ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

The Relation of Ultrafine Particle Emission Production to Temperature from Wood Burning

Arinto Y.P. Wardoyo
Physics Department, Brawijaya University, Jl. Veteran. Malang, Indonesia

Abstract— Ultrafine particles have attacked some scientists to investegate the properties due to their impacts on human health. Wood burning is a source of the ultrafine particle producer identified as a significant contributor of the particles in the air. This study investigated the relationship between ultrafine particle emission production and combution temperature of wood burning under controlled laboratory conditions called fast and slow burnings. The results show that particle concentrations emitted during the burnings are proportional to temperature. Under fast burning conditions, a linear relationship was found between ultrafine particle number concentration and temperature, and the linearity ratio varied between 0.93 - 0.97 depending on the type of sample burned.

Keywords : Emission Production, Temperature, Wood Burning.

I. INTRODUCTION

Many large areas around the world are affected by biomass burning and data shows that 500 - 1000 million hectares of open forest and savannas are burned every year [1]. More than 1.3 million ha of forest were burnt in China in 1987. In the same year, forest fires in eastern Asia consumed approximately 14 million hectares [2]. Forest burning destroyed more than 5-20 million hectares in Indonesia in 1994 and 1997 [3]. Other data show that 10 million hectares of forest in northern latitudes; 40 million hectares of tropical and sub tropical forest, and 500-1000 million hectares of open forest and savannahs are burnt every year. More than 5 million hectares of forest was destroyed by fires in Kalimantan during the 1982-83 El Nino drought, and 9 million hectares of vegetation were burnt in Sumatra and Kalimantan in 1997-98. Between 5 and 20 million hectares of forest are consumed by uncontrolled fire every year in North America and Eurasia. In Australia, 40 – 130 million hectares of land are burned annually [4]. The particle and gaseous emissions that result from biomass burning [5-11] not only impact upon human health ([12, 13] Samet et al. 2000; Levy et al. 2000; and Tolbert et al. 2000), but they also play an important role in a number of atmospheric processes [14-16].

Quantification and characterization of the emissions, as well as the factors influencing them, has been identified as a very important element in developing a quantitative assessment of their impacts on both humans and the environment. In general, laboratory measurements of particle number emission factors were found to range from 0.5×10^{13} to 40×10^{16} [7, 17].

Due to the complex processes that occur during biomass burning [18], a number of factors affect particle emission characteristics, including the type of biomass, as well as burning conditions [1, 7, 19-24]. Temperature also plays a vital role in biomass burning processes (hydrolysis, oxidization, dehydration and pyrolyzation) [18], where biomass compounds (celluloses, hemicelluloses, lignin, lipid, proteins, simple sugars, starches, water, hydrocarbon components (HC), ash and other compounds) [25] are converted into emission products. Although the characteristics of particle emissions from biomass burning has been reported in previous papers [18, 26], however there is still a limited understanding of the relationship between temperature and particle emission during the burning processes, and this relationship is not yet to be quantified. This study aimed to quantify the relationship between ultrafine particle emissions and temperature for different burning conditions, in order to gain a better understanding of the biomass burning process, as well as to provide information for emission production and dispersion models.

II. METHODOLOGY

The study was conducted by burning several wood samples, collected from Queensland forest trees, under controlled laboratory conditions. The experimental setup consisted of a burning system (modified stove), a dilution and sampling system, and a particle measurement system [7, 24] (see Figure 1). A modified commercial stove ($66 \times 74.5 \times 55 cm^3$), fitted with a ventilation system to enable the introduction of a controlled amount of air into the stove, and was used to simulate different burning rates. In order to obtain a homogeneous

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

rate of air flow, the outlet of the ventilation system was connected to a rectangular hood, which was connected to a blower with a maximum capacity of 14 L/s, by a pipe 30 mm in diameter. The flow rate of the air was adjusted by a valve located at this connection.

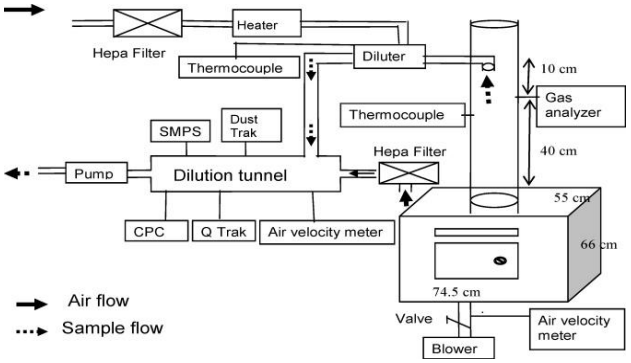

Fig 1. Experimental Setup Consisting Of The Burning System (Modified Stove), A Dilution And Sampling System, A Particle Measurement System and Temperature Measurement System [7, 24, 27].

