Jurnal Teknologi

Full paper

# Welding Waste In Vocational College: Should It Be Properly Managed?

Jimmy C[a,c*], Sethuprakhash V[a], Siti Eshah Mokshein[b]

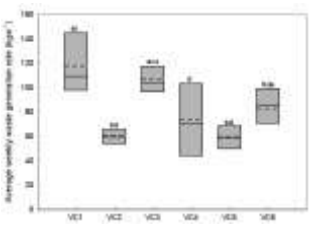
[a]*Engineering Technology Department, Faculty of Technical and Vocational Education, Sultan Idris Education University, 35900 Tanjong Malim, Perak, Malaysia*
[b]*Department of Education Studies, Faculty of Education and Human Development, Sultan Idris Education University, 35900 Tanjong Malim, Perak, Malaysia*
[c]*Sungai Buloh Vocational College, Km 22, Jalan Kuala Selangor, 47000 Sungai Buloh, Selangor, Malaysia*

[*]Corresponding author: jimmychg@gmail.com

**Article history**

Received: 4 September 2014
Received in revised form:
15 October 2014
Accepted: 1 December 2014

**Graphical abstract**



**Abstract**

This article outlines the study findings on solid waste composition and generation rates in six vocational college welding workshops in Malaysia. Our data indicated that vocational college welding waste was composed of scrap metal, metal dust, welding electrodes, and grinding disks which constituted 92.89, 3.64, 3.07 and 0.4 percent of the total welding waste, respectively. The total welding waste generation rates were varied from 59.57 to 117.63 $kgw^{-1}$ across the study workshops with the average of 83.42 $kgw^{-1}$. Per capita generation rates were varied from 0.60 to 1.90 $kgw^{-1}st^{-1}$ with the average of 1.23 $kgw^{-1}st^{-1}$. These data illustrate the potential environmental impact of welding waste due to its amount and hazardous nature of the constituents as some components were known to contain various metal oxides. These data are important in determining the dimensions of solid waste management in vocational educational institutions.

*Keywords*: Vocational college, welding workshop, solid waste, metal waste, waste management



## 1.0 INTRODUCTION

Educational institutions have been recognized to have the same standard as industries with regards to its impact on the environment [1]. Human activities resulting from educational institutions may give more pressure on the environment partly due to high solid waste generation rates [2-4]. Additionally, solid wastes generated from educational institutions are also known to be composed of hazardous and scheduled waste [2-3].

In Malaysia, as of May 2014, the Ministry of Education has listed on its website that there are 10,119 schools currently operating with approximately 5.1 million students enrolled and 0.42 million teachers employed. As a result, approximately 20 percent of Malaysia population is directly involved with activities in school. These numbers depict that a significant amount of wastes could be generated in schools. In general, it has been suggested that educational institutions may generate between 20 to 30 percent of the total national wastes [5]. Moreover, reports have shown that school's waste materials, particularly from laboratory or workshop, are considered as hazardous with health risks potential [5-7]. This potentially hazardous waste issue is more pronounced in vocational schools or colleges as 70 percent of their student's learning time are in the workshop [8]. Additionally, recent transformation of vocational school to vocational college resulted in higher students enrollment in the vocational colleges, thus further contributing to waste-related issues. Among other workshops in vocational college, welding workshop is considered as the one that is actively generating waste.

Welding activities produces many types of waste and by-products such as scrap metal, welding electrode, grinding disk, welding dust and powder that may contain various hazardous metal oxides [9-10]. Additionally, hazardous by-products and wastes may also present in terms of atmospheric emissions such as volatile organic compounds (VOCs), fumes, mists, metal oxide vapors and acid/alkali vapors [9-10]. These facts are highlighting the importance of proper waste management in vocational college welding workshop. It is extremely important to ensure proper waste management being carried out in vocational college welding workshop to reduce its potential environmental negative impact. In Malaysia, lack of proper waste management in vocational college welding workshop could be related to the fact that this issue has not been given adequate attention by the authorities and college communities. Additionally, this issue has

not been seen as important enough to be taken into account for integrated waste management program. At this stage, data on vocational college welding waste generation and composition in Malaysia remain scarce. For this reason, it is crucial to obtain some early data on the lacking aspects of vocational college welding waste. This article outlines the findings on the welding composition and generation in vocational colleges. These data will provide an evidence of the current scenario of vocational college welding waste composition and generation. The obtained welding waste composition and generation data could have an essential role in determining the dimensions of the key elements in solid waste management.

