence. In theory, both are of nearly equal priority, but in practice it can be very difficult to manage. A risk assessment would be simpler if transformed into a single metric which could embody all of the important information (Kirch, 2008). Thus, transforming the risk assessment into an environmental index form would be the best solution.

Although there is a broad range of hazards that exist in welding operations, only 2% of Occupational Safety and Health Association (OSHA) general industry citations address this matter (Asfahl, 2004). Welding is a common industrial process. A hazard that has both acute and long-term chronic effects is welding fume/ particulate matters. Fumes are solid particles that originate from the 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 (Ashby, 2002; Fiore, 2006; Ravert, 2006). Most of the particles in welding fumes are less than 1µm in diameter when produced, but they appear to grow in size with time due to agglomeration (Isaxon et al., 2009). This study was conducted in order to determine the customer requirement for the development of a Welding Fumes Index as an assessment tool for exposure to welding fumes in automotive related industries in Malaysia.

LITERATURE REVIEW

Occupational Safety and Health in Malaysia

Malaysia is a developing nation and the manufacturing sector is the major contributor to the Malaysian economy, with a total of 1,023,072 people engaged in the sector in November 2012 (Department of Statistic, 2013). Welding is a common industrial process in the manufacturing sector that has both acute and long-term chronic hazards, mainly from the inhalable welding fumes. Currently in Malaysia, according to the Occupational Safety and Health Act (1994), under the Use and Standards of Exposure to Chemicals Hazardous to Health (USECHH), chemical health risk assessment (CHRA) needs to be carried out by an assessor appointed by the employer (Malaysia, 2000). A chemical health risk assessment report is produced by the assessor which includes potential risks, nature of hazards to health, methods and procedures in the use of chemicals, degree of exposure and control measures. Chemical health risk assessment in the welding workplace is essential in order to ensure that the minimum level of exposure is maintained, as required by the prevailing standards. However, important information provided by the assessor, especially the degree of exposure, has usually been held by the safety and health officer and company management. In terms of health effects, the employees should also be notified of the degree of exposure in their workplace. Good safety and health practises can be improved further if the chemical exposure is well understood by the employees. Thus, there is an urgent need to develop an index as a ranking tool to simplify complex health-hazard issues of welding fumes so that they can be comprehended easily by the employees.

Occupational Safety and Health Assessment

Occupational safety and health assessment of the exposure to chemicals hazardous to health has attracted the attention of researchers all over the world. However, assessment related to human health aspects is very limited. Employees are the personnel most affected by exposure to chemicals hazardous to health. However, in general, risk is evaluated in terms of its consequences with respect to project performance and rarely in terms of human suffering (Badri, Nadeau, & Gbodossou, 2011). (Smallwood, 2004) confirmed that quality, planning and costs are the parameters given the greatest consideration. Instead of developing a risk assessment method focused on project performance, planning and cost, this study will try using a new and different approach by focusing on the human health aspect. This study highlights that employees should know what type of health risk they face. By using the QFD approach, this study will ask employees what health risks the index should portray, based on the NIOSH Pocket Guide to Chemical Hazards (NIOSH, 2007). Development of welding fumes indices according to employee demand will hopefully increase the knowledge and awareness of occupational safety and health among employees. In welding processes, only a very limited risk assessment model has been developed. (Karkoszka & Sokovic, 2012) developed an integrated risk estimation in the welding process using qualitative methods of assigning the probability of occurrence, significance and risk involved in aspects of occupational health and safety. However, this model did not consider the quantitative data on chemical exposure. Thus, there is still gap in developing a suitable risk assessment method relating welding fume exposure to health risks for welders in a quantitative manner.

(NIOSH, 1998a) highlighted that research is needed to pursue a means of indexing exposure by job type or process, taking into account the intensity of the welding job and work practices. However, welders are not a homogeneous group, and the potential adverse effects of welding fume exposure are often difficult to evaluate. Differences exist in welder populations, such as industrial setting, types of ventilation, type of welding processes and materials used (Antonini et al., 2006). Indexing exposure by job type or process is almost impossible to implement. However, indexing exposure according to the location would be of benefit as a ranking tool between different locations and to assist comparison with the same scale before and after implementation of any exposure control. The index value should relate proportionally to the health symptoms of the welders. (Kirch, 2008) also agreed that risk assessment would be simpler if a single metric could embody all of the information in the measurement. The main idea of the development of the welding fumes index by the authors can be referred to (Hariri, Leman, & Yusof, 2012; Hariri, Yusof, & Leman, 2012). (Hewitt, 2001) highlighted the challenges for developing countries in strategies for risk assessment and control in welding. Developing countries are being increasingly drawn into the global economy, where the transfer of technologies such as welding from developing economies into those which do not have similar infrastructures in terms of health and safety may be disastrous. Uncritical adoption of new welding technologies by developing countries opens the door to future health problems. This view was also supported by (Baram, 2009). Hence, there is an urgent need to develop an index that can interpret the chemical exposure in welding processes into a simpler form to be comprehended easily by employees. In such conditions, a welding fumes index for welders is seen as a positive move in developing ranking tools to highlight risks and give awareness to the welder when dealing with their daily work.

