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The Development of Toxic Gas Exposure Guidelines Using Preliminery Hazard Analysis (PHA) Approach

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Abstract

Manufacturing and assembly of car component basically involved with welding process. The demand on vehicles in development country has push the small and medium industry (SMIs) to contribute the economic forward.The purpose of this study is to develop the toxic gases exposure guidelines using preliminery hazard analysis (PHA) approach. The PHA were used for the risk classification and risk assessment The case study was done in car component manufacturer which is a supplier for national car. The data from monitoirng process was analyze and compare with the guidelines that has been devloped. Futhermore from the toxic gas exposure guidelines, hazard assessment matrix was clearly defined. The guidelines will used as a baseline for the furthur action as a need to comply with the regulation set-up by the government. The monitoring and analyze toxic gas exposure as a key of the occupational safety and health(OSH) approach. The target for work environment quality improvements has significanlty evaluated.

Keywords: Operations management, Work environment, Welding, Toxic gas, Safety and health.

1.Introduction

Malaysian automotive related industries in Malaysia are generally a small and medium industries (SMIs) to cater the need of welding and assembly services. It generally run on affordable cost operation and employed general ventilation. Currently, each welding workplace need to be monitor and evaluate to ensure the minimum level of exposure is maintained according to the regulations and standards.[4] From the previous monitoring done on toxic gases in industries, there have significant that welding process is one of the source of air pollution.These hazards need to be identified, assessed and controlled in the workplace. The Malaysian Government has introduce a guidelines on monitoring of airborne contaminants for chemicals hazardous to health. [9]However from the observation and case study done, it is noticed that monitoring process has not been given priority and due to insufficient of equipments, hence the toxic gases are not measured in the workplace.[1]In providing solutions to the above problems, it is necessary to conduct a monitoring, in order to create healthy working condition in Malaysian SMIs. Monitoring activities will get the underlying causes of the problem and ensure to provide a means by which hazards can be systematically evaluated. Thus objective of this study is to develop the toxic gas exposure guidelines using prelimenary hazards analysis (PHA) approah. [18, 20]

2. Literature Review

Over the past few decades, Malaysia has achieved significant improvements in the standards of OSH. The rate of occurrence of work related accidents has dropped from 11.0 for every 1,000 workers in the year 2000 to

6.1 per 1,000 workers in the year 2007. However, for the same period, the rate of fatalities has remained stagnant at around 12.8 for every 100,000 workers. (OSH MP 15). Although Malaysian industries growths are rapid and their expansion is fast, they still face challenges that influence their competitiveness. From the scenario on occupational safety and health, the Malaysian industries need to improve the situation. The data about industrial accident and occupational diseases from year 2005-2009 was tabulated in table 1.[8]

Table 1: Industrail Accidents and occupational dieseases statistic from 2005-2009.

Total	Industrial Accidents			Occupational Diseases		
Year	D	PD	NPD	Case Reported	Case Investigation	Legend: D -Death PD -Permanent Disability NPD -Non-Permanent Disability
2005	196	182	3459	300	451	
2006	209	174	4348	409	362	
2007	219	168	3008	594	546	
2008	230	159	2109	545	453	
2009	224	108	2053	791	669	

The occurrences of the industrial accidents and the unconducive work environment reported shows the factor that influence the evidence. Hence, the study was carried out look into Malaysian SMIs welding work environment. There are many questions about the OSH aspect of the working environment, and workers.[6] As legislation continues to develop for the recognition, assessment and control of risks in the workplace, at the planning stage and at the design stage for products and equipments, the knowledge and skills of those involved will also have to be developed. More and more enterprises have realized that a healthy and safe work environment improves competitiveness, which is reflected as an improvement in the cost-effectiveness of production.[15]

2.1 Welding Process and Effect of Toxic Gases

Welding has been around for centuries and is a common industrial process.[6]Hazard that has both acute and long-term chronic effect is welding fume/dusts, toxic gases and radiation.[3-5] 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. Toxic gases also produce from welding processes which include nitric oxide, nitrogen dioxide, carbon monoxide and ozone.[5][10] Factor such as chemical (toxic gas, fumes), physical (radiation, flammability, reactivity), and biological (carcinogenetic, toxicity), are closely to characterize the welding exposure. Workers deal with great percentage of health injuries when they are exposed to the toxic gases and fumes.[5] The major toxic gases associated with welding are classifies as primary pulmonary and non pulmonary. Exposure to the harmful gases and fumes in context of welding fall into two main categories, asphyxiating shielding gases and pollutant fumes. The adverse health effects and exposure limits relating to gases and vapours are tabulated below:

Table 2: Adverse health effects and Exposure limits relating to gases and vapours.[5-6]