## 2.0 MATERIALS AND METHODS

Six vocational colleges which offer welding technology program in the central zone of peninsular Malaysia were selected for this study. The study colleges were Sungai Buloh Vocational College, Klang Vocational College, Setapak Vocational College, Ampangan Vocational College, Port Dickson Vocational College and Slim River Vocational College. Due to ethical reason, the selected vocational colleges for this study were randomly coded as VC1, VC2, VC3, VC4, VC5 and VC6. Waste composition and generation data were obtained through weekly on-site waste quantification in all six selected vocational college welding workshops. The accumulated weekly welding waste were quantify using weighing balance of capacity up to 30kg. All types of waste produced from students welding activities in the welding workshop were also separated and weighed according to its individual component. The on-site waste quantification process was commenced on 1st April 2013 and ended on 10th May 2013. The duration used for waste quantification was related to the period when teaching and learning in welding workshops was in the most active state. This period was selected to obtain an accurate or worst case scenario weekly waste generation rates. The collected data were analyzed using the Statistical Package for the Social Science version 17 (SPSS 17.0). Descriptive statistics was used to summarize the main findings of this study.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Welding Waste Composition

The major components of welding waste include scrap metal, used welding electrode, grinding disk and metal dust. The data on waste composition and its associated fraction were analyzed and presented as constituent percentage in each welding workshop (Table 1).

As shown in Table 1, scrap metal was the major fraction of total welding in all the study workshops. Scrap metal made up between 89.96 to 95.41 percent of total waste across the study workshops. In average, scrap metal constituted of 92.89 percent of the total waste. Metal dust on the other hand, only contributed between 2.60 and 6.74 percent of the total welding waste. On average, 3.64 percent of the total welding waste was made up by metal dust. Apart from that, welding electrode was also one of the major waste types as it was considered as the most demanded consumables by students for their welding work. Across the study workshops, welding electrodes contributed between 1.73 to 3.69 percent of the total waste. On average, 3.07 percent of the total waste was constituted by welding electrodes. Grinding disk contributed to less than 1 percent of the total waste in all study workshops, with the average of 0.40 percent

**Table 1** Constituent percentages of welding waste in six vocational colleges

| College | Scrap Metal (%) by weight | Electrodes (%) by weight | Grinding Disk (%) by weight | Metal Dust (%) by weight |
|---|---|---|---|---|
| VC1 | 93.51 | 3.29 | 0.31 | 2.89 |
| VC2 | 92.71 | 3.69 | 0.34 | 3.25 |
| VC3 | 91.41 | 3.31 | 0.58 | 4.70 |
| VC4 | 92.89 | 3.62 | 0.27 | 3.22 |
| VC5 | 89.96 | 2.43 | 0.87 | 6.74 |
| VC6 | 95.41 | 1.73 | 0.26 | 2.60 |
| Mean | 92.89 | 3.07 | 0.40 | 3.64 |

The composition of welding waste reported in this study had illustrated the potential adverse impact of welding waste on the environment due to its hazardous nature. Welding waste components which include welding electrode, metal dust and grinding disk are known to contain various hazardous metal oxides [9, 11-12]. As reported in the literature, welding electrode, metal dust and grinding disk are known to contain aluminum oxide, silicon carbide, zirconium oxide, manganese compounds and zinc compounds [11-13]. These metals are considered as environmental pollutants with significant consequences when polluting the physical environment and interact with the biological component in the environment [14-16]. As published in Adekeye, Ojo, and Ajayi [15], welding waste is a source of serious metal pollution in soil. Additionally, exposure to hazardous metal oxides from welding waste could lead to various adverse effects in human. As published in Work Safe Alberta [17], long term or excessive exposure to manganese and zinc compound can cause Parkinson's-like disease and other neurological effects. Furthermore, exposures to metal oxides are also leading to other health issues including serious respiratory problems and reproductive effects [18]. Due to these harmful nature, metal bearing waste requires special consideration and management. In Malaysia, metal and metal bearing wastes were classified as scheduled waste and required management according to the specified regulations in Environmental Quality (Scheduled Wastes) Regulations 2005 [19].