A Particle Emission Measurements

Smoke samples were taken from the flue through a probe 1 cm in diameter and then introduced into an DEKATI ejector dilutor where they were diluted 10 times with heated, compressed, particle-free air, in order to obtain a dry, diluted sample and prevent further coagulation. The sample was then mixed in a dilution tunnel with a constant flow of HEPA (High Efficiency Particulate Air) filtered ambient air get the concentration below 10^6 particles/ cm^3. The flow rate and temperature of the samples were measured using an air velocity meter. The velocity of air in the dilution tunnel was kept > 1 m/s to obtain a good mixing of the sample. The tunnel temperature was between 28°C and 30°C. The dilution ratio was calculated as:

$$DR = \frac{C_f - C_b}{C_d - C_b} \quad (1)$$

where C_f, C_d, and C_b are CO_2 concentrations measured using a flue gas analyzer and a TSI 8554 Q Trak Plus, in the flue, dilution tunnel and background, respectively [7]. Both instruments were calibrated prior to obtaining the measurements. The dilution ratio was found to vary from 100 to 200 depending on the burning conditions. Particle number concentrations during the burning process were measured continuously using a TSI 3022 CPC (condensation particle counter) opearted to measure particles for the diameter in the range of 8 to 560 nm. The sampling interval was set of 20s.

B Temperature Measurements

Real-time temperature measurements were conducted during the burning process by using a K-type thermocouple in the flue. The L shaped thermocouple having a 30cm length of the end was placed 30 cm above the stove, with the end of the thermocouple passing through the stack, in order to measure real temperature during the burning process. The thermocouple was connected to a data logger, via an analogue to digital converter, for temperature recording. The temperature was recorded every 20 seconds during the burning process.

C. Sample Material and Preparation

The samples consisted of different species of hardwood collected from the trees growing in open forests at Mount Samson, located about 40 km west from the city of Brisbane, in Queensland, Australia. Five species of Eucalyptus were selected as samples according to their prevalence in the forest and these 5 species represent 5 existing types according to a classification. These were: Spottedgumm (Eucalyptus citriodora), Bluegum (Eucalyptus tereticornis), Blood wood (Eucalyptus intermedia), Ironbark (Eucalyptus crebra) and Stringybark (Eucalyptus umbra). The pieces of wood were placed in an open area of the laboratory for several months to obtain homogeneous moisture contents within the optimum range for burning (i.e. 20 - 30 %) [28]. The moisture was not measured directly from the trunk because the sharp part of the moisture meter was only one centimeter in length and therefore, the moisture content of each piece of the wood was measured after the logs were cut into smaller pieces suitable for burning (about 15 - 25 cm in length, with a diameter of 5 - 12 cm). The moisture content measurements were conducted by measuring the dry part (outer part) and wet part (inner part) of the wood several times. The measured moisture content of the samples varied from 18 - 26% for Spotted Gum (outer and inner,

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

respectively), 15 - 26% for Blue Gum, 14 - 24% for Blood wood and 17 - 25% for Iron Bark. The moisture contents of the branches were 16 - 18% for Spotted Gum, 18 - 22% for Iron Bark and 18 - 20% for Stringybark.

D Burning Conditions

The experiment was designed and carefully controlled to capture the maximum number of parameters, which can be controlled under laboratory conditions. In particular, the flow rate for the experiments was chosen to correspond as closely as possible with the flow rates under natural conditions, represented by wind speed. It has been reported in the literature that most fires occur at a wind speed between 70 and 120 km/h. Bushfires in Australia occur under typical wind speed of about 80 km/h and with a rate of spread of 18-20 km/h (http:// www.ffp.csiro.au). The experiments were set up to simulate burning conditions by injecting air with the speed of 20 m/s (72 km/h) into the stove for fast burning and by keeping the stove unconnected to the blower during slow burning, so as not to force the air supply through the ventilation system (unforced flow rate of the incoming air was in the range between 1.7 and 2.5 m/s). The samples were burned in the stove under 'fast burning' and 'slow burning' conditions. During fast burning, the stove was connected to a blower that introduced fresh air with a maximum velocity of 20 m/s. Under slow burning conditions, the blower was not connected to the ventilation system during the burning process. Air velocity at the base of the stove was measured at several points, using an air velocity meter, while the door of the stove was closed. The air velocity across the horizontal cross section was relatively homogeneous for a radius of 15 cm from the middle of the stove base, with a speed of 1.8 - 2.0 m/s. Therefore, the samples were placed in the centre of the stove's base, in order to ensure the same air velocity across each set of experiments. To ignite the wood, newspaper and small pieces of the same wood type were used for the first sample. Pieces of the same wood type were used to ignite the following samples [24]. Each type of wood was burned 3 times, under both fast and slow burning conditions, with some sets of measurements repeated several days later, in order to confirm the reproducibility of the results for the same wood species. These results showed that the measurements conducted on different days gave consistent results. However, since ambient conditions varied between the different days, only the data collected during one day was used.

E Data Analysis

Ultrafine particle concentration and temperature were plotted as a function of time, in order to investigate real-time emission production. The concentration and temperature data were also statistically analysed for each sample and plotted against each other, in order to quantify the relationship between temperature and emission production.

