J. Appl. Environ. Biol. Sci., 2(12)625-633, 2012

ISSN 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Indoor Particulate Matters Dispersion Potency

Indri Santiasih[1,]*, Joni Hermana[2] and Didik Bambang Supriadi[2]

[1]Department of Safety Engineering, Surabaya Shipbuilding Polytechnic, ITS campus Sukolilo, Surabaya Indonesia 60111
[2]Department of Environmental Engineering, Sepuluh Nopember Institute of Technology. ITS campus Sukolilo, Surabaya Indonesia 60111

ABSTRACT

This research was conducted by means of particulate matters (PM_{10} and $PM_{2,5}$) emission from wood surface coating process with the objectives to verify that the material balance could be used to estimate indoor particulate matters concentration and to verify the correlation between particulate matters with microorganisms concentration. The material balance was calculated from the emission rates and air flow rates, where the model goodness of fits was calculated by the root mean square error (RMSE). The correlation between particulate matters and microorganisms were analysed with linier regression. The results showed that the material balance could be used to estimate indoor particulate matters concentration. Respectively there were sufficient evidence of correlation between the concentration of PM_{10} and $PM_{2,5}$ with the concentration of microorganism, where R^2_{fungi} more significant than $R^2_{bacteria}$.

Keywords: Particulate matters, PM_{10} and $PM_{2,5}$, indoor, microorganism, bacteria, fungi

INTRODUCTION

Surface coating is an application of decorative or protective materials in liquid or powder form to substrates. These coatings normally include general solvent type paints, varnishes, lacquers, and water thinned paints. After application of coating by 1 of a variety of methods such as brushing, rolling, spraying, dipping and flow coating, the surface is air and/or heat dried to remove the volatile solvents from the coated surface. Powder type coatings can be applied to a hot surface or can be melted after application and caused to flow together. Other coatings can be polymerized after application by thermal curing with infrared or electron beam systems [29].

Particulate matter (PM) constitutes are a major class of air pollution. Particulates comes in a variety shape and sizes, and can be either liquid droplets or dry dusts, with wide range of physical and chemical properties. Particulates are emitted from many different sources, including surface coating processes [5]. The activities produced particulate matter significantly are abrasive blasting and painting process. While blasting with abrasive materials is often conducted in contained environments, there are situations where state agencies allow unconfined blasting. In both scenarios particulates are released to the environment, therefore there is a need to estimate the potential risk on humans and the environment from the toxic metals in the particulate releases from this unit operation [27]. Painting involves the application of decorative or protective materials onto the surface of a substrate. These decorative or protective materials can be in the form of a primer, sealant, finish coat, or another type of material such as an anti-corrosion coating. The coating material will have different components and properties depending on its intended use. Paint will usually consist of a binder, a pigment, a solvent or thinner, and a drier. Paint may also be solvent- or water-based. Most paint spray-gun operations take place in a paint booth. A pressurised spray gun applies the paint as a fine mist or aerosol [22]. The spray painting more dangerous than conventional painting with brush, because at the spray painting, the small particulates could spread broadly [1].

Mass Balance Models for Indoor Air Quality

Indoor concentration of air contaminants can be predicted by simple mathematical models. The key variables are emission rates and ventilation rates. In some buildings, the airflow is very simple, and can be assumed the whole buildings acts likes a single, well-mixed room. For other situasion, it be might have to model the building as many such rooms connected in series and parallel [5]. The estimation methods with mass balance models useful when other developed methods are not available or practical, besides that it is useful for sources resulting in evaporative losses and it can be assumed that 100% solvent relesases in the air by evaporation [31]. There are tree methods to estimate the exposure conventionally including non directly methods [15] where the pollutant levels

Corresponding Author: Indri Santiasih, Department of Safety Engineering, Surabaya Shipbuilding Polytechnic, ITS campus Sukolilo, Surabaya Indonesia 60111. Email: indri.santiasih@gmail.com

choose based on the exposure route and the microenvironment [11]. Material balance is used most often where a relatively consistent amount of material is emitted during use, and/or all air emissions are uncaptured. The material balance emission rate is calculated by multiplying the raw material used times the amount of pollutant in the coating, and subtracting the amount of pollutant recycled, disposed, or converted to another form [4]. Open coating operations include those operations that are open to the atmosphere or nonvented operations. Where there is a choice of methods, material balance is generally preferred over an emission factor unless the assumptions needed to perform a material balance (e.g., estimate of fugitive flash off) have a high degree of uncertainty and/or the emission factor is site-specific .