Environmental Index

The purpose of an environmental index is to summarize a large volume of information and represent it as a single ordinal number that is easy to understand. The environmental index is used to describe the quality or health of a specific environmental system such as air, water, soil and sediments (Sadiq, Haji, Cool, & Rodriguez, 2010). The index is a single number aggregated mathematically from two or more environmental indicators, where an indicator is a single quantity derived from one pollutant variable (Ott, 1978). An index is constructed from several indicators weighted together to describe the total impact on a certain aspect of the broader state of the environment. The aggregation process simplifies the complexity of the issues at hand and forms a link between the scientific community, the public and decision makers because the index communicates the state of the environment in terms that the public can easily comprehend (Sofuoglu & Moschandreas, 2003). From a regulatory compliance perspective, threshold levels of parameters are established in the context of possible adverse human health impacts. These threshold values can be standardized, guidelines, self-imposed limits or best practice. As a result, it is useful to relate the index to some sort of acceptability measure. The development of an environmental index involves the following four basic steps: 1. selection of relevant factors and parameters, 2. transformation of selected parameters into a sub index; 3. derivation of weights, and 4. aggregation of the sub index to determine the value model using a specific model (Sadiq et al., 2010).

In selecting appropriate and relevant parameters, the overall index must first have a specific goal or objective. Practically, it is impossible to include every single parameter related to the index. Therefore, a few representative measurable parameters are selected for practical and cost-effective purposes. After the selection of relevant factors and parameters, they are converted into a sub index on a dimensionless scale using a transformation function such as a linear, segmented linear, or non-linear system in varying degrees. Therefore, the weights are assigned based on their importance and their possible impact on the environmental system to be investigated. The last step in developing the index is to combine all the sub indexes using an aggregation model that describes the overall condition of the environmental system. Some of the information is lost during this process, but that loss should not lead to the results being misinterpreted, otherwise the usefulness of the index will decline (Ott, 1978; Sadiq et al., 2010).

Quality Function Deployment

Quality Function Deployment (QFD) is a well-known customer-oriented methodology for planning quality and controlling product development processes, from the conceptual design to manufacturing operations, in response to the voice of the customer (Akao, 1990). QFD involves two main aspects: customer requirements and design specifications. Customer requirements are usually expressed in qualitative characteristic terms collected through questionnaires (e.g. desire to be notified of respiratory effect, neurotoxins effect and carcinogenicity effect). Design specifications are the conversion of customer needs into measurable characteristics (welding fumes concentration, analysis of metal elements existing in welding fumes and metal element threshold limit). House of Quality (HoQ) is the main construct of QFD. HoQ is a matrix that provides an efficient means of relating customer requirements and design specifications. The matrix consists of several sections or sub matrices joined together in various ways, each containing information related to the others, as shown in Figure 1 (Cohen, 1995).