### 3.2 Welding Waste Generation Rate

Quantification of welding waste generated across six vocational college welding workshops revealed the amount of waste with limitation to only on waste produced by students metal work activities. Generation rates of total waste were summarized in Table 2.

**Table 2** The average weekly total waste generation rates ($kgw^{-1}$) in six vocational college welding workshops

| College | Total waste ($kgw^{-1}$) |
|---|---|
| VC1 | 117.63 |
| VC2 | 106.60 |
| VC3 | 60.33 |
| VC4 | 73.58 |
| VC5 | 59.57 |
| VC6 | 82.80 |
| Mean | 83.42 |

Based on the average of six weeks' data, these workshops generated up to 83.42kg total waste in one week. When analyzed separately by workshop, the average total waste generation was varied from 59.57 to 117.63 $kgw^{-1}$ across the study workshops. The analysis of variance revealed that the weekly total waste generation rates were found to be significantly different across these workshops ($F(5, 30) = 7.662$, $p < 0.05$). The differences of weekly waste generation rates between vocational colleges as suggested through Least Significance Difference post-hoc test are illustrated as in Fig.1.

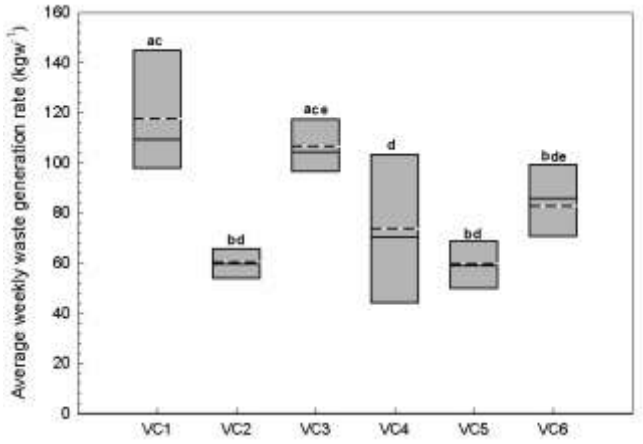



**Figure 1** Boxplots of weekly waste generation rates over the whole study period in all vocational colleges, boxes represent 25th to 75th percentiles, straight lines within the boxes mark the median and short dashed lines indicate the mean. Waste generation rates in vocational colleges with common letters are not statistically different ($P > 0.05$).

Based on the constituent percentages presented in Table 1, weekly generation rates of each waste component were calculated and presented in Table 3. In accordance to the highest constituent percentage, on average, scrap metal registered the highest weekly generation rates of 77.49 $kgw^{-1}$ in the study workshops. Meanwhile, the average of metal dust and electrodes weekly generation rates in the study workshop were 3.04 $kgw^{-1}$ and 2.56 $kgw^{-1}$, respectively. Other than that, grinding disk was the least generated waste with the average weekly generation rates of only 0.34 $kgw^{-1}$. When analyzed separately by workshop, weekly scrap metal generation rates were ranged between 53.58 and 110.00 $kgw^{-1}$. Scrap metal generation rate was the highest in VC1, which almost double the rates showed in VC3 and VC5. On the other hand, electrodes was generated weekly at the rates between 1.43 and 3.93 $kgw^{-1}$ with VC2 being the highest generator. Metal dust generation rates were varied between 2.15 and 4.02 $kgw^{-1}$. Meanwhile, grinding disk generation rates were varied between 0.20 and 0.43 $kgw^{-1}$ and considered as the lowest in comparison to other waste components. VC5 showed the highest generation rates for metal dust and grinding disk with the average of 0.43 $kgw^{-1}$ and 4.02 $kgw^{-1}$, respectively.

**Table 3** Weekly generation rates ($kgw^{-1}$) of each welding waste component in six vocational college welding workshop

| College | Scrap metal | Electrodes | Grinding disk | Metal dust |
|---|---|---|---|---|
| VC1 | 110.00 | 3.87 | 0.37 | 3.40 |
| VC2 | 98.83 | 3.93 | 0.37 | 3.47 |
| VC3 | 55.15 | 2.00 | 0.35 | 2.83 |
| VC4 | 68.35 | 2.67 | 0.20 | 2.37 |
| VC5 | 53.58 | 1.45 | 0.43 | 4.02 |
| VC6 | 79.00 | 1.43 | 0.22 | 2.15 |
| Mean | 77.49 | 2.56 | 0.34 | 3.04 |