Airborne Microorganism

Airborne particles are present throughout the environment. They originate in many different forms and affect visibility, climate, human health and the quality of life [25]. Once particles are in the atmosphere, transformation, transport and removal can take place. These processes depend on several factors, such as aerosol sizes, concentration and chemical composition, location and meteorological effects. Above land surfaces almost a 25% of the total airborne particulate matter may be made up of biological materials [9]. Biological material is present in the atmosphere in the forms of pollens, fungal spores, bacteria, viruses, any fragments from plants, animals or any living organism. The various types of material that occur in the biological aerosol (bioaerosol) have size range which varies from 0.02 up to 100 μm [14].

Airborne microbial quantity and quality vary with time of day, year and location [12]. The microbial flux and therefore the quantity in the air are thought to be associated with solar heating processes that somehow cause the release and affect the survival of bacteria and fungi into the atmosphere [12][10]. Considering the importance of their potential implications for human health, agricultural productivity, and ecosystem stability, surprisingly little is known regarding the composition or dynamics of the atmosphere's microbial inhabitants. Most of the published studies focused on the study of bioaerosols of the indoor [20] or outdoor air originated from specific emission sources [26], such as waste water treatment plants [23][19][10] and Sahara dust events [18]. Even less is known about the natural microbial community in the urban areas [3] and their relationship to the particulate matter in ambient air [2].

MATERIALS AND METHODS

This research used material balance models as indirectly exposure methods to estimate particulate matters concentration (PM_{10} and $PM_{2,5}$) which emitted from indoor surface coating process. The primary datas are indoor and outdoor particulate matters concentration (PM_{10} and $PM_{2,5}$), air flow rate and room volume.

Emission Rate Calculation Method

The emission rate calculated based on raw material, operational time, material density and particulate matters emission factor of abrasive blasting and basic painting that emitted PM_{10} and $PM_{2,5,}$ The emission rate from blasting activities was calculated using Equation 1.

$$PM = A \times OpHrs \times S_A \times Po \quad (1)$$

Where:

PM = particulate matters emission rate from blasting operations (kg/hours)
A = activity rate of using raw material (kg/hours)
OpHrs = totality of time of blasting operations.
S_A = solid percentage of materials.
Po = particulate percentage which emitted from blasting operations.

The emission factors from blasting operation of PM_{10} and $PM_{2,5}$ was showed on Table 1.

Table 1.Emission Factors of PM_{10} and $PM_{2,5}$ Candidates

Surface	PM Emission Factors, kg/kg sand	
	PM_{10}	$PM_{2,5}$
Precleaned	0,0099	0,0018
Painted	0,022	0,0011
Oxidized	0,0074	0,0011
Average	0,013	0,0013

Source : USEPA, 1997.

While the emission rates from basic painting operation were calculated using Equation 2.

$$PM = \rho_n \times S_T \times S_A \times Po \quad (2)$$

Where:
ρ_n = mixing density of materials.
ST = maximum of spray gun rate (L/hour).
SA = solid percentage of coating materials (%).
Po = percentage of PM_{10} or $PM_{2,5}$ that emitted from painting operations (%).
The solid percentage in coating materials was 49.0 for primary surfacer and 57.2 for primary epoxy. The results of this calculation were used as input for material balance equation with the outdoor particulate concentrations, air flow rate and room volume [29].

Material Balance Calculation Methods

As pointed out by Nevers [17], an indoor air quality model can be made more realistic (and more complicated), that schematically shows a building that experiences infiltration, forced ventilation with treatment, recirculated air with separate treatment of that airstream. It is assumed that the air within the building is completely mixed. This model is still simplified compared to a real building in which there maybe many separate room, with air flowing simultaneously from some rooms and into others, and with different emission rates and different concentration in many of the rooms. The material balance equation describing the process is:

$$V\frac{dCi}{dt} = Q_1C_0 + Q_3C_0\,(1-\eta_1) + Q_4C_i\,(1-\eta_2)] - (Q_2+Q_4+Q_5)C_i + S - R \qquad (3)$$