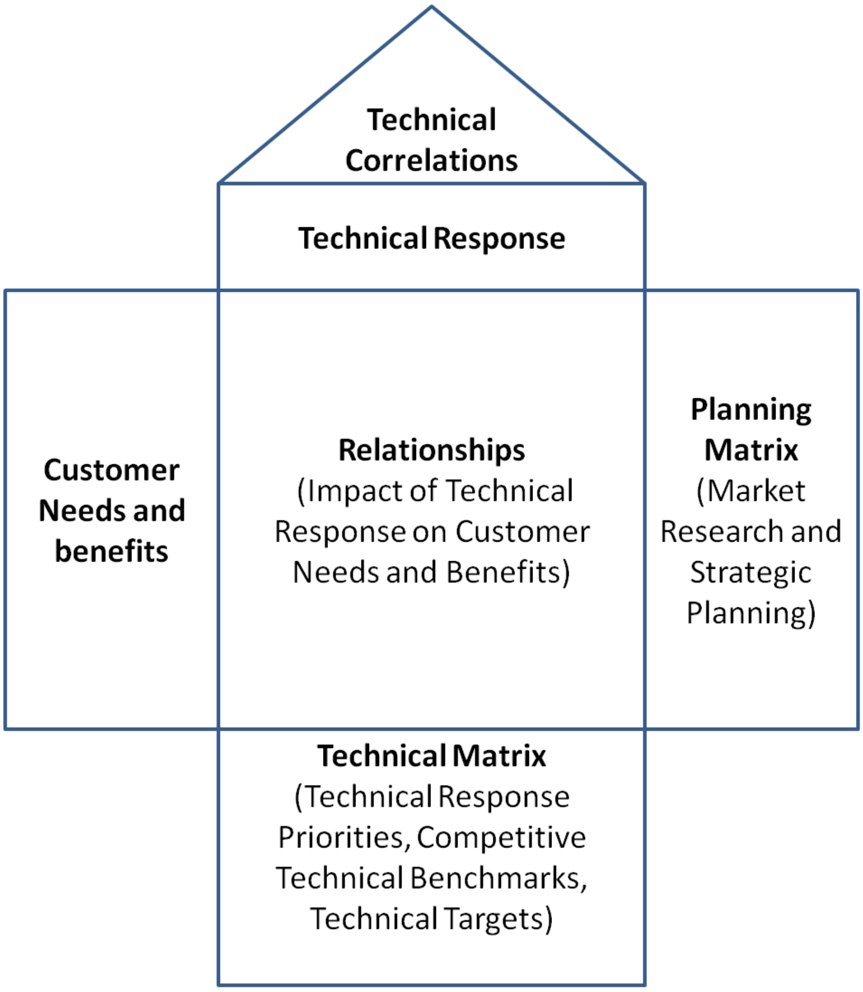


Figure 1. House of Quality (HoQ).

QFD is mainly applied for manufacturing purposes and there is very limited work on the application of QFD for health and safety purposes. (Francisque, Rodriguez, Sadiq, Miranda, & Proulx, 2011) used the QFD approach to identify and prioritize the factors to reconcile the actual and perceived risk of drinking water by considering customer complaints about water safety. The author concludes that the customer requirement for water safety can be satisfied by improving the highest impact characteristics to the level expected by the customer. (Leman, Yusof, Omar, & W.Jung, 2010) used the QFD approach in designing an industrial air pollution monitoring system for safety and health enhancement of toxic gases produced by welding processes. The system was developed according to employee requirements collected through a questionnaire and successfully fulfils the criteria required by the customer. Both of these studies successfully integrated QFD in the safety and health area and proved the flexibility and reliability of QFD approach.

METHODOLOGY

A pilot case study (n=11) was conducted in the automotive industry in Pahang. Welders were asked to answer a self-administered questionnaire on their desire to know about the health effects that arise in their workplace. A 5-point Likert scale was used in the questionnaires (1: really do not want to know, 2: do not want to know, 3: not sure, 4: want to know, 5: really want to know). These questionnaires were then collected and analyzed using the QFD method. The internal consistencies of the scale used in the pilot case study were analyzed by Cronbach's Alpha for reliability. Based on the pilot case study, improvements were made to the questionnaire and an actual case study (n=32) was carried out on all welders in the same companies.

Customer Requirement

Customer requirements are the list of basic demands that play a major role in the QFD approach. In this case, the customers are the welders in the automotive industry. To shortlist the customer requirements on health effects during welding processes, data on the health effects of metal fumes were collected from the Pocket Guide to Chemical Hazards (NIOSH, 2007) and OSHA Welding Health Hazard Report (OSHA, 1996). There are seven categories of health effect associated with welding fumes: irritants, sensitizers, respiratory effect, systemic toxins, neurotoxins, reproductive toxins and carcinogens. One more element to consider in this study is the combined effect of exposure to the metal fumes. Apart from the health impacts of the individual metal elements, the hazards from mixtures of these metal elements also need to be considered. The mixture hazard can be initially quantified using the Hazard Index (HI) approach by summing the concentration of the individual mixture components after they have been scaled for toxic potency relative to each other (Mumtaz, 2010; Nims, 1999; Nordberg, Fowler, Nordberg, & Friberg, 2007). If the HI value exceeds 1, further analysis is needed. From these eight major health effects of welding fumes, welders were asked through the questionnaire about what type of health effects they wanted to know about in their welding workplace.