III. RESULTS AND DISCUSSION

Figure 2 shows the time series of the ultrafine particle concentration and temperature measured during fast burning. From the figure it can be seen that particle number concentration followed the variation in temperature. The highest particle number concentration occurred at the same time as the highest temperature for all samples measured. Overall, the fast burning of blood wood and ironbark produced the highest particle number concentrations, being 9.3×10^8 particles/cm^3 at 540 ^{o}C and 8.5×10^8 particles/cm^3 at 535 ^{o}C, respectively. Spotted gum, stringy bark, and bluegum emitted 6.9×10^8 particles/cm, 6.8×10^8 particles/cm^3 and 6.1×10^8 particles/cm^3 at temperatures of 565 ^{o}C, 535 ^{o}C and 436 ^{o}C, respectively. Therefore, this data shows that burning temperature is an important factor in the determining particle number concentration, and that. in general, high particle number concentrations resulted in from high burning temperatures.

As shown in Figure 3, a similar relationship was also observed for slow burning, however slow burning generally yielded lower particle number concentrations and lower temperatures than fast burning. The lower temperatures observed during slow burning were the result of an unstable flame, which would ignite and go out every few seconds, as a result of the limited flow of air in the chamber. Large fluctuations in particle number concentration during slow burning were also observed as a result of the unstable flame. Consequently, the production of UFP particles varied greatly during the burning process, especially for blood wood, bluegum and spotted gum, being the harder types of wood among the samples burned.

For slow burning, stringy bark and bluegum produced the highest particle number concentrations, being 6.2×10^8 particles/cm^3 at 425 ^{o}C and 3.3×10^7 particles/cm^3 at 400 ^{o}C, respectively. In contrast, blood wood produced the lowest particle number concentrations, being 1.7×10^7 particles/cm^3 at 370 ^{o}C. This result was not unexpected, given that blood wood was the hardest of the woods sampled, and the influence of hardness on particle emission production was established in a previous paper by the authors [7]. Ironbark and spotted gum emitted 2.9×10^7 particles/cm^3 and 1.9×10^7 particles/cm^3 at temperatures of 390 ^{o}C and 385 ^{o}C, respectively.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

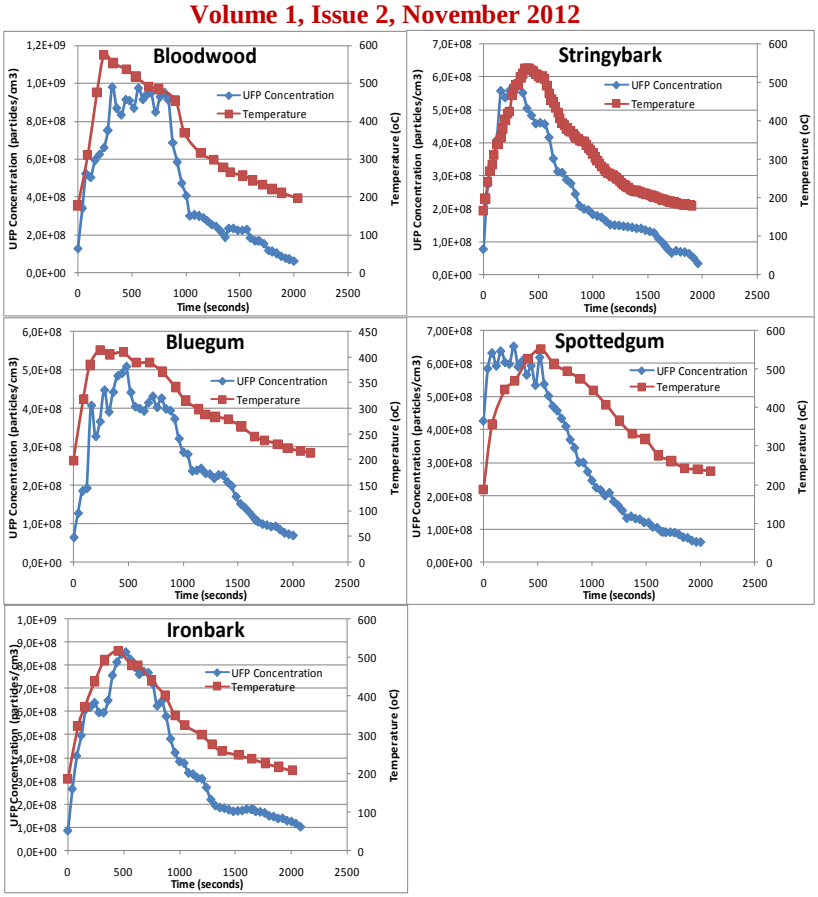

Fig 2. Time Series of Average UFP Concentrations and Temperatures For Fast Burning