Where:
η_1 dan η_2 = removal efficiencies of the two filters (%).
Q = air flow rates (m^3/s)
S = emission rate (µg/s)
C0 = outdoor particulate matters concentration (µg/ m^3)
Ci = indoor particulate matters concentration (µg/ m^3)
R = pollutant removal rates (µg/s).
t = time (s)
V = room volume.
Furthermore, note that if the term "filters" is used broadly, it can refers not only to particulate filter but also for the others one. While the estimation results of the particulate matters concentration can be calculated using Equation 4.

$$C_{PM} = C_0 + \frac{S}{Q} \qquad (4)$$

Where:
CPM = estimation results of particulate matters concentration.
C_0 = outdoor particulate matters concentration (mg/m^3)
S = emission rate (mg/hour)
Q = air flow rate (m^3/minute)

Error Calculation Method

The evaluation of model performance was done to evaluate model prediction accuracy with the observation. Index of agrreement (IOA) and root mean square error (RMSE) are the methods were used to model testing using statistical analysis using Equation 5. RMSE value shows the error levels of the model to the observation. The error levels of the model is low if the totality of RMSE value closed to zero [28]. RMS was used to measure the deviation between the random variable with the standart or accepted value.

$$RMSE = \sqrt{\frac{\sum_1^n((x_i-a_i)}{N}} \qquad (5)$$

Where :
x_i = N data set
a = accepted value

Airborne Microorganism Settling Method

Airborne microorganism (bacteria and fungi) were measured by impinger on six point at research room, and it were repeated four times (4 weeks) during the period studies. Microbiological investigations were carried out during ordinary workdays by means of settling plates and an active sampler. The samples were simultaneously collected in flanking sites. Throughout the period studied, A range of methods were available, non-quantitative techniques such as settle plates (simply exposing an agar plate to the atmosphere). It was used include collection directly onto agar plates, using Andersen microbial impactors, collection into liquid using impingers, and filtration. Bacterial counts were expressed as colony forming units (CFU) per petri plate area (64 cm^2). For the

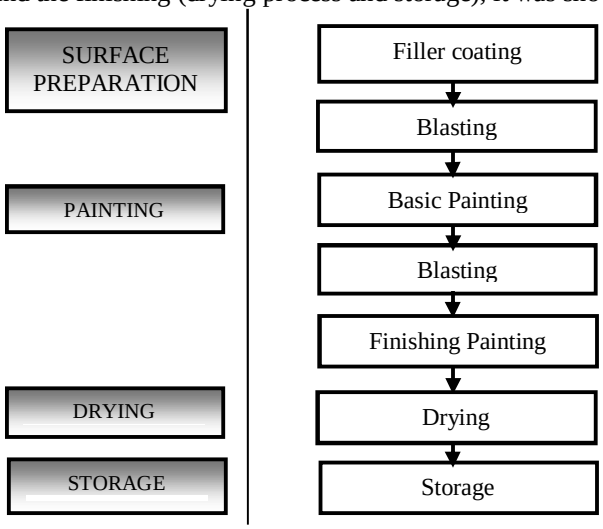
investigation of fungi, settling plates were incubated at 25°C in a natural day/night period and examined for another 4 weeks. Counts of fungal colonies were expressed as colony forming units per petri plate area (154 cm^2) and pure cultures were made from all the morphologically different colonies. Fungal isolates were transferred to culture media suitable for classification. Identification was based on morphological and physiological characteristics following the standardized procedures for the various genera of fungi [24][8] [6][21][16][7]. Qualitative data regarding airborne fungi were collected by identification of all the fungal colonies grown on both the settling petri plates.

Statistical Method

The relationship between particulate matters and microorganism concentration analysed using simple linier regression with Minitab 14.00. The chart was plotted using excel to describe the linier equation.

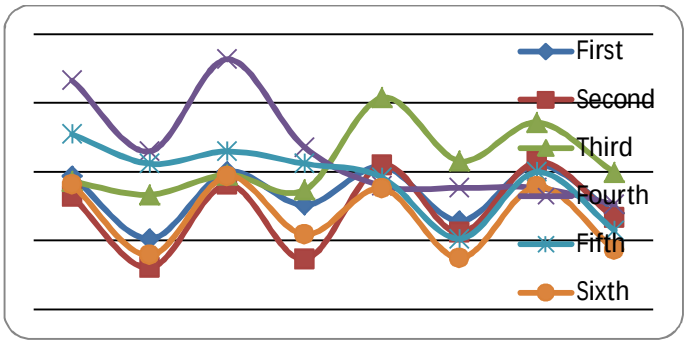
RESULTS AND DISCUSSION

The research focus was finishing room, in which there was surface coating process including surface preparation, painting process, and the finishing (drying process and storage), it was showed on Picture 1.