Technical Requirement

On the technical characteristics to meet these customer requirements, a total of nine technical requirements were considered, as follows: personal sampling, area sampling, direct reading sampling, multi chemical analysis, blood/tissue test, chest x-ray, exposure limit, health questionnaire and lung function test. The technical requirements were shortlisted according to the Guidelines on Monitoring of Airborne Contaminants for

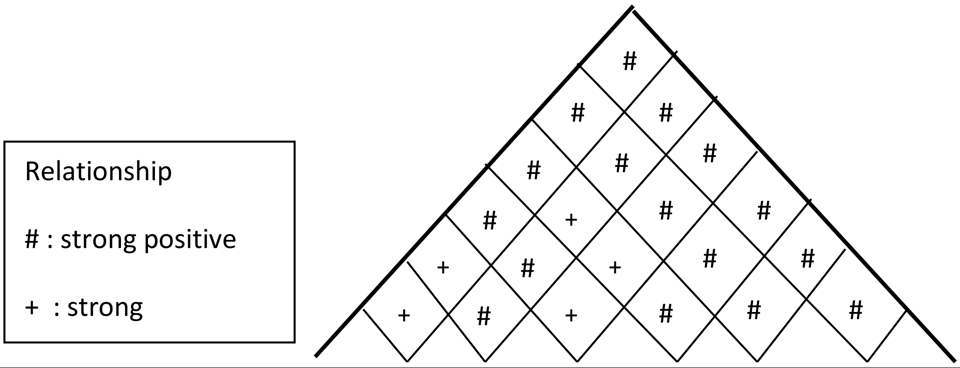
Chemicals Hazardous to Health (DOSH, 2005) and NIOSH USAPublication No. 2005-110: Specific Medical Tests or Examinations Published in the Literature for OSHA-regulated Substances (NIOSH, 2004). However, blood/tissue tests and chest x-rays were omitted due to limitations in cost and practicality.

RESULTS AND DISCUSSION

QFD involves two main aspects: customer requirements and technical characteristics. Customer requirements are usually expressed in qualitative characteristic terms collected through questionnaires (desire to know the health effects that exist in the workplace; irritants, sensitizers, respiratory system, systemic toxins, neurotoxins, reproductive toxins, carcinogens and mixture hazard). Technical characteristics are the conversion of customer needs into measure characteristics. The technical characteristics considered in this study were personal sampling, area sampling, direct reading sampling, multi chemical analysis, exposure limits, health questionnaire and lung function test. House of Quality (HoQ), which is the main construct of a QFD, is a matrix that provides an efficient means of relating customer requirements to technical characteristics. The relationships between customer requirements and technical characteristics were weighted with numerical values (0,1,3,9) in ascending order from none to a strong intensity of relationships. The roof of the house is used to identify the correlation and the relationship between technical characteristics. The importance of each of the customer requirements was obtained using a questionnaire distributed to the welders.

In the pilot case study done in January 2012, from the 20 persons involved in the welding assembly line, only 11 questionnaires were returned. It was found that all the customer requirements score a mean criteria value between 3.64 and 4.09 (3.41 to 4.20: want to know) which indicates that all the customer requirements were equally important to the welders. The Cronbach's alpha analysis resulted in 0.967, which indicates a high level of internal consistency for our scale with this specific sample. However, the percentage of welders answering 'not sure' in the questionnaire was high. 30–40% of the welders answered 'not sure' for systemic toxins, neurotoxins, reproductive toxins, carcinogens and the mixture effect. This is mainly because the technical terms were difficult to understand for the welders. Thus, improvements were made to make the questions more easily understood. To avoid the social desirability bias, only 4 scales were used in the actual study: 1. really do not want to know, 2. do not want to know, 3. want to know, 4. really want to know (Garland, 1991; Matell & Jacoby, 1972; Worcester & Burns, 1975). The actual case study was carried out in January 2013. The number of welders had increased to 32 and all the welders answered the self-administered questionnaire. It was found that all the customer requirements scored a mean criteria value between 3.31 and 3.41 (3.25 to 4.00: really want to know), which indicates that all the customer requirements were equally important to the welders. Table 1 shows the HoQ for the actual case study. It is apparent that the highest degree of technical importance is the personal sampling (23.0%), multi chemical analysis (20.8%), exposure limits (19.7%), health questionnaire (17.6%) and lung function test (14.7%).