Substance	Common Source	Possible adverse effects	Exposure limit (UK) (ppm)	Exposure limit (USA) (ppm)	Exposure Limit (MALAYSIA) (ppm)
Carbon dioxide	Shielding gases, Combustion of fuel	Asphyxiants	5000	5000	5000
Carbon Monoxide	Partial Combustion of fuel, decomposition products	Block the attachment of oxygen to haemoglobin	30(long) 200(15 min)	50	25 (8 -TWA)
Nitrogen dioxide	Action of welding torch on the gases in the air	Pulmonary oedema, shortness of breath, coughing,etc	3(long) 5(15 min)	5 (C)[c]	3 (8-TWA)
Ozone	Action of UV on air near the weld	Irritant. In excess causes Pulmonary oedema. Thought to have longterm effects on the lungs	0.2(15min)	0.1	Heavy work 0.05 Moderate work 0.08 Light work 0.10 Heavy moderate, or light workloads 0.2 (≤ 2 h)
Phosgene	Action of arc on chlorinated degreasing compounds	Highly toxic, produces hydrogen chloride in the lungs	0.02(8 hour) 0.06(15 min)	0.1	0.1
Trichloroethylene	Degreasing	Mildly toxic. Produces headache, drowsiness.	100[a]	100[b] 200(c)[c]	50

[a] maximum exposure limits – exposure must be reduced so far as is reasonably practicable, and in no case exceed these limits.
[b] Substances that have ceiling values(refer regulations)
[c] (C) is a ceiling value

2.2 Risk Assessment Method

The PHA appoach was chosen for this study. From the creation and management program in a system under development to the analysis that must be performed as it is designed and produced to assure acceptable risk in its operation.[14, 16-17]Table 3 below illustrate the method to establish a hazard risk index (HRI) with the use of frequency of occurance and hazard category and Table 4 illustrates the relationship of event occurance level to a quantitative value.

Table 3: Hazard assessment matrix.[14]

Frequency of Occurance	HAZARD CATEGORIES				Hazard Risk Index	Suggested criteria
	I Catastrophic	II Critical	III Marginal	IV Negligible		
(A) Frequent	1A	2B	3A	42	1A,1B,1C,2A,2B,3A	Unacceptable
(B) Probable	1B	2B	3B	4B	1D,2C,2D,3B,3C	Undesirable
(C) Occasional	1C	2C	3C	4C	1E,2E,3E,4A,4B	Acceptable with review
(D) Remote	1D	2D	3D	4D	4C,4D,4E	Acceeptable without review
(E) Improbable	1E	2E	3E	4E		

Table 4: Relationship of qualitative probability rangkings to quantitative values.[14]

Description	Level	Frequency of Occurance	Potential Relationship to Quantitative Value *
Frequent	A	High	10^{-1}
Probable	B	Medium – high	$<10^{-3}$ t0 10^{-1}
Occasional	C	Medium	$>10^{-3}$
Remote	D	Low to medium	$>10^{-4}$
Improbable	E	Low	$>10^{-6}$

* All quantitative values required a database for establishing the value.

3. Methodology

The methodology introduced in this study represent areas of PHA approach and were classified according to modified for toxic gas exposure monitoring. Figure 1 below show the methodology framework.

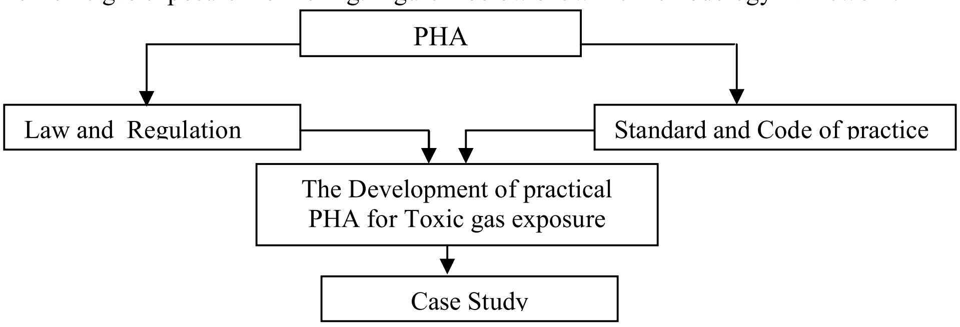

Figure 1: Methodology framework

Main methods used in this research are modified PHA, and also physical and gases measurements. Physical measurements and testing methods employed were based on widely used accepted scientific practice, as described in standards.[2, 19]The selection of the height of the sensor is 1.7 meter respectively because there are the standard measurements of the breathing zone for the worker that standing at work. The location near to the worker to ensure the data capture of air contamination is exposure by the operator. Figure 1 above show the methodology of the study. The technique of sampling used a direct reading method to measure the contaminants [7].The calculation of the individual pollutants concentration level is based on the ACGIH Threshold Limit Value-Time Weighted Average, TLV-TWA[2]. The equations are stated below:

$$TWA = \frac{(c_1T_1 + c_2T_2+\ldots+c_nT_n)}{8 \text{ hours}} \qquad (1)$$

Where c_1,c_2 and c_n are pollutant concentration at time T_1,T_2 and T_n respectively.