Picture 1 : Flow diagram of surface coating process.

Particulate matters (PM_{10} and $PM_{2,5}$) and microorganisms (bacteria and fungi) concentrations were taken at six points at research room, and it were repeated four times (4 weeks) during the research. Estimation method with mass balance was useful to estimate the emission from the source which evaporation losses, it was assumed that 100% emitted by evaporation. The result was showed on Picture 2.



Picture 2 : The PM_{10} and $PM_{2,5}$ concentration at the six point measurement.

Emission Rate Estimation

The surface preparation method was the initiation step before painting operation. The purposes of this steps was covering the wood spots, used filler and thinner. After filler coating, the next process was blasting, to make the wood surface more rough. There was two kind of blasting, blasting after filler coating and after basic

painting one. While there is a blasting operation in the unconfined space, so it is important to make potential risk analysis of particulate and toxic materials that emitted from this process to human and environment [27].

After filler coating, the next step was basic painting operation. Painting is a process decorating or protecting the material on the wood surface, like thinner and hardener. Generally, painting process was done by spraying, which cause fine dust and aerosol [22]. Paint spraying more dangerous than brush painting, because paint spraying can transform the material to aerosol so the fine particle can spread broadly. The fine aerosol is easier inhalated, so it is potentially high risk exposure to human health [1].

Painting process included basic painting and finishing one. In the finishing room was basic painting, which used stain, thinner and hardener as the main materias, while the finishing one was in the other room (not as an object studies). The mixing density was 1,1247 kg/m^3, the maximum spray gun rate was 2,4 L/hour, and the S_A value based on USEPA [29] was 57.2% for primary epoxy. The result was showed on the Table 2.

Table 2. The result of Emission Rate Estimation from Surface Coating Process.

Surface Coating Activities	Emission Rate	
	PM_{10} (mg/hour)	$PM_{2,5}$ (mg/hour)
Blasting after filler coatings	$16.41.10^2$	$2.98.10^2$
Blasting after basic painting	$36.47.10^2$	$1.82.10^2$
Basic Painting	37.2873	7.2413

The totality of emission rates from surface coating in the finishing room were:

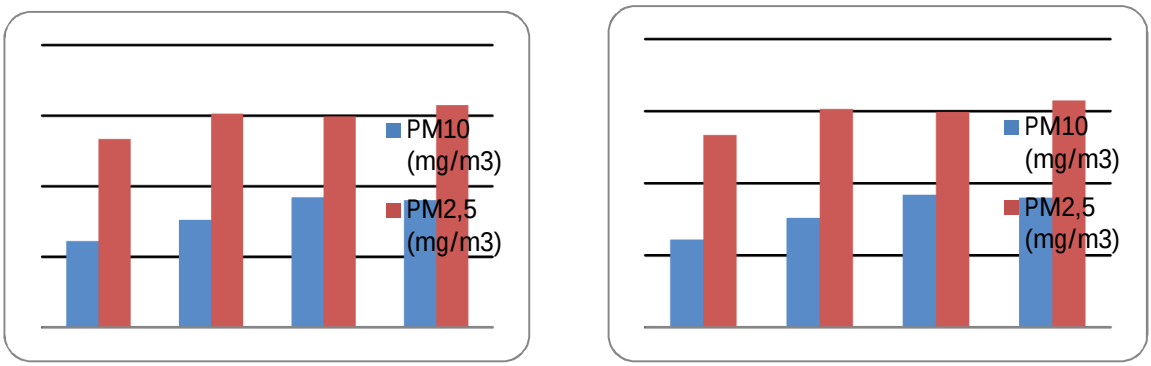
The totality of emission rates = emission rates from blasting operation + emission rates from basic painting

The totality of PM_{10} emission rates = 5325,2873 mg/hour

The totality of $PM_{2,5}$ emission rate = 487,2413 mg/hour

Material Balance Calculation

The particulate matters were measured on the six points in the finishing room and repeated four times of each one. The estimation method with mass balance is useful to estimate the emission from the source which emitted evaporation losses. it can be assumed that 100% of solvents were releases to the air by evaporation[5]. The estimation result of PM_{10} and $PM_{2,5}$ concentration showed on the Picture 3 (a).