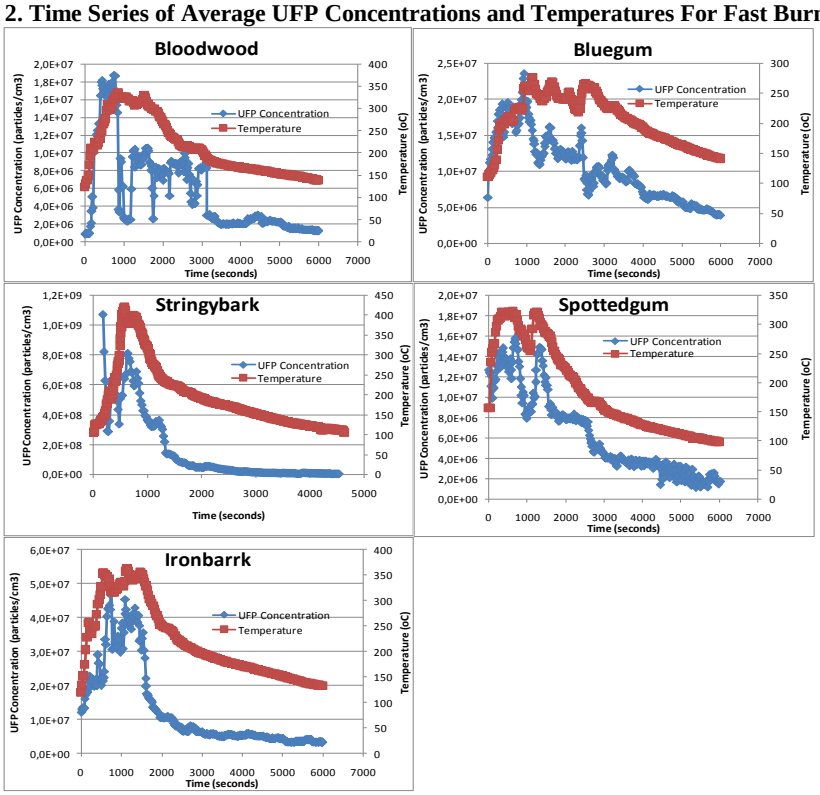

Fig 3. Time Series of Average UFP Concentrations and Temperatures for Slow Burning

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

Figure 4 shows the relationship between particle number concentration and temperature during fast burning. A significant linear relationship ($R^2 > 9.3$) was observed for all samples except bluegum and stringybark. Although fluctuations in particle number concentration meant that there was a large error when calculating the R^2 for slow burning, it was found that particle number concentrations were still proportional to temperature during slow burning. Whilst previous studies reported that particle production was proportional to flame size during the flaming process [29, 30], this paper reports particle production data throughout the entire burning process.

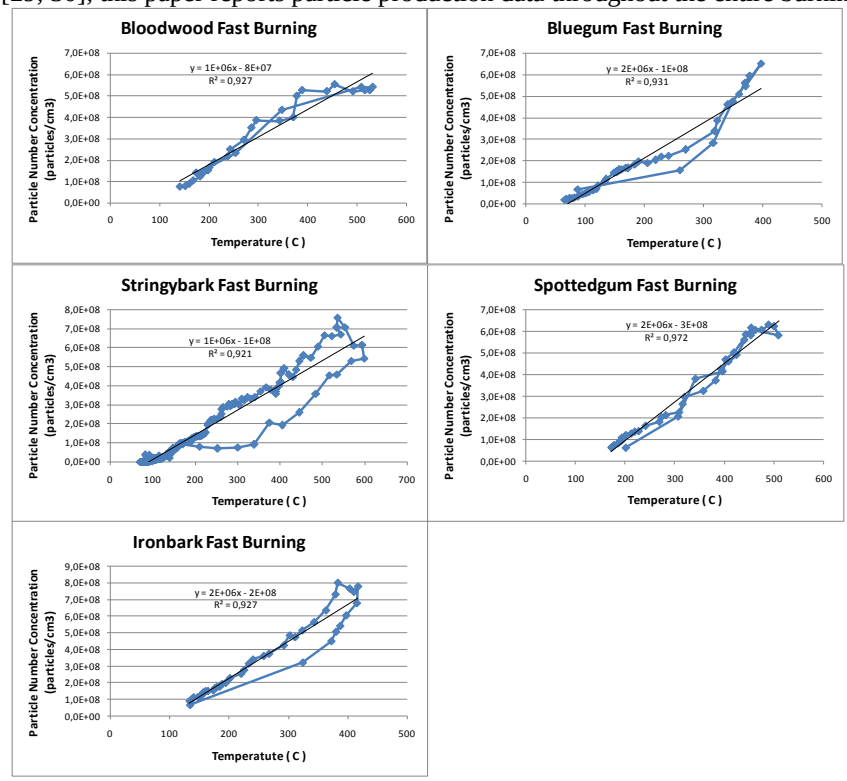

Fig 4. UFP Concentration Versus Temperature Of Fast Burning (The Arrows Show Temperature Increases and Decreases)

Overal results show that ultrafine particle formation in fast and slow burnings depends on combution temperature. To understand the UFP particle formation, it may necessary to discuss burning process that involves physical dan chemical processes and is devided into ignition, flamming and smouldering processes [31, 32]. The particle formation is started by the creation of condensation nuclei in the flame zone in which most particles are cyclic molecules in polycyclic aromatic hydrocarbons (PAHs) [33-35]. Then the PAH molecules grow to higher molecules through chemical and coagulation processes [36]. In flaming, arising temperature causes a pyrolysis process in which the molecules decompose into small ones [31, 37]. In terms of fast burnng, high temperature results in more decomposition of the molecules,consequently more ultrafine particles are emitted . In slow burning, less oxygen supplying during the burning produces lower temperature. In sufficient oxygen transported during pyrolysis process may be not high enough to complete oxidation process. This causes the ultrafine particles undergo a secondary condensation growth phase as a result the larger particles is formed. The preious studies confirm this phenomena that is smaller particles are produced during fast burning rather than slow burning [27, 38].

