

Sampling Method for Welding Fumes and Toxic Gases in Malaysian Small and Medium Enterprises (SMEs)

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Abstract

In 2009 there were 28,840 small and medium enterprises (SMEs) in Malaysia which represented 94.2 % of the total establishments in the manufacturing sector. Job tasks in manufacturing sectors above all involve welding processes. The issues in SMEs mainly resolve around poor working conditions contributing to worker's safety and health problem. Welding fumes and toxic gas assessment in SMEs welding workplace is essential in order to ensure the minimum level of exposure is maintained as required by the prevailing standards. This paper outlines the methodology for fumes and toxic gas sampling by taking into account analytical method currently available for analysis in the government accredited laboratory. The proposed methods are divided into two; the pilot test and the actual measurement. Standardize sampling method using sampling pump along with direct reading measurement are consider in both the pilot test and actual measurement. The proposed sampling method hopefully will benefit researcher, stakeholders or SMEs by giving guidance on the suitable method for welding workplace assessment.

Keywords: welding fumes, small and medium industries, welding fumes sampling method

1. Introduction

Welding is a common industrial process. Hazard that has both acute and long-term chronic effects is welding fumes/ 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 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 (Mansouri, Atbi, Moharamnezhad, Rahbaran & Alahiari, 2008; Isaxon et al., 2009). 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 (Blunt & Balchin, 2000).

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 (Blunt & Balchin, 2000; Hewitt, 2001).

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 (Small Medium Enterprise Corporation, 2010). 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 (Hajime et al., 2006).

Currently in Malaysia, according to Occupational Safety and Health Act, under the Use and Standard of Exposure of Chemical Hazardous to Health (USECHH) of Occupational Safety and Health, chemical health risk assessment (CHRA) need to be carried out by an assessor appointed by the employer. A chemical health risk assessment report is produced by the assessor which includes potential risk, nature of hazard to health, method and procedure in the use of chemical, degree of exposure and control measures (Department of Safety and Health [DOSH], 2002; DOSH, 2006). SMEs have difficulty in complying with this requirement due to the extra cost that need to be borne when appointing an assessor. Thus, this study is carried out by outlining sampling method that can be used to assess welding fumes and toxic gases in welding related workplace in Malaysia.

2. Method

The chemical exposure due to the welding process in forms of fumes and toxic gases are enormous in quantity. In this study, the limitation is the available laboratory analytical method for analyzing the fumes and toxic gas samples. The government accredited laboratory in Malaysia is the Industrial Hygiene Analytical Laboratory of the National Institute of Occupational Safety and Health (NIOSH), Malaysia. Currently this laboratory capable of analyzing welding fumes sample using the atomic absorption spectrometry (AAS) equipment for scanning one metal element per sample as shown in Table 1. The price per sample for one metal element analysis is range between (Malaysian Ringgit) MYR 50 to MYR 60. Unfortunately none of the laboratory analysis on toxic gases is available except for the non-government laboratory that required higher cost up to 500% for analyzing a sample. However, according to NIOSH Manual of Analytical Method (NMAM) 6604, the concentration of carbon dioxide can be measured using portable direct reading instrument using electrochemical sensor techniques (National Institute of Occupational Safety and Health [NIOSH], 1996). Since these proposed sampling method is developed for the SMEs, a structured sampling and analysis approach should be arranged which enables the most efficient use of resources.

Table 1. List of the analytical method available for welding fumes metal element analysis

No.	Chemical name	Analytical method	Analytical Technique
Welding Fumes			
1	Arsenic	NMAM 7900 (NIOSH, 1994)	AAS
2	Cadmium	NMAM 7048 (NIOSH, 1994)	AAS
3	Chromium (total)	NMAM 7024 (NIOSH, 7024)	AAS
4	Copper	NMAM 7300 (NIOSH, 2003)	AAS
5	Ferum	OSHA-ID 121 (OSHA, 2002)	AAS
6	Lead	NMAM 7105 (NIOSH, 1994)	AAS
7	Manganese	OSHA ID -121 (OSHA, 2002)	AAS
8	Nickel / Zinc / Cobalt / Aluminum	NMAM 7300 (NIOSH, 2003)	AAS