Gaseous pollutants such as Carbon dioxide (CO), carbon monoxide(CO^2), sulfur dioxide(SO^2), nitrogen dioxide (NO^2) and ozone(O^3) were measured using standard indoor air quality meter (recognized by DOSH).[7] A velocity meter was used to measure the air velocity, temperature and also the relative humidity. Results obtained from the measurement were analyzed and was compared with USECHH regulation then will be the database for the Risk assessment matrix [12].

4. The Developmet of Toxic Gas of Exposure Guidelines

The goal of this study is to develop a toxic gas risk assessment through welding process. In this study, we present specifically,quantified through data, the indices of occurrence (OCC) (refer table 5) and severity (SEV) (refer table 6). Then from the analysed standard regulation and guidelines to established risk classification matrix (RCM). RCM is constructed based on occurrence and severity.

Table 5:Occurrence rank

Occurrence Rank	Criteria	Toxic Gas
A	Daily	All Toxic Gas
B	>1 times daily	Several Toxic Gas
C	Once a week	One Toxic Gas
D	Once a month	One Toxic Gas
E	One a year	One Toxic Gas

Table 6: Adverse health effect rank

Effect Rank	Severity
I	Most probably effected
II	Will be effected
III	Medium
IV	Non effected

4.1The Risk Classification Matrix

The output from the toxic gas level is a risk classification for the identified the severity. The classification results of the assessment are the reflection of possiblibility and complication to health posed hazard. The risk classification matrix of toxic gas exposure tabulated in table 7.

Table 7: The Risk Classification Matrix

Occurrence	**Hazard Risk Index**			
	I	II	III	IV
A	IA	IIA	IIIA	IVA
B	IB	IIB	IIIB	IVB
C	IC	IIC	IIIC	IVC
D	ID	IID	IIID	IVD
E	IE	IIE	IIIE	IVE
Unacceptable - It is catastrophic for run the welding process				
Marginal - It is critical , management must consider				
Difficult - It is probable to do the welding process				
Negligible - It is allowable to run the welding process				

Red-The toxic exposure located in red color area are unacceptable for welding process since the goal is to do beneficial manufacturing, if a work process requires unreasonable time or technology cost to repair, it would be stop.
Yellow-The toxic exposu re located in yellow color area are revealed as the most critical for manufacturing since these proces are very common and need difficult and complicated processes. Clearly, these cause the most difficulty to minimize the risk.
Green-The toxic exposure located in green color area are reveled as probable to do welding process. The welding process can be done by going through the general ventilation.
White-The toxic exposure located in white color area are good for OSH. The welding process can be done with no harmful to human.

5. Case Study

To access the practical value of toxic gas parameter, case study was carried in one manufacturing companies which is located in Shah Alam and this companies are vendor for national car producer where the main business are manufacturing of metal stamping components. The operation in the said industries including manufacturing and sub assembly of body and panel using various types of spot welding machines such as robotic spot welding, stationary spot welders, portable, projection and MIG welders. The observation was done on daily basis to ensure the similarities of activities.[1] The data collection was done in one month duration for each industry for welding work environment This is for ensure the reliability of data regarding the toxic gases exposure by the worker's. Three (3) probes were used in this measurement which are Indoor Air Quality Probe (IQ-410) and two (2) numbers of Toxic Gas Probe (TG-501). The data collected was transfer to the software and it was tabulated for the separated gas. [1

6. Result and Discussion

Numerous toxic geseous were involved during routine activities of the various work station. The detail data for daily was tabulated in table 8 below and it shows the average level on the particular types of toxic gases produce by the welding process. The result obtained show that at certain measurement point recorded above the limit (CO_2 and O_3) as mentioned in the standard according to the OSHA 1994, (schedule 1).[12] Hence from the study, it was found that the work environment was not sufficiently ventilated. From the result, the management and the planning unit will have some idea how to schedule the working process and the workers arrangement for the safety and health purposes. From the data above, the employer and employee must take action against this issues.

Table 8: Measurement result (manufacturing area) and toxic gas exposure guidelines.