IV. CONCLUSION

In summary, it was found that burning conditions influenced the relationship between particle concentration and temperature, and that fast burning resulted in relatively high particle concentrations and temperatures, when compared to slow burning. For fast burning, a statistically significant linear relationship was obtained between UFP concentration and temperature, however whilst slow burning displayed similar trends, large fluctuation in concentration meant that this relationship was not statistically significant. Knowledge of the relationship between particle concentration and temperature is very important to estimate particle emissions released in the atmosphere

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

during open biomass burning, and also useful for dispersion model for biomass burning particles, especially for emission production model. In terms of emission production model, heat rates (heat intensity (heat released per second) and heat severity (heat released per unit area)) are related to convective energy used to transport the particles vertically before they disperse horizontally. More heat released means the higher the emissions are raised in the air. The height of the emissions causes the mixing height of the atmosphere boundary layer to become larger, which affects the dispersion process of the emissions. Heat rate also can be related to estimated particles released by biomass burning. This study obtained that particle concentrations are proportional to temperature. Based on this study, more heat released by biomass burning means more particles produced. By measuring temperature from burned area, amount of particles released in the area can be estimated.

REFERENCES

[1] C. Lauk and K.-H. Erb, "Biomass consumed in anthropogenic vegetation fires: Global patterns and processes," Ecological Economics, vol. In Press, Corrected Proof, 2009.

[2] D. R. Cahoon, B. J. Stock, J. S. Levine, W. R. Cofer III, and C. C. Chung, "Evaluation of a technique for satellite-derived estimation of biomass burning," Journal of Geophysical Research, vol. 97, pp. 3805-3814, 1992.

[3] J. Nichol, "Bioclimatic impacts of the 1994 smoke haze event in southeast Asia," Atmospheric Environment, vol. 31, pp. 1209-1219, 1997/4 1997.

[4] WHO, "Vegetation Fires," Http://www.who.int/mediacentre/factsheets/fs254/en/print.html, 2000.

[5] A. Y. P. Wardoyo, L. Morawska, and Z. Ristovski, "CO2 Emissions from the Combustion of Native Australian Trees," International Journal of Basic & Applied Sciences, vol. 11, pp. 70-77, 2011.

[6] T. G. S. Neto, J. Carvalho, .A. .,, C. A. G. Veras, E. C. Alvarado, R. Gielowe, E. N. Lincoln, T. J. Christian, R. J. Yokelson, and J. C. Santos, "Biomass consumption and CO2, CO and main hydrocarbon gas emissions in an Amazonian forest clearing fire," Atmospheric Environment 43 vol. 43, pp. 438-446, 2009.

[7] A. Y. P. Wardoyo, L. Morawska, Z. Ristovski, and J. Marsh, "Quantification particle number and mass emission factors from combustion Queensland trees." Environmental Science and Technology, vol. 40, pp. 5696-5703, 2006.

[8] C. P. Meyer, A. K. Luhar, and R. M. Mitchell, "Biomass burning emissions over northern Australia constrained by aerosol measurements: I--Modelling the distribution of hourly emissions," Atmospheric Environment, vol. 42, pp. 1629-1646, 2008.

[9] T. Ranta, P. Lahtinen, J. Elo, and J. Laitila, "The effect of CO2 emission trade on the wood fuel market in Finland," Biomass and Bioenergy, vol. 31, pp. 535-542, 2007.

[10] T. G. Soares Neto, J. A. Carvalho Jr, C. A. G. Veras, E. C. Alvarado, R. Gielow, E. N. Lincoln, T. J. Christian, R. J. Yokelson, and J. C. Santos, "Biomass consumption and CO2, CO and main hydrocarbon gas emissions in an Amazonian forest clearing fire," Atmospheric Environment, vol. 43, pp. 438-446, 2009.

[11] J. Tissari, J. Lyyränen, K. Hytönen, O. Sippula, U. Tapper, A. Frey, K. Saarnio, A. S. Pennanen, R. Hillamo, R. O. Salonen, M. R. Hirvonen, and J. Jokiniemi, "Fine particle and gaseous emissions from normal and smouldering wood combustion in a conventional masonry heater," Atmospheric Environment, vol. 42, pp. 7862-7873, 2008.

[12] M. A. Arbex, "Assesment of the effects of sugar cane plantation burning on hospital respiratory admissions," Journal of Air and Waste Management Association, vol. 50, pp. 1745-1749, October, 2000.

[13] K. Torigoe, "Influence of emission from rice straw burning on bronchia astma in children," Pediatrics International, vol. 42, pp. 143-150, 2000.

[14] S. Wurzler and M. Simmel, "Impact of vegetation fires on composition and circulation of the atmosphere." vol. Accessed March 2005, 2005.

[15] J. V. Martins, P. Artaxo, C. Liousse, J. S. Reid, P. V. Hobbs, and Y. J. Kaufman, "Effects of black carbon content, particle size, and mixing on light absorption by aerosols from biomass burning in Brazil.," J. Geophys. Res-A,, vol. 103, pp. 32041-32050, 1998.