To determine the influence of student numbers on waste quantities, a weekly waste generation per-capita ($kgw^{-1}st^{-1}$) was calculated and presented in Table 4. The calculated per capita generation rates demonstrated that the amount of welding waste generated per student on a weekly basis were also varied across workshops. Based on the per capita waste generation, significantly higher rates were obtained in VC1 and VC2 with the total waste generation up to 1.90 and 1.84 $kgw^{-1}st^{-1}$, respectively. In other workshops, per capita generation rates were varied between 0.60 and 1.23 $kgw^{-1}st^{-1}$. The calculated per capita generation rates were varied from 0.60 to 1.90 $kgw^{-1}st^{-1}$ with the average of 1.23 $kgw^{-1}st^{-1}$. The lowest per capita generation rate of 0.60 $kgw^{-1}st^{-1}$ was registered in VC5. As per waste component basis, scrap metal per capita generation rates were the highest amongst the other waste components. The scrap metal per capita generation rates were varied across workshops between 0.58 $kgw^{-1}st^{-1}$ in VC5 and 1.77 $kgw^{-1}st^{-1}$ in VC1, with the average of 1.14 $kgw^{-1}st^{-1}$. Meanwhile, per capita generation rates for electrodes were varied between 0.02 $kgw^{-1}st^{-1}$ in VC5 and VC6, and 0.07 $kgw^{-1}st^{-1}$ in VC2. For metal dust, the per capita generation rates were varied between 0.03 $kgw^{-1}st^{-1}$ in VC6 and 0.06 $kgw^{-1}st^{-1}$ in VC2. The average per capita generation rates for both electrodes and metal was registered at 0.04 $kgw^{-1}st^{-1}$. As mentioned earlier, generation rates of grinding disk were the lowest amongst other waste components. Grinding disk per capita generation rates were varied from 0.003 to 0.006 $kgw^{-1}st^{-1}$ across the vocational colleges, with the average of 0.005 $kgw^{-1}st^{-1}$.

**Table 4** Per capita generation rates ($kgw^{-1}st^{-1}$) of each welding waste components in six vocational college welding workshops

| College | Number of students | Scrap metal | Electrodes | Grinding disk | Metal dust | Total waste |
|---|---|---|---|---|---|---|
| VC1 | 62 | 1.77 | 0.06 | 0.006 | 0.05 | 1.90 |
| VC2 | 58 | 1.70 | 0.07 | 0.006 | 0.06 | 1.84 |
| VC3 | 64 | 0.86 | 0.03 | 0.005 | 0.04 | 0.94 |
| VC4 | 60 | 1.14 | 0.04 | 0.003 | 0.04 | 1.23 |
| VC5 | 93 | 0.58 | 0.02 | 0.006 | 0.04 | 0.60 |
| VC6 | 70 | 1.13 | 0.02 | 0.003 | 0.03 | 1.18 |
| Mean | | 1.14 | 0.04 | 0.005 | 0.04 | 1.23 |

Variability in the per capita generation rates between vocational colleges suggest that the amount of welding waste being produced was not only subjected to the number of students undergo welding training in the workshop. In fact, the amount of welding waste maybe connected to raw material control system adopted by certain welding workshop. As revealed through interview conducted in other study on these vocational colleges (Jimmy

Chong unpublished data), the per capita generation rate was lowest in VC5 as in this vocational college, raw material and consumable usages were controlled by all welding teachers. In contrast, limiting raw material and consumable usages was not practiced by all teachers in other five vocational colleges. Due to the strict material control in VC5, students in VC5 were only given the limited amount of raw material for each welding project. This approach was associated with low per capita generation rate; however, this approach may also limit the students' acquisition of vocation skills [20-21].