(a) The estimation results of PM_{10} and $PM_{2,5}$ concentration (b) The Estimation result of PM_{10} and $PM_{2,5}$ concentration which were stayed in the room

Picture 3 : Comparison of the estimation results of PM_{10} and $PM_{2,5}$ concentration with the estimation result of PM_{10} and $PM_{2,5}$ concentration which were stayed in the room

As if the estimation results of PM_{10} and $PM_{2,5}$ concentration and the Estimation result of PM_{10} and $PM_{2,5}$ concentration which were stayed in the room where same (so as if there was no particulate matters went outside), but actually there was a little part of particulate matters which went out (for the example there was 0.373 µg/m^3 of $PM_{2,5}$ flowed outside). It related how to write the results which suited with the tool accuracy.

Indoor air pollutant concentration can be predicted using the simple mathematical model with the key variable are emission rates and ventilation rates [5]. On the end of work operation, the PM_{10} and $PM_{2,5}$ concentration

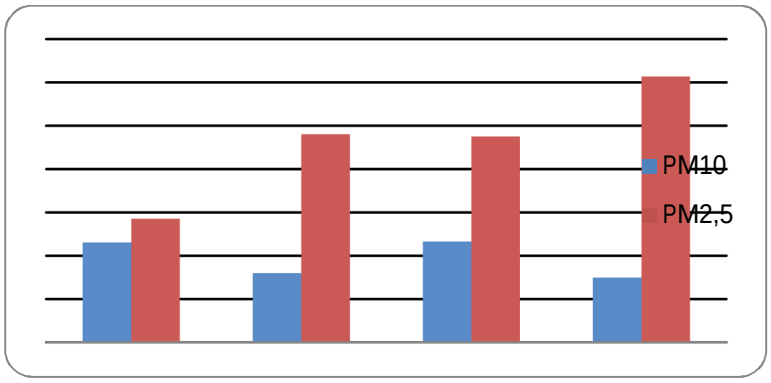
were stayed in the room could be showed by Equation 3. Note that there was no make up air (R=0), no resirculated air (Q_3=0), and no exhaust fan (Q_4 and Q_5=0), so the equation were influenced by infiltrated air into the room only.

$$V\frac{dCi}{dt} = Q_1C_0 - Q_2C_i \qquad (6)$$

The estimation result of PM_{10} and $PM_{2,5}$ concentration which were stayed in the room after the end of the work operation on the Picture 3(b).

Data Validation with Root Mean Square Error (RMSE)

Root mean square error (RMSE) was used to measure the deviation between random variable (x_i) and standart or accepted value (a). RMSE value shows the error levels of the model to the observation, showed on the Picture 4. The error levels of the model is low if the totality of RMSE value closed to zero [28]. The random variable (x_i) were the estimation result of PM_{10} and $PM_{2,5}$ concentration, and the accepted value were the observation.

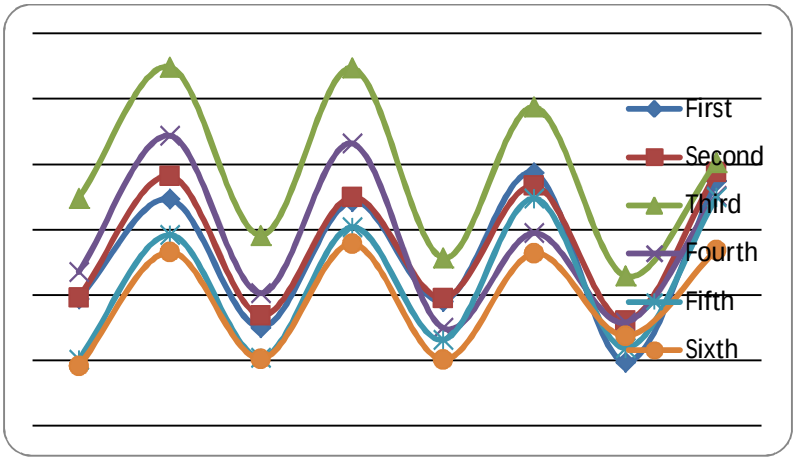


Picture 4 : The Result of Root Mean Square Error (RMSE) Calculation

The result of RMSE calculation showed that if the errors between the observation and the estimation for four days were closed to zero. It could be concluded that the estimation closed to accepted value.

The Relationship Between The Microorganism and PM_{10} dan $PM_{2,5}$ Concentration.