[16] Y. J. Kaufman, P. V. Hobbs, V. Kirchhoff, P. Artaxo, L. Remer, B. N. Holben, M. D. King, D. E. Ward, E. M. Prins, K. M. Longo, L. F. Mattos, C. A. Nobre, J. D. Spinhirne, J. Q. Thompson, A. M. Gleason, S. A. Christopher, and S. C. Tsay, "Smoke, Clouds, and Radiation-Brazil (SCAR-B) experiment," J. Geophys. Res-A,, vol. 103, pp. 31783-31808, 1998.

[17] U. Wieser and C. k. Gaegauf, "Nanoparticle emissions of wood combustion processes." vol. Accessed March 2005: Laboratories for Sustainable Energy System, 2005.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

[18] B. R. T. Simoneit, "Biomass burning -- a review of organic tracers for smoke from incomplete combustion," Applied Geochemistry, vol. 17, pp. 129-162, 2002.

[19] M. D. Hays, P. M. Fine, C. D. Geron, M. J. Kleeman, and B. K. Gullett, "Open burning of agricultural biomass: Physical and chemical properties of particle-phase emissions," Atmospheric Environment, vol. 39, pp. 6747-6764, 2005/11 2005.

[20] L. S. Johansson, C. Tullin, B. Leckner, and P. Sjövall, "Particle emissions from biomass combustion in small combustors," Biomass and Bioenergy, vol. 25, pp. 435-446, 2003.

[21] H. Keshtkar and L. L. Ashbaugh, "Size distribution of polycyclic aromatic hydrocarbon particulate emission factors from agricultural burning," Atmospheric Environment, vol. 41, pp. 2729-2739, 2007.

[22] M. J. Kleeman, M. A. Robert, S. G. Riddle, P. M. Fine, M. D. Hays, J. J. Schauer, and M. P. Hannigan, "Size distribution of trace organic species emitted from biomass combustion and meat charbroiling," Atmospheric Environment, vol. 42, pp. 3059-3075, 2008.

[23] J. J. Lee, G. Engling, S.-C. Candice Lung and K.-Y. Lee, "Particle size characteristics of levoglucosan in ambient aerosols from rice straw burning," Atmospheric Environment, vol. 42, pp. 8300-8308, 2008.

[24] A. Y. P. Wardoyo, L. Morawska, Z. D. Ristovski, M. Jamriska, S. Carr, and G. Johnson, "Size distribution of particles emitted from grass fires in the Northern Territory, Australia," Atmospheric Environment vol. 41, pp. 8609-8619, 2007.

[25] B. M. Jenkins, L. L. Baxter, M. J. T.R, and T. R. Miles, "Combustion properties of biomass " Fuel Processing Technology, vol. 54, pp. 17-46, 1998.

[26] J. S. Reid, R. Koppmann, T. F. Eck, and D. P. Eleuterio, "A review of biomass burning emissions part II: intensive physical properties of biomass burning particles," vol. Atmos. Chem. Phys., p. 5, 2005.

[27] A. Y. P. Wardoyo, L. Morawska, Z. Ristovski, and J. Marsh, "Quantification particle number and mass emission factors from combustion Queensland trees," Environmental Science and Technology, vol. 40, pp. 5696-5703, 2006.

[28] J. E. Core, J. A. Cooper, and R. M. Neulicht, "Current and projected impacts of residential wood combustion on Pacific Northwest air quality," Journal Air Pollution Control Association, vol. 34, pp. 138 - 143, 1984.

[29] W. R. Cofer III, E. L. Winstead, B. J. Stock, L. W. Overby, J. G. Goldammer, D. R. Cahoon, and J. S. Levine, "Emissions from boreal forest fires: are the atmospheric impacts underestimated ?," in: Global Biomass Burning and Global Change, edited by Levine, J.S., MIT Press, Cambridge, Mass, pp 716-7332, 1996.

[30] I. Glasmann, "Soot formation in combustion processes," In Twenty-Second Symposium (International) on combustion, The combustion Institute, Pittsburgh, p.295., 1988.

[31] M. D. Hays, C. D. Geron, K. J. Linna, N. D. Smith, and J. J. Schauer, "Speciation of gas-phase and fine particle emissions from burning of foliar fuels," Environmental Science and Technology, vol. 36, pp. 2281-2294, 2002.

[32] B. M. Jenkins, L. L. Baxter, T. R. Miles Jr., and T. R. Miles, "Combustion properties of biomass," Fuel Processing Technology, vol. 54, pp. 17-46, 1998/3 1998.

[33] M. Frenklach, "Reaction mechanism of soot formation in flames" Phys. Chem. Chem. Phys, pp. 2028-2037, 2002.

[34] I. Glassman, "Soot formation in combustion processes, ," in Twenty Second Symposium (International) on Combustion, The Combustion Institute, Pittsburgh. , p. 295, 1988.

[35] S. R. Turns, "An Introduction to Combustion, Concepts and Applications," pp. 291-297, New York: McGraw Hill, 1996.

[36] I. Glassman, "Combustion," p. 275, Academic Press, New York, 1977.

[37] B. R. T. Simoneit, "Biomass burning -- a review of organic tracers for smoke from incomplete combustion," Applied Geochemistry, vol. 17, pp. 129-162, 2002/3 2002.