In addition, the study results also suggest the potential adverse impact of welding waste on the environment due to the amount being produced. The weekly welding waste generation rate obtained in this study had illustrated the contribution of the vocational college welding waste to the total national scheduled waste stream. The average generation rate obtained in this study is needed for the projection of the total welding waste being generated across all vocational college welding workshop in Malaysia. Based on the average generation rate of 83.42 $kgw^{-1}$ for one workshop, and the assumption of 20 most active practical exercises weeks in an academic year, the total amount of welding waste generated in one workshop could reach 1668.4 kg on yearly basis. Therefore, the total welding waste possibly being produced by 44 vocational college welding workshops could reach 73.4 tonnes in one academic year. This number might only contribute to a small fraction of the current national scheduled waste which was estimated at 33 million tonnes. However, the total welding waste predicted in this study has proven that vocational college welding waste deserved a proper management. Proper welding waste management is needed to minimize its potential adverse environmental impacts due to a hazardous nature of some welding waste component. Additionally, proper management which will lead to minimum waste generation and maximum waste recovery is needed as each addition of waste to landfill will significantly shorten the expected life-span of the available landfill [16, 22-24].

Waste generation data obtained in this study also can be analyzed from the economic perspective. The amount of waste generated in welding workshops had also illustrated the amount of money that went down as waste materials. As described earlier, scrap metal was generated in the highest quantity as compared to other waste components. Based on the average scrap metal generation rate of 77.49 $kgw^{-1}$ for one workshop, and the assumption of 20 active practical exercises weeks in an academic year, the total amount of scrap metal being generated in one workshop could reach 1549.8 kg on yearly basis. As the average Asia carbon steel price in January 2014 is USD632/tonne or MYR2,054.95/tonne (World Steel Prices, 2014), the amount of metal produced by 44 vocational college welding workshops can worth up to USD43,096.84 (MYR140,129.51) in one academic year. Due to this, measures should be taken to minimize metal waste generation as a measure to reduce money loses as waste materials.

## 4.0 CONCLUSION

Welding waste was composed of scrap metal, metal dust, welding electrodes, and grinding disks which constituted 92.89, 3.64, 3.07 and 0.4 percent of the total welding waste, respectively. On amount wise, welding waste could be generated at rate 83.42 $kgw^{-1}$ during the active period of teaching and learning activities. Additionally, per capita generation rates were also varied from 0.60 to 1.90 $kgw^{-1}st^{-1}$ with the average of 1.23 $kgw^{-1}st^{-1}$. The obtained data had illustrated the potential adverse environmental impact of welding waste due to a hazardous nature of waste constituents and the amount of waste produced. Even so, the potentially high metal waste generation in vocational colleges may provide high metal recycling potential. Recycling scrap metal to produce new metal products has numerous benefits for the environment as this process release lower amounts of greenhouse gases and use less water if compared to the production of new metal product from mined ore [25-26].

In general, this new data is essential to trigger necessary actions towards achieving sustainable waste management practices in vocational educational institutions. Moreover, the obtained welding waste composition and generation data could have an essential role in determining the dimensions of the key elements in solid waste management. A list of such elements would certainly include method and type of storage, on-site handling, on-site collection and disposal, and the degree of potential resource recovery. As this study only focused on welding workshop, the future study could expand the scope to other workshops in vocational colleges such as construction technology workshops, industrial machining workshops, and automotive technology workshops.

## Acknowledgement

The researchers gratefully acknowledge the supports provided by Malaysia educational institutions including Sultan Idris Education University (UPSI), Sungai Buloh Vocational College, Setapak Vocational College, Klang Vocational College, Ampangan Vocational College, Port Dickson Vocational College, and Slim River Vocational College.

## References

[1] Savely, S.M., Carson, A.I., Delclos, G.L. 2007. An Environmental Management System Implementation Model for U.S. Colleges and Universities. *J Clean Prod.* 15 (7): 660 – 670.

[2] USEPA 2008. Mercury and Hazardous Chemicals in Schools: A Manual for Students in Southeast Asia. *U.S. Environmental Protection*. Agency. http://www.epa.gov. Accessed on 16 March 2014.

[3] Kuhlemeier, H., Van Den Bergh, H., Lagerweij, N. 1999. Environmental Knowledge, Attitudes, and Behavior in Dutch Secondary Education. *J Environ Educ.* 30(2): 4–14.

[4] Ana, G.R.E.E., Oloruntoba, E.O., Shendell, D., Elemile, O.O., Benjamin, O.R., Sridhar, M.K.C. 2011. Solid Waste Management Problems in Secondary Schools in Ibadan, Nigeria. *Journal of Environmental Health*. 74(2): 24–28.

[5] USEPA 2006. Hazardous Waste Management for School Laboratories and Classrooms. *U.S. Environmental Protection Agency*. http://www.epa.gov. Accessed on 16 March 2014.