Airborne particles are present throughout the environment. They originate in many different forms and affect visibility, climate, human health and the quality of life [25]. These processes depend on several factors, such as aerosol sizes, concentration and chemical composition, location and meteorological effects. Above land surfaces almost a 25% of the total airborne particulate matter may be made up of biological materials [9]. Biological material is present in the atmosphere in the forms of pollens, fungal spores, bacteria, viruses, any fragments from plants, animals or any living organism. The various types of material that occur in the biological aerosol (bioaerosol) have size range which varies from 0.02 up to 100 µm [14]. The microorganism (bacteria and fungi) concentrations were showed on the Picture 5.

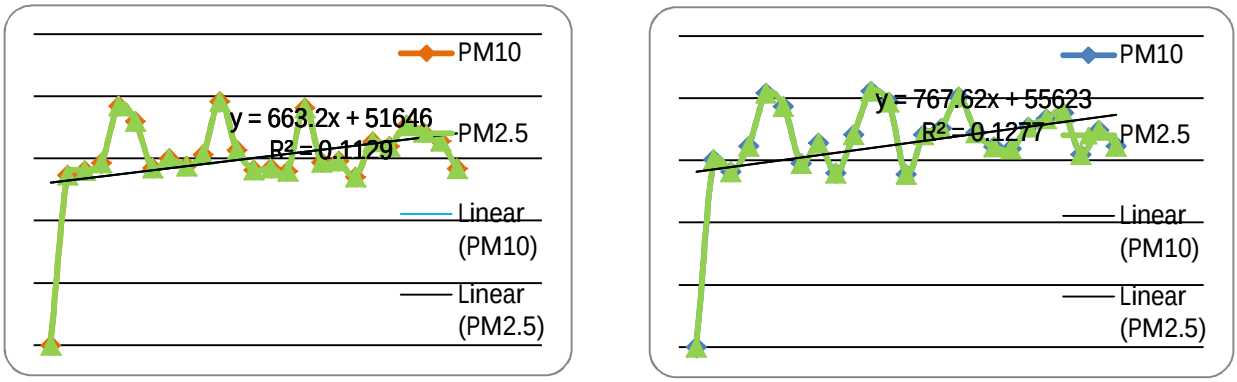


Picture 5 : The Microorganism concentration from the measurement.

Indoor air polution and bad HVAC system which emitted particulate matters, could increased indoor particulate matters concentration. There was sufficient correlation between the microorganism concentration and dust quatity, more dust deposition more microorganism would growth [13]. The linier regression analysis explained that there was sufficient correlation between the bacteria and particulate matters concentration as on Equation 7.

$$\text{Bacteria} = 37361 + 4735\ PM_{10} + 8581\ PM_{2.5} \quad (7)$$

That equation meaned that if the $PM_{2,5}$ increased one point, so the bacteria concentration would added 8581 point, it could be assumed that the PM_{10} concentration was constant; or if the PM_{10} increased one point, so the bacteria concentration would added 4735 point, it could be assumed that the $PM_{2,5}$ concentration was constant. The p value of F testing was 0.000 ($\alpha = 0.05$), it meaned that there was one x variable minimally which influenced to the microorganism concentration. While the p value of T testing of PM_{10} was 0.04 and the $PM_{2,5}$ was 0.001 ($\alpha = 0.05$). The T testing was done to know the influence of each x variable. It meaned that the two of PM_{10} and $PM_{2,5}$ influenced to bacteria concentration.



(a) Linier Equation Chart of The Bacteria and Particulate Matters Concentration (b) Linier Equation Chart of The Fungal and Particulate Matters Concentration.

Picture 6: Comparison of Linier Equation Chart of The Bacteria and Particulate Matters Concentration with Linier Equation Chart of The Fungal and Particulate Matters Concentration

While the regression analysis of particulate matters to fungal concentration showed as on Equation 8.

$$\text{Fungi} = 42761 + 7835\ PM10 + 6601\ PM2.5 \quad (8)$$

It meaned that if the $PM_{2,5}$ concentration increased 1 point, so the fungal concentration would be added 6601 point, it could be assumed that PM_{10}; or the PM_{10} concentration increased 1 point, so the fungal concentration would be added 7835 point, it could be assumed that the $PM_{2,5}$ was constant. The p value of F testing was 0.000 ($\alpha = 0.05$), it meaned that there was one x variable minimally which influenced to the fungal concentration. While the p value of T testing of PM_{10} was 0.03 and the $PM_{2,5}$ was 0.014 ($\alpha = 0.05$). The T testing was done to know the influence of each x variable. It meaned that the two of PM_{10} and $PM_{2,5}$ influenced to fungal concentration. The result were similar with Li *et al.* [13] showed that there was positive correlation between microorganism concentration and dust quantity, more deposition dust more the microorganism growth.