Mac 2009	CO (ppm)	CO_2 (ppm)	NO_2 (ppm)	SO_2 (ppm)	O_3 (ppm)
3	1.3	7561	0.1	0.01	0.01
4	0.2	8690	0.01	2	0.13
5	1.5	7418	0	0.3	0.01
6	0.4	7500	0	0	0
8	0.7	7520	0	0	0.01
9	1.8	7555	0.01	0.2	0.1
10	1.4	7945	0.02	0	0.01
11	0.9	7550	0.01	0	0.02
12	0.6	7425	0.01	0	0.01
13	1.6	7600	0.01	0.01	0.01
14	0.7	7547	0.01	0	0.01
15	0.9	7558	0.01	0	0.04
16	0.9	7569	0.01	0	0.02
17	0.8	7449	0.01	0	0.03
18	0.3	7315	0.01	0	0.001
19	0.2	7528	0.03	0	0.03
22	0.1	7567	0.1	0	0.1
23	0.1	7680	0.03	0	0.001
24	1.1	7605	0.01	0	0.02
25	1.2	7584	0.01	0	0.1
26	1.1	7270	0.03	0.01	0.11

Occurrence	Hazard Risk Index			
	I	II	III	IV
A	IA	IIA	IIIA	IVA
B	IB	IIB	IIIB	IVB
C	IC	IIC	IIIC	IVC
D	ID	IID	IIID	IVD
E	IE	IIE	IIIE	IVE
Unacceptable - It is catastrophic for run the welding process				
Marginal - It is critical , management must consider				
Difficult - It is probable to do the welding process				
Negligible - It is allowable to run the welding process				

* For the toxic gas monitoring in these case study, it shown that toxic gas exposure are between BII and B III (means immediately action must be taken); engineering control or administration control.

7. Conclusion

The toxic gas exposure guidelines will be up-date and can be used for the other mechanical process. The resulting improvement in work safety and health will contribute to a safer, healthier and more productive pool of human capital.

References

1. A.M Leman,A.R Omar and M.Z.M Yusof : "Monitoring of Toxic Gases Exposure in welding process of Small and Medium Indutries (SMIs)".International Conference on Advanced in Mechanical Engineering,24-25 June 2009.,Shah Alam.
2. ACGIH: "Industrial Ventilation 23rdEdition". *A Manual of Recommended Practice*. 1998, Cincinnati.OH
3. American Welding Society: "Fumes and gases. Safety and Health Fact Sheet no 1.2005", Miami.
4. American Welding Society: "Ventilation for Welding & Cutting.Safety&Health Fact Sheet 36.09",Miami.
5. Ashby, H.S., "Welding Fumes in the Workplace: Preventing Potential Health Problems Through Proactive Controls". Professional Safety, 2002.(April 2002), 55-60.
6. Blunt, J. and N.C. Balchin, "Health and Safety in Welding & Allied Processe".2000, Cambridge:Woodhead Ltd.
7. Department of Occupational Safety and Health : "Code of Practice on Indoor Air Quality". 2005, Putrajaya
8. Department of Occupational safety and Health(DOSH) : "2008 Annual Repor". Putrajaya.
9. Department of Occupational Safety and Health: "Guidelines on Monitoring of Airborne Contaminant for Chemicals Hazardous to Health". 2002, Ministry of Human Resources of Malaysia. Putrajaya.
10. Herman Koren and Micheal Bisesi: "Handbook of Environmental Health",Vol.1,4th Edition. Biological, Chemical, and Physical Agents of Environmentally Related Disesae' , 2002, Lewis Publisher. Florida.

11. Hewitt, P.J., 2001, "Strategies for Risk Assesment and Control in Welding: Challenges for Developing Countries". Annals Occupational.Hygiene, 45(4), 295-298
12. Occupational Safety and Health Act 1994 and Regulations, 2006, MDC Publication. Kuala Lumpur.
13. Occupational Safety and Health Master Plan for Malaysia 2015. Ministry of HumanResource Malaysia. Putrajaya.
14. Roland Harold E and Moriaty, Brian,1990. "System Safety Engeneering and Management". J. Wiley& Sons.
15. Sointu Högström. " Work Environment". 2010,Finnish Institte of Occupational Health.Helsinki.
16. Vladimir Popović and Branko Vasić, 2008 "Review of Hazard Analysis Methods and Their Basic Characteristics". FME Transactions, 36 (4), 181-187.
17. Geoffrey Raymond and Stephen Grey. Risk Management- Hazard and Technical Risk. The Mining Chronicle, 2 (11), November 1997.
18. S.M.L.Carvalho and M.G.C.Silva, 2002, " Preliminary Risk Analysis Applied oo The Handling of Health-Care Waste". Brazilian Journal of Chemical Engineering, 19 (4)Sao Paulo Oct./Dec.
19. Gressel, M.G., Gideon, J.A., 1991, "An Overview of Process Hazard Evaluation Techniques" American Industrial Hygiene Association Journal; Volume: 52:4.p158-163.
20. Byounggwan Kang, En Sup Yoon and Jung Chul Suh. 2001, "Application of Automated Hazard Analysis by New Multiple Process-Representation Models to Chemical Plants" Ind. Eng. Chem. Res., 40 (8), 1891–1902