Coffey and Pearce highlighted that when considering the important performance characteristic of method used for hazard screening, requirements of accuracy and precisions are not stringent as long as the method can separate the presence of the agent of interest at levels that are protective (Coffey & Pearce, 2010). Thus, series of hazard screening by using direct reading equipments although maybe less accurate, would be the best choice for hazard screening/ pilot testing purpose. This is most benefited especially in our case when the accredited laboratory have limitation in analyzing the exposure of interest such as other sources of toxic gases and particulate matters that may exist in the investigated workplace.

Currently only direct reading instrument for toxic gas are available. While on the other hand, welding fumes can be preliminary analyze by using scanning electron microscope with energy dispersive spectroscopy (SEM-EDS) to shortlist the metal element exists. Jenkins and Eager highlighted that the SEM-EDS found to be effective techniques for evaluating the elemental composition of welding fumes after conducted a comparison study with inductively coupled mass spectroscopy (ICPMS), X-ray fluorescence spectrometry (XRF), neutron activation analysis (NAA), X-ray induced photo electron spectrometry (XPS), X-ray diffraction (XRD) and transmission electron microscopy with energy dispersive spectroscopy (TEM EDS) (Jenkins & Eager, 2005). However it is also highlighted that the usage of SEM-EDS would be accurate only on particles size larger than half of micrometer

size. In our cases, the welding fume sample is collected onto 0.8 micrometer mixed cellulose ester filter according to suggested filters for welding fumes by NIOSH (DOSH, 2005).

Figure 1 shows the example of metal element analysis that had been done by using SEM-EDS in Universiti Tun Hussein Onn Malaysia for welding fumes sample conducted during student welding practice in welding laboratory. A personal sampling of welding fumes using sampling pump with 0.8 micrometer mixed cellulose ester filter were attached to the breathing zone of the welder for four hours with flowrate setting of 3 m/s. The filters were then cut into four equal sections, coated and mounted on the stubs SEM-EDS which is an adapted method from Antonini et al. (2006). The analysis shows the trace of Manganese (Mn) and Ferum (Fe) elements with 5.9 mass % and 21.67 mass% respectively that can be analyze further using personal sampling pump focused on these two shortlisted metal elements of interest. The other elements such as Sodium (Na), Silicon (Si) , Carbon (C) and Potassium(K) are usually found in welding fumes but not generally considered to be of hygienic significance (Yeo & Neo, 1998).