R^2 value showed that the correlation of particulate matters to microorganism concentration was 80.6%. it meaned that particulate matters concentration could explained bacteria concentration 80.6%, and 19.4% by errors. While R^2 value of the relationship between fungal and particulate matters concentration was 80.2%. it meaned that particulate matters concentration could explained fungal concentration 80.2%, and 19.8% by errors. The statistical analysis showed that $R^2_{fungi} > R^2_{bacteria}$, it meaned that particulate concentration could explained fungal concentration greater than the bacteria. The similar result was showed by earlier researchers [13] that the positive correlation of fungi was more significant than the bacteria ($R^2_{fungi} > R^2_{bacteria}$). The earlier researchs explained that the microorganism growth faster at 22°C-32°C and at relative humadity 40-90%, while if the relative humadity up to 80% was suitable for microorganism growth and reproduction [13]. The temperatures and relative humidity of object study were not different significantly (about 33.8°C-34°C), so it were denied.

CONCLUSION

The material balance model is the simple mathematical model, which can used to estimation indoor particulate matters (PM_{10} and $PM_{2,5}$) concentration. It was proven by root mean square error (RMSE) closed to zero, so it could be concluded that the estimation errors closed to the observation.

There was positif correlation between (PM_{10} and $PM_{2,5}$) and microorganism (bacteria and fungi) concentration. The increasing of particulate matters concentration would be followed by the increasing of microorganism concentration. The linier regression analysis showed that $R^2_{fungi} > R^2_{bacteria,}$ it meaned that the positif correlation of fungal was greater than the bacteria.

REFERENCES

1. Budiono, I. (2007). The Risk Factors that Effected to Car Painting Hepar Workers Disfunction. The Thesis of Department of Magister Epidemiology Diponegoro University of Semarang.
2. Boreson, J. Dillner, A.M. Peccia J. (2004). Correlating Bioaerosol Load with $PM_{2.5}$ and PM_{10} Concentrations: A Comparison Between Natural Desert and Urban-Fringe Aerosols. Atmospheric Environment, 38 : 6029–6041.
3. Brodie, E.L. De-Santis, T.Z. Parker, M.J.P. Zubietta, I.X. Piceno, Y.M. Andersen, G.L. (2007). Urban Aerosols Harbor Diverse and Dynamic Bacterial Populations. Proceedings of The National Academy of Sciences of The United States of America, 104 : 299–304.
4. Celebi, U.B. Vardar, N. (2008). Investigation of VOC Emissions from Indoor and Outdoor Painting Processes in Shipyards. Atmospheric Environment, 42 : 5685 – 5695.
5. Cooper, C.D dan Alley, F.C. (2002). Air Pollution Control A Design Approach. Waveland Press Inc. Third Edition, 46-49.
6. Domsch, K.H. Gams, W. Anderson, T.H. 1980. Compendium of Soil Fungi. Academic Press London, 859pp.
7. De Hoog, G.S. Guarro, J. 1995. Atlas of Clinical Fungi. CBS, Baarn, Delft, The Netherlands, 720pp.
8. Ellis, M.B. 1971. Demaziaceous Hyphomycetes. Commonwealth Mycological Institute. Kew, Surrey, England, 608pp.
9. Jones, A.M. Harrison, R.M. (2004). The Effects of Meteorological Factors on Atmospheric Bioaerosol Concentrations : A review, Science of the Total Environment, 326 : 151–180.
10. Karra, S. Katsivela, E. 2007. Microorganisms in Bioaerosol Emissions from Wastewater Treatment Plants during Summer at A Mediterranean Site. Water Research, 41 : 1355-1365.
11. Lebret, E. 1995. Models of Human Exposure Based Monitoring on Environmental. The Science of the Total Environment, 168 : 179-185.
12. Lighthart, B. 2000. Mini-review of The Concentration Variation Found in The Alfresco Atmospheric Bacterial Populations. Aerobiologia, 16 : 7-16.
13. Li, A. Liu, Z. Zhu, X. Liu, Y. Wang, Q. 2010. The Effect of Air-Conditioning Parameters and Deposition Dust on Microbial Growth in Supply Air Ducts. Energy and Buildings, .42 : 449–454.
14. Macher, J. Ammann, H.A. Burge, H.A. Milton, D.K. Morey, P.R. 1998. Bioaerosols: Assessment and Control. American Conference of Governmental Industrial Hygienists. Cincinnati, OH, Cincinnati, USA.
15. Moschandreas, D.J. Watson, J. Abreton, P.D. Scire, J. Zhu, T. Klein, W. Saksena, S. (2002). Chapter Three: Methodology of Exposure Modeling. *Chemosphere*, 49 : 923–946.
16. Nelson, P.E. Tousson, T.A. Marasas, W.F.O. 1983. Fusarium Species. The Pennsylva-nia State University Press, University Park, London. Washington. 193pp.
17. Nevers, N.de. (1995). Air Pollution Control Engineering. Mc. Graw Hill. International Edition. 328-330pp.