[38] A. Y. P. Wardoyo, L. Morawska, Z. D. Ristovski, M. Jamriska, S. Carr, and G. Johnson, " Size distribution of particles emitted from grass fires in the Northern Territory, Australia," Atmospheric Environment, vol. 41, pp. 8609-8619, 2007.

AUTHOR BIOGRAPHY

ARINTO YUDI PONCO WARDOYO
Home address: Jl. Srigading Dalam 47, RT 02 RW 02,
Malang 65145, Indonesia
Nationality: Indonesian
Home Tel: +62-341-481584
Office Tel: +62-341-575833,

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

Fax : +62-341-575834
Mobile: +62-81389829911
E-mail: a.wardoyo@ub.ac.id; arintoy@yahoo.com

CAREER OBJECTIVE
I aim to use my skills, knowledge and experiences in any challenging research and teaching job opportunities

TERTIARY EDUCATION
2003 – 2007 PhD in Physics (Environmental Physics), Queensland University of Technology,
Brisbane, Australia
Thesis title: Biomass burning: particle emissions, characteristics, and airborne measurements.

1992 – 1995 MSc in Physics (Radio astronomy), University of Tasmania,
Hobart, Tasmania, Australia
Thesis title: Pulse Timing measurements of the millisecond pulsar PSR 0437-47.

1983 – 1988 BSc honours in Physics (Electronics and Instrumentations), Gadjah
Mada University, Yogyakarta, Indonesia
Thesis title: Analysis of Respond Frequency and Stability of 400 MW Power Generator PT Krakatau Steel Cilegon.

EMPLOYMENT HISTORY
1989 – now Lecturer in the Dept. of Physics, Brawijaya University, Malang, Indonesia
2008 – now Head of The Instrumentation Laboratory in the Dept. of Physics, Brawijaya University, Malang, Indonesia.
2003 – 2007 Study leave for PhD degree
1996 – 2000 The secretary of the Dept. of Physics Brawijaya university, Malang, Indonesia.
1995 – 1996 Head of The Electronics and Instrumentation Laboratory in the Dept. of Physics, Brawijaya University, Malang, Indonesia
1992 – 1995 Study leave for Master degree
1989 – 1990 Head of The Electronics and Instrumentation Laboratory in the Dept. of Physics, Brawijaya University, Malang, Indonesia.

MAIN DUTIES AND RESPONSIBILITIES
Lecturer
Undergraduate teaching, research, and
community service.

Head of Electronics and Instrumentation Laboratory
Managing electronics workshop and lab work
for 2nd and 3rd year students.

Secretary of The Physics Department
- Officially responsible to the Rector of Brawijaya University for all teaching learning activities in the department.
- Organizing, coordinating and managing all activities within the department to provide high quality teaching learning processes in the department.

RELATED EXPERIENCE
2011 – Member of Procurement Team of Brawijaya Univeristy, Malang, Indonesia.
2010 – Now Assesor of National Acreditation committe of High Education (BAN PT).
2009 - Member of Procurement Team of Brawijaya Univeristy, Malang, Indonesia.
2007 – now Internal Auditor for Quality for Teaching and Learning Process of Brawijaya University, Malang, Indonesia.
2007 – 2009 The Coordinator of The Accreditation Team of The Physics Department, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, Indonesia.
2001 – 2002 Secretary of The Technological and Professional Skills Development Sector Project (TPSDP), The Physics Department, Faculty of Mathematics and Natural Sciences Brawijaya University, Malang, Indonesia.
1996 – 2000 Secretary of The Accreditation Team of The Physics Department, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, Indonesia.

AWARDS AND HONOURS
IDP, International Development Program Scholarship, 1992.
Australian International Development Assistance Bureau (AIDAB) scholarship, 1993-1995.
Visiting Researcher Scholarship from Japan Society for the Promotion of Science (JSPS), 1999.
Indonesian High Education Department Scholarship, 2003-2006.
The 2007 Dean's Award for Academic Excellence from Queensland University of Technology, Brisbane, Australia.
Posdoctoral Scholarship from Program Academic Recharging (PAR) DIKTI at Queensland University of Technology, Brisbane, Australia. , October 2009 – February 2010.

JOIN RESEARCH
Department of Applied Physics, Faculty of Engineering, Hokkaido University, Japan, 1999.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

International Laboratory for Air Quality and Health, Queensland University of Technology, Brisbane, Australia, October 2009- February 2010.