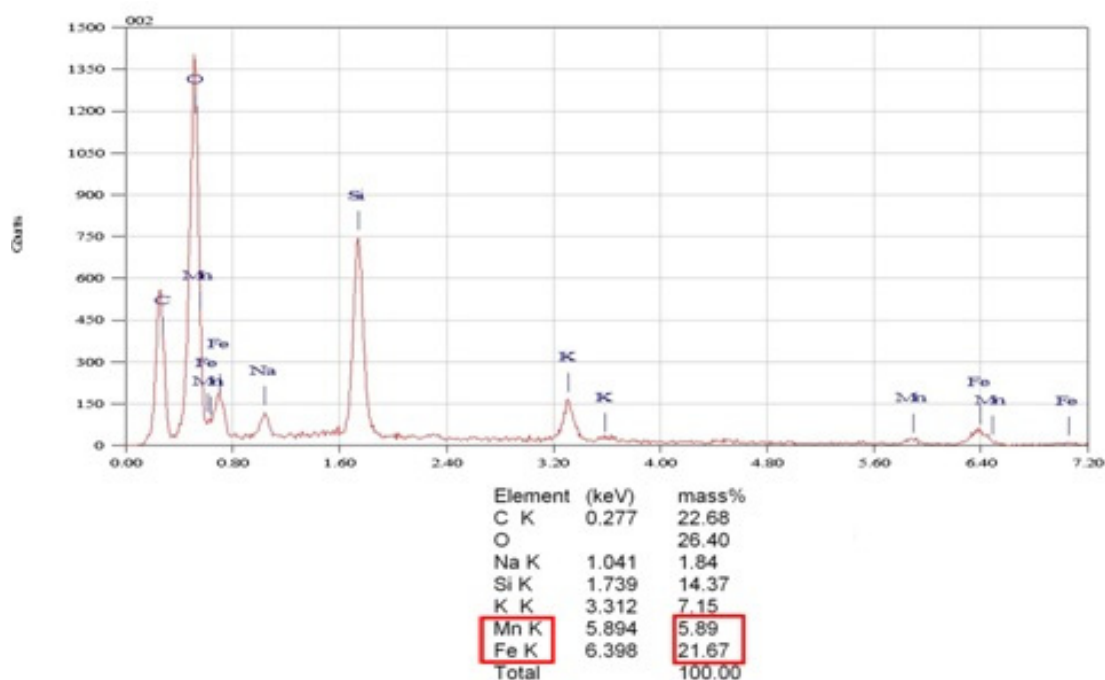


Figure 1. Example of SEM-EDS analysis of metal elements in sampled welding fumes

The structural physical sampling for welding fumes and toxic gases will be conduct according to the strategies outlined in Table 2. Whereas pilot test will be conducted before the actual measurement being carried out for both toxic gases and welding fumes.

Figure 2 shows the direct reading instrument designated as Graywolf Directsense toxic gas monitor TG501 for measuring carbon monoxide toxic gases using an electrochemical sensor. It is connected to pocket pc as data logging platform. Figure 3 shows the same direct reading instrument with additional accessories suitable for personal sampling purpose. Additional accessories needed for personal sampling include hood, tubing and air sampling pump.

Table 2. Propose sampling method for toxic gases and welding fumes in welding related SMEs

	Toxic gases		Welding Fumes
Pilot Test	a) Conduct pilot test of fixed point sampling for toxic gases (carbon monoxide) before welding process executed using direct reading instrument	a)	Conduct pilot test of fixed point sampling for particulate matters (range from 0.1 to 10 microns particle sizes) before welding process executed using direct reading instrument
	b) Analyze the data collection to make sure no other source of contaminant exist	b)	Analyze the data collection to make sure no other source of contaminant exist
Actual Measurement	a) Conduct personal sampling of welder during welding process using direct reading instrument	c)	Conduct preliminary personal sampling of welding fumes using sampling pump and filter media
	b) Analyze the data collection to identified presence of carbon monoxide toxic gas	d)	Analyze welding fumes collected using SEM-EDS to shortlist element for further investigation
		a)	Conduct personal sampling of the shortlisted element using standardize sampling method
		b)	Conduct standardize laboratory method analysis