18. Polymenakou, P.N. Mandalakis, M. Stephanou, E.G. Tselepides, A. 2008. Particle Size Distribution of Airborne Microorganisms and Pathogens during An Intense African Dust Event in the Eastern Mediterranean. Environmental Health Perspectives, 116 : 292–296.

19. Pascual, L. Perez-Luz, S. Yanez, A.M. Santamaria, A. Gibert, K. Salgot, M. Apraiz, D. Catalan, V. 2003. Bioaerosol Emission from Wastewater Treatment Plants. Aerobiologia, 19 : 261–270.

20. Parat, S. Perdrix, A. Mann, S. Baconnier, P. 1999. Contribution of Particle Counting in Assessment of Exposure to Airborne Microorganisms. Atmospheric Environment, 33 : 951-959.

21. Pitt, J.I. 1980. The Genus Penicillium. Academic Press, London, 634pp.

22. Queensland Department of Environment and Heritage : National Pollutant Inventory. 1999. Emission Estimation Technique Manual for Surface Coating. 1st published.

23. Ranalli, G. Principi, P. Sorlini, C. 2000. Bacterial Aerosol Emission from Wastewater Treatment Plants: Culture Methods and Biomolecular Tools. Aerobiologia, 16 : 39–46.

24. Rapper, K.B. Fennel, D.I. 1965. The Genus Aspergillus. Williams & Wilkins Co. Baltimore Reprint Hafner. New York. 686pp.

25. Ruzer, L.S. Harley, N.H. 2005. Aerosols Handbook: Measurement, Dosimetry, and Health Effects. CRC Press, Florida. USA.

26. Stelzenbach, L.D. 2007. Introduction to Aerobiology In: Hurst, C.J., et al., (Eds.), Manual of Environmental Microbiology. ASM Press, Washington, DC, 925–938pp.

27. Serageldin, M. 2007. Emission Factors (Proposed) for Abrasive Blasting Materials. A&WMA's 100th. Annual Conference and Exhibition, Baltimore, M.D. Paper No. A616.

28. Sivacoumar, R. Bhanarkar, A.D. Goyal, S.K. dan Anggarwal, A.L. 2001. Air Pollution Modelling for an Industrial Complex and Model Performance Evaluation. Environmental Pollution. 111 : 471-477.

29. US Environmental Protection Agency (US EPA). 1995. "Compilation of Air Pollutant Emission Factor; Stationary Point and Area Sources". Edisi 5. Volume 1. Hal. 4.2.2.1-4

30. US Environmental Protection Agency (US EPA). 1997. National Ambient Air Quality Standards for Particulate Matter: Final rule. US Environmental Protection Agency, Research Triangle Park, NC. Federal Register 62 (138) : 38651-38701.

31. US Environmental Protection Agency (US EPA). 2004. Chapter 7: Quantification of Exposure: Development of The Emission Inventory for The Inhalation Risk Assesment. National Center for Environmental Assessment-RTP Division. Research Triangle Park, NC. 7-4pp.

32. US Environmental Protection Agency (US EPA). (1995). "Compilation of Air Pollutant Emission Factor; Stationary Point and Area Sources". Edisi 5. Volume 1. Hal. 4.2.2.1-4

33. Serageldin, M. (2007). "Emission Factors (Proposed) for Abrasive Blasting Materials." A&WMA's 100th. Annual Conference and Exhibition, Baltimore, M.D. Paper No. A616.