SCIENTIFIC PUBLICATION

- **Wardoyo, A.Y.P., Morawska, L**, and **Ristovski, Z** , **2011,** CO2 Emissions from the Combustion of Native Australian Trees, International Journal of Basic & Applied Sciences 11 (4) : 70-77.
- **Ristovski, Z., Wardoyo, A.Y.P., Morawska, L., Jamriska, M., Carr, S., Johnson, G., 2010**, Biomass burning influenced particle characteristics in Northern Territory Australia from airborne measurement, Atmospheric Research, 96 : 103-109.
- **Wardoyo, A.Y.P., Moraswka, L., Ristovski, Z., Marsh, J., 2007**. Size distribution of particles emitted from grass fires in the Northern Territory of Australia, Atmospheric Environment, **41** (38), 609-8619.
- **Wardoyo, A.Y.P., 2007.** Biomass burning: particle emissions, characterization, and airborne measurements, Queensland University of Technology, Brisbane, Australia (PhD Thesis).
- **Wardoyo, A.Y.P., Moraswka, L., Ristovski, Z., Marsh, J., 2006**, Quantification of particle number and mass emission factors from combustion of Queensland trees. Environmental Science & Technology, **40**, 5696-5703.
- **Wardoyo, A.Y.P., 2002,** Measurements of the Depth Narrow Slot using Resonance Method, Natural, March.
- **Rianto, S., Wardoyo, A.Y.P., Rahardi, D, Aniwati., 2001,** Two Dimension Simulation of Electrical Impedance Tomography, Natural, Brawijaya University, Malang.
- **Rianto, S., Wardoyo, A.Y.P., Rahardi, D., 2001,** Application of psedocolour image processing for enhance 3-D image of helical CT scanner, Brawijaya Univeristy, Malang.
- **Wardoyo, A.Y.P., Nadhir, A., 2001,** Design of frequency meter, Natural, Brawijaya Univeristy, November, 2001.
- **Wardoyo,A.Y.P., Nuriyah, L., 2000,** Measurements of frequency respond of the electromechanical sensor of P(VF_2/VF_3), Brawijaya University, Malang.
- **Rianto, S., Wardoyo, A.Y.P., Rahardi, D., Aniwati., 2000,** Application of psedocolour image processing for enhance x ray film analysis, Brawijaya University, Malang.
- **Wardoyo, A.Y.P., Nuriyah, L.,1998,** Characterization of electrical properties of copolymer P(VF_2/VF_3) with VF_2 65% and VF_3 35% mol, Brawijaya University, Malang.
- **Wardoyo, A.Y.P., 1998, Nuriyah, L.,** Design and characterization of the electromechanical sensor using copolymer P(VF_2/VF_3) with VF_2 65% and VF_3 35% mol, Brawijaya University, Malang.
- **Wardoyo, A.Y.P., Kusno, K., Dardiri, A.,1996,** Measurements of river turbidity in Madura island using light absorption method, Brawijaya University, Malang.
- **Wardoyo, A.Y.P., 1995,** Pulse Timing measurements of the millisecond pulsar PSR 0437-47, University of Tasmania (Master Thesis)
- **Wardoyo, A.Y.P., 1993,** Low Frequency oscillator in step of 10^4, University of Tasmania, Tasmania.
- **Wardoyo, A.Y.P., 1988,** Analysis of Respond Frequency and Stability of 400 MW Power Generator PT Krakatau Steel Cilegon, Gadjah Mada University, Yogyakarta.(BSc Thesis).

CONFERENCE/ SEMINAR

- **Wardoyo, A. Y. P.,** 2012, Analysis of Dispersion Models for Biomass Burning Particle Emissions : A Case of Study in Malang, The second BASIC International Conference, Malang, 24-25 January 2012.
- **Wardoyo, A. Y. P.,** 2011, Airborne Measurements of Particle Concentration From Biomass Burning in Northern Territory Australia Indonesia, International Conference on Basic Science II, 10 February 2011, Malang, Indonesia.
- **Wardoyo, A. Y. P.,** 2010, Measurements of CO_2 Emissions Emitted from Burning of Queenslsnd Trees, The Second National Seminar of Physics, 17 July 2010, Surabaya, Indonesia.
- **Wardoyo, A.Y.P., Moraswka, L., Ristovski, Z, 2009.,** Particle Characteristics Emitted from Frass Fires in the Northern Territory, Australia, The 19th International Clean Air and Environment Conference, 6-9 September 2009, Perth, Western Australia, Australia.
- **Wardoyo, A.Y.P., 2008.** Contribution of Biomass Burning on Global Climate Change, The 33rd annual convention of Geophysicists, 3-5 November 2008, Bandung, Indonesia.
- **Wardoyo, A.Y.P., 2008.** Transport mechanism of biomass burning emissions, The 5th Basic Science National Seminar, The faculty of Mathematics and Natural Sciences, Brawijaya University, 16 February 2008, Malang, Indonesia.
- **Wardoyo, A.Y.P., 2007.** Biomass burning: particle emissions and characterization, National Seminar of The Role of The faculty of Mathematics and Natural Sciences, Brawijaya University on Science and Technology Development, 7 August 2007, Malang, Indonesia.
- **Wardoyo, A.Y.P., Moraswka, L., Ristovski, Z., Marsh, J., 2005.**, Particle number and mass emission factors from combustion of wood samples collected from Queensland forest, proceeding of the 17th International Clean Air & Environment Conference, Hobart 3-6 May 2005, Hobart, Tasmania, Australia.
- **Wardoyo, A.Y.P., Moraswka, L., Ristovski, Z., Marsh, J., 2006**. Particle emission from biomass burning., proceeding of the 7th International Aerosol Conference, St. Paul 10-15 September 2006, St. Paul, Minnesota, USA.
- **Ristovski, Z., Wardoyo, A.Y.P., Morawska, L., Jamriska, M., Carr, S., Johnson, G., 2006**, Airborne measurements of particles from biomass burning in Northern Territory, Australia, proceeding of the 7th International Aerosol Conference, St. Paul 10-15 September 2006, St. Paul, Minnesota, USA.