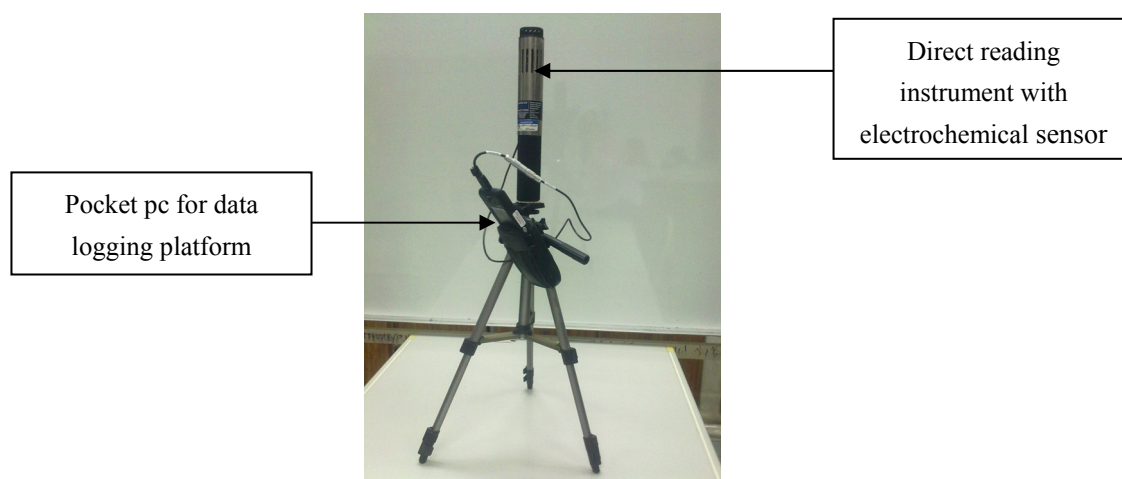


Figure 2. Direct reading instrument using electrochemical sensor for measuring carbon monoxide in area sampling

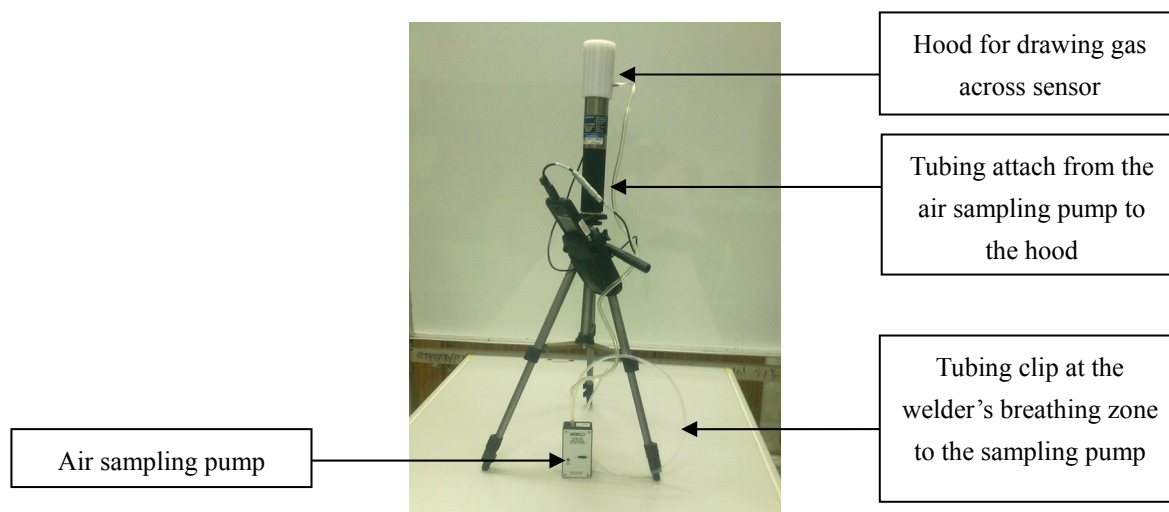


Figure 3. Direct reading instrument set up for personal sampling

Figure 4 show the direct reading instrument known as the TSI Dustrak aerosol monitor using 90 degree light scattering photometer for measuring dust/particulate matters (range from 0.1 to 10 microns particle sizes).



Figure 4. A direct reading instrument using 90 degree light scattering for measuring dust/particulate matters (range from 0.1 to 10 microns particle sizes) in area sampling

Table 3 shows the proposed sampling method for pilot test in welding related SMEs. Area sampling for carbon monoxide and particulate matters will be done using direct reading instruments. Meanwhile one sample of welding fumes from the highest risk workers should be personal sampled using sampling pump in order to be analyzed with the SEM-EDS. Highest risk workers are selected by considering these 4 factors (DOSH, 2005).

- a. Nearest to source
- b. Duration and frequency of source
- c. Nature of work and work practice
- d. Availability of control measure

Methods of sampling are referred to the standard /guidelines by American Conference of Industrial Hygienists (ACGIH,) British Standard and Department of Safety and Health Malaysia (DOSH).