Table 1. House of Quality (HoQ) for actual case study.



	DEMANDED QUALITY	Importance	Personal Sampling	Area Sampling	Direct Reading	Multi Chemical Analysis	Exposure Limit	Health Questionnai	Lung Function	TOTAL
			TECHNICAL CHARACTERISTIC							
CUSTOMER REQUIREMENTS	Irritants effect	3.41	0 0	0 0	0 0	0 0	0 0	9 30.69	0 0	9
	Sensitizer effect	3.41	9 30.69	0 0	0 0	3 10.23	0 0	9 30.69	9 30.69	30
	Respiratory system effect	3.38	9 30.42	1 3.38	1 3.38	9 30.42	9 30.42	9 30.42	9 30.42	47
	Systemic toxin effect	3.34	9 30.06	1 3.34	1 3.34	9 30.06	9 30.06	9 30.06	9 30.06	47
	Neurotoxins effect	3.34	9 30.06	1 3.34	1 3.34	9 30.06	9 30.06	3 10.02	1 3.34	33
	Reproductive toxins effect	3.31	9 29.79	1 3.31	1 3.31	9 29.79	9 29.79	3 9.93	0 0	32
	Carcinogen effect	3.38	9 30.42	1 3.38	1 3.38	9 30.42	9 30.42	3 10.14	3 10.14	35
	Mixture effect	3.41	9 30.69	1 3.41	1 3.41	9 30.69	9 30.69	3 10.23	9 30.69	41
	Technical Importance		212.1	20.2	20.2	191.7	181.4	162.2	135.3	923.1
Percent Importance (%)			23.0	2.2	2.2	20.8	19.7	17.6	14.7	100

CONCLUSIONS

The development of a welding fumes index by taking into consideration the voice of the welders will benefit the developer and is at the same time capable of fulfilling the requirements of the customer. The pilot and actual case study carried out in one of the automotive industries has shown the realibility of the QFD approach in relating the customer requirements to the technical characteristics, thus giving a clearer picture of how to further develop the welding fumes index based on the shortlisted technical characteristics. Future works will consider several case studies and larger groups of respondents to determine the most important parameters and technical characteristics for the development of a welding fumes index.

ACKNOWLEDGMENTS

This work was supported by the Exploratory Research Grant Scheme (Persson, Hogmark, & Bergström), Vote E003 under the Malaysian Ministry of Higher Education (MOHE). The first author is grateful to Mrs. Noraishah Mohamad Noor (International College of Automotive, Pahang) for her assistance in this project.

REFERENCES

Akao, Y. (1990). *Quality function deployment-integrating customer requirements into product design*: Productivity Press, New York, NY.

Antonini, J. M., Afshari, A. A., Stone, S., Chen, B., Schwegler-Berry, D., Fletcher, W. G.et al.Frazer, D. G. (2006). Design, construction, and characterization of a novel robotic welding fume generator and inhalation exposure system for laboratory animals. *Journal of Occupational and Environmental Hygiene,* 3(4), 194-203.

Asfahl, C. R. (2004). *Industrial safety and health management*: New Jersey: Pearson Prentice Hall.

Ashby, H. S. (2002). Welding fumes in the workplace: Preventing potential health problems through proactive controls. *Professional Safety*(April 2002), 55-60.

Badri, A., Nadeau, S., & Gbodossou, A. (2011). Proposal of a risk-factor-based analytical approach for integrating occupational health and safety into project risk evaluation. *Accident Analysis & Prevention*(0).

Baram, M. (2009). Globalization and workplace hazards in developing nations. *Safety Science,* 47(6), 756-766.

Cohen, L. (1995). *Quality function deployment: How to make qfd work for you*: Addison Wesley Publishing Company.

Department of Statistic, M. (2013). Monthly manufacturing statistics malaysia for november 2012. Retrieved 6/2/2013, from www.statistics.gov.my.

DOSH, M. (2005). *Guidelines on monitoring of airborne contaminant for chemicals hazardous to health*.

Fera, M., & Macchiaroli, R. (2010). Appraisal of a new risk assessment model for sme. *Safety Science,* 48(10), 1361-1368.

Fiore, S. R. (2006). Reducing exposure to hexavalent chromium in welding fumes. *Welding Journal*(August 2006), 38-43.

Francisque, A., Rodriguez, a. M. J., Sadiq, R., Miranda, L. F., & Proulx, F. (2011). Reconciling actual risk with perceived risk for distributed water quality: A QFD-based approach. *Journal of Water Supply: Research and Technology*, 321-342.