[6] Larijani, M. 2010. Assessment of Environmental Awareness among Higher Primary School Teachers. *J Hum Ecol* 31(2): 121–124

[7] Hens, L., Wiedemann, T., Raath, S., Stone, R., Renders, P., Craenhals, E. 2010. Performance of Newly Implemented Environmental Management Systems in Primary Schools in South Africa. *J Environ Manage*. (91): 906–917.

[8] Kementerian Pelajaran Malaysia 2011. Transformasi Pendidikan Vokasional: Pelan Strategik. http://www.bptv.edu.my. Accessed 12 March 2014

[9] Geraghty, R., Doolan, M., Egan, T., Prior, P. 2011. Environmental Compliance in Ireland's Engineering Sector, Ireland. *Enterprise Ireland*. http://www.envirocentre.ie. Accessed 26 January 2014.

[10] Alam, P., Ahmade, K. 2013. Impact of Solid Waste on Health and The Environment. *International Journal of Sustainable Development and Green Economics (IJSDGE)*. 2: 165–168.

[11] OECD 2010. Environmental and Climate Change Issues In The Shipbuilding Industry. *Council Working Party on Shipbuilding (WP6)*. http://www.oecd.org. Accessed 12 March 2014.

[12] WHO (World Health Organization). 1999. Hazard Prevention and Control in the Work Environment: Airborne Dust, Occupational and Environmental Health. *Department of Protection of the Human Environment*. http://www.who.int. Accessed 14 February 2014.

[13] New Zealand Department of Labour. 2006. Health and Safety in Welding. Wellington, *New Zealand Department of Labour*. http://www.business.govt.nz. Accessed 26 January 2014.

[14] Wang. L., Chen, J.P., Hung, Y.T., Shammas, N.K. 2009. *Heavy Metals in the Environment*. CRC Press
[15] Adekeye, E.A., Ojo, M.A., Ajayi, O.O. 2011. Contributions of Metal Welding Workshops to Environmental Pollution in Akure Metropolis, Ondo State, Nigeria. *Journal of Environmental Issues and Agriculture in Developing Countries.* 3 (1): 1─7.
[16] Mahayuddin S.A., Zaharuddin, W.A.Z.W. 2013. Quantification of Waste in Conventional Construction. *International Journal of Environmental Science and Development.* 4(3): 296─299.
[17] Work Safe Alberta. 2009. Welder's Guide to the Hazards of Welding Gases and Fumes. Alberta, *Government of Alberta*. http://work.alberta.ca. Accessed 12 March 2014.
[18] Ittiravivongs, A. 2012. Recycling As Habitual Behavior: The Impact of Habit on Household Waste Recycling Behavior in Thailand. *Asian Social Science.* 8(6): 74─81.
[19] Environmental Quality (Scheduled Wastes) Regulations. 2005. Report Number: P.U.(A) 294/2005. http://cp.doe.gov.my. Accessed 26 January 2014.
[20] Achieng, N.R. 2012. *Factors Affecting Acquisition of Vocational Skills Among Youth Learners in Maranda Division Siaya Country*. Dissertation, University Of Nairobi, Nairobi.
[21] Gill, I.F., Fluitman, F., Dar, A. 2000. *Vocational Education and Training Reform: Matching Skills to Markets and Budgets*. New York: Oxford University Press.
[22] Chandrappa, R., Das, D.B. 2012. *Solid Waste Management: Principles and Practice*. New York, Springer.
[23] Tchobanoglous, G. 2009. *Solid Waste Management: Environmental Health and Safety for Municipal Infrastructure, Land Use and Planning, and Industry*. John Willey & Sons.
[24] Mwanthi, M.A., Nyabola, L.O., Tenambergen, E. 1997. Solid Waste Management in Nairobi City: Knowledge and Attitudes. *J Environ Health*. 60(5): 23─29.
[25] Johnson, J., Reck, B. K., Wang, T., Graedel, T. E. 2008. The Energy Benefit Of Stainless Steel Recycling. *Energy Policy*. 36(1): 181─192.
[26] Damgaard, A., Larsen, T. H. 2009. Recycling Of Metals: Accounting Of Greenhouse Gases And Global Warming Contributions. *Waste Management & Research.* 27(8): 773─780.