Table 3. Proposed pilot test sampling method

Measurement Data	Equipment	Method of Measurement
Pilot test measurement of toxic gas (carbon monoxide) before welding process executed to make sure no other source of contaminant exist.	Carbon monoxide Direct reading instrument (electrochemical sensor) Unit : ppm	Do measurement at fixed point sampling before welding process conducted: a) Locate sampling probe at 150 and 170cm from the floor at the centre of the room or an occupied zone (American Conference of Industrial Hygienists [ACGIH], 1998) b) At least one samples should be taken at the entrance to the building or at the entrance of the fresh air intakes (DOSH, 2010)
Pilot test measurement of particulate matters (range from 0.1 to 10 microns particle sizes) before welding process executed to make sure no other source of contaminant exist	Direct reading instrument TSI Dusttrak Aerosol Monitor (model 8520) (light scattering photometer) Unit: mg/m ³	Number of sampling point: At least one sample should be taken per 500m ² from each floor or from each area serviced by a separate air-handling unit (DOSH, 2010). Propose sampling time: At least 20 sample with 1 minutes interval for homogeneous workers performing similar task (British Standard, 1996)
Personal sampling of welding fumes to be analyzed by SEM-EDS to shortlist element for further investigation_	Personal sampling pump, filter holder and cassette, filter media, connecting tube. Unit: mg/m ³	Personal sampling: Locate sampling probe within the breathing zone (hemisphere (generally accepted to be 0.3 m in radius) extending in front of the human face, centered on a midpoint of a line joining the ears; the base of the hemisphere is a plane through this line, the top of the head and the larynx.)(British Standard 2001) Duration of samples: Based on workplace condition. • Good working condition : higher sampling flow rate (2-3 L/min) ○ Full period (8 hours) consecutive sample(DOSH, 2005) • Moderate working condition : lower sampling flow rate (1-1.5 L/min) ○ Full period (8 hours) single sample (DOSH, 2005) Number of sample: One workers of the highest risk

Table 4 shows the proposed sampling method for the actual measurement. Personal sampling of toxic gases and welding fumes are structured according to the standard /guidelines by British Standard and DOSH.

Table 4. Proposed sampling method for actual measurement

Measurement Data	Equipment	Method of Measurement
Actual measurement for personal sampling of toxic gas (carbon monoxide)	Carbon monoxide Direct reading instrument (electrochemical sensor) Unit : ppm	Personal sampling: Locate sampling head within the breathing zone (hemisphere (generally accepted to be 0.3 m in radius) extending in front of the human face, centered on a midpoint of a line joining the ears; the base of the hemisphere is a plane through this line, the top of the head and the larynx)(British Standard, 2001) Duration of samples : Based on workplace condition and maximum volume to be sampled.
Actual measurement for personal sampling of welding fumes according to the shortlisted metal element to investigate	Personal sampling pump, filter holder and cassette, filter media, connecting tube. Unit: mg/m ³	• Full period (8 hours) single sample(DOSH, 2005) or • Full period (8 hours) consecutive sample(DOSH, 2005) Number of sample: At least one employee in ten in a properly selected homogeneous group performing similar tasks (British Standard, 1996)

3. Conclusion

It is important that the sample taken on each selected enterprises represent the investigated welder population before any conclusion is made on the workplace safety level. It is most important to analyze the exposure data in correct manner and understanding before comparing with the minimum exposure level standard. The proposed methods were outlined after considering the available analytical method offered by the government accredited lab and available direct reading instrument in the author's universities. This proposed sampling method is hoped to benefit researcher, stakeholders or SMEs by giving guidance on the suitable method for welding workplace assessment in the light of providing a sustainable work environment.