Garland, R. (1991). The mid-point on a rating scale: Is it desirable?. *Marketing Bulletin*, 2, 66-70.

Hariri, A., Leman, A. M., & Yusof, M. Z. M. (2012). Proposal of development of welding helath-hazard index (whi) for small and medium enterprises (smes). *ARPN Journal of Science and Technology*, 2(2), 62-67.

Hariri, A., Yusof, M. Z. M., & Leman, A. M. (2012). Sub-index derivation of welding health-hazard index (whi) for small and medium enterprises (smes) in malaysia. *Applied Mechanics and Materials*,, 229-231, 2546-2550.

Hewitt, P. J. (2001). Strategies for risk assesment and control in welding: Challenges for developing countries. *Ann. occup.Hyg.*, 45(4), 295-298.

Isaxon, C., Pagels, J., Gudmundsson, A., Asbach, C., John, A. C., Kuhlbusch, T. A. J.et al.Bohgard, M. (2009). Characteristics of welding fume aerosol investigated in three swedish workshops. *Journal of Physics: Conference Series*, 151(1), 012059.

Karkoszka, T., & Sokovic, M. (2012). Integrated risk estimation of metal inert gas (mig) and metal active gas (mag) welding processes

integrirana procjena mig (metal inertni plin) i mag (metal aktivni plin) procesa zavarivanja. *Metalurgija*, 51(2), 179-182.

Kirch, W. (2008). *Encyclopedia of public health*: London: Springer.

Leman, A. M., Yusof, M. Z. M., Omar, A. R., & W.Jung. (2010). Environmental quality index (eqi) for industrial ventilation and occupational safety and health evaluation in manufacturing plant. *The Asian Journal on Quality*, 11(3), 210-222.

Occupational safety and health (use and standards of exposure to chemical hazardous to health) (usechh) regulation (p.U. (a) 131) (2000).

Malaysia. (2010a). *Factories and machinery act (act 139)*. MDC Publisher Sdn. Bhd.

Malaysia. (2010b). *Occupational safety and health act (act 514)*. MDC Publisher Sdn. Bhd.

Matell, M., & Jacoby, J. (1972). Is there an optimal number of alternatives for likert scale items? Effects of testing time and scale properties. *Journal of Applied Psychology*,56(6), 506-509.

Mumtaz, M. (2010). *Principle and practice of mixture toxicology*: Weinheim: Wiley-VCH.

Nims, D. K. (1999). *Basics of industrial hygiene*. Canada: John Wiley and Sons Inc.

NIOSH. (1998a). Criteria for recommended standard: Welding, brazing and thermal cutting In DHHS (Ed.), *publication 88-110*: NIOSH.

NIOSH. (2004). Specific medical test or examinations published in the literature for osha-regulated substance. 2005-110.

NIOSH. (2007). *Niosh pocket guide to chemical hazards*.

Nordberg, G. F., Fowler, B. A., Nordberg, M., & Friberg, L. T. (2007). *Handbook on the toxicology of metals*: California: Elsevier.

OSHA. (1996). Welding health hazards *Dept. of Labor, OSHA Office of Training and Education, May 1996*: OSHA Washington, DC: U.S.

Ott, W. R. (Ed.). (1978). *Environmental indices theory and practise*. Michigan: Ann Arbor Science Publisher Inc.

Persson, A., Hogmark, S., & Bergström, J. (2005). Thermal fatigue cracking of surface engineered hot work tool steels. *Surface and Coatings Technology,* 191(2), 216-227.

Ravert, E. (2006). Controlling chromium fumes. *Welding Journal*(November 2006).

Sadiq, R., Haji, S. A., Cool, G. v., & Rodriguez, M. J. (2010). Using penalty functions to evaluate aggregation models for environmental indices. *Journal of Environmental Management,* 91(3), 706-716.

Smallwood, J. J. (2004). The influence of engineering designers on health and safety during construction. *Journal of the South African Institution of Civil Engineering,* 46(1), 2-8.

Sofuoglu, S. C., & Moschandreas, D. J. (2003). The link between symptoms of off ice building occupants and in-office air pollution: The indoor air pollution index. *Indoor Air,* 13(4), 332-344.

Worcester, R., & Burns, T. (1975). A statistical examination of the relative precision of verbal scales. *Journal of Market Research Society,* 17(3), 181-197.