References

- American Conference of Industrial Hygienists (ACGIH). (1998). *Industrial ventilation: A manual of recommended practice*.
- Antonini, J. M., Afshari, A. A., Stone, S., Chen, B., Schwegler-Berry, D. Fletcher, W. G., ... 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. <http://dx.doi.org/10.1080/15459620600584352>
- Ashby, H. S. (2002). Welding fumes in the workplace: Preventing potential health problems through proactive controls. *Professional Safety*, (April 2002), 55-60.
- Blunt, J., & Balchin, N. C. (2000). *Health and safety in welding and allied processes*. Cambridge: Woodhead Publishing Limited.
- British Standard. (1996). BS EN 689:1996 *Workplace atmospheres — Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy*.
- British Standard. (2001). BS EN ISO 10882-1: 2001 *Health and safety in welding and allied processes: Sampling of airborne particles and gases in the operator's breathing zone. Part 1: Sampling of airborne particles*.
- Coffey, C. C., & Pearce, T. A. (2010). Direct-reading methods for workplace air monitoring. *Journal of Chemical Health and Safety*, 17(3), 10-21.
- Department of Occupational Safety and Health (DOSH). (2002). *Guidelines on monitoring of airborne contaminant for chemical hazardous to health*.
- Department of Occupational Safety and Health (DOSH). (2005). *Guidelines on monitoring of airborne contaminant for chemicals hazardous to health*.
- Department of Occupational Safety and Health (DOSH). (2006). *Guidelines on occupational safety and health act 1994 (ACT 514)*.
- Department of Occupational Safety and Health (DOSH). (2010). *Industry code of practice on indoor air quality*.

- Fiore, S. R. (2006). Reducing exposure to hexavalent chromium in welding fumes. *Welding Journal*, (August 2006), 38-43.
- Hajime, Y., Yasushi, S., Yasushi, O., Toshiaki, M., Mirei, U., Etsuko, K., & Koji, N. (2006). Health status of workers in small and medium-sized companies as compared to large companies in Japan. *Journal of Occupational Health*, 48(3), 166-174. <http://dx.doi.org/10.1539/joh.48.166>
- 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., ... Bohgard, M. (2009). Characteristics of welding fume aerosol investigated in three Swedish workshops. *Journal of Physics: Conference Series*, 151(1), 012059. <http://dx.doi.org/10.1088/1742-6596/151/1/012059>
- Jenkins, N. T., & Eager, T. W. (2005). Chemical analysis of welding fume particles. *Welding Journal*, June 2005, 87-93.
- Mansouri, N., Atbi, F., Moharamnezhad, N., Rahbaran, D. A., & Alahiari, M. (2008). Gravimetric and analytical evaluation of welding fume in an automobile part manufacturing factory. *J. Res. Health Sci.*, 8, 1-8.
- National Institute of Occupational Safety and Health (NIOSH). (1994a). *Arsenic and compound, as As*. NIOSH Manual of Analytical Methods 7900.
- National Institute of Occupational Safety and Health (NIOSH). (1994b). *Cadmium and compounds, as Cd*. NIOSH Manual of Analytical Methods 7048.
- National Institute of Occupational Safety and Health (NIOSH). (1994c). *Chromium and compound, Cr*. NIOSH Manual of Analytical Methods 7024.
- National Institute of Occupational Safety and Health (NIOSH). (1994d). *Lead by GFAAS*. NIOSH Manual of Analytical Methods 7105.
- National Institute of Occupational Safety and Health (NIOSH). (1996). *Carbon Monoxide*. NIOSH Manual of Analytical Methods 6604.
- National Institute of Occupational Safety and Health (NIOSH). (2003). *Elements by ICP*. NIOSH Manual of Analytical Methods 7300.
- Occupational Safety and Health Association (OSHA). (2002). *Metal & Metalloid Particulates in Workplace Atmospheres (Atomic Absorbtion)*. OSHA Analytical Methods. M. ID-121.
- Ravert, E. (2006). Controlling chromium fumes. *Welding Journal* (November 2006).
- Small Medium Enterprise Corporation. (2010). SME Annual Report 2009/2010. Retrieved from www.smecorp.gov.my
- Yeo, S. H., & Neo K. G. (1998). Inclusion of environmental performance for decision making of welding processes. *Journal of Materials Processing Technology*, 82(1-3), 78-88. <http://dx.doi.org/10.1088/1742-6596/151/1/012059>