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Emission Estimation Model of Dioxin / Furan Releases from Cement Industry Used Wastes in Co-Processing

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Abstract:
Dioxins/furans are chlorinated aromatic compounds which produced unintentionally from the combustion process, it has a very stable nature of the change, toxic, and does not easily decompose in a long period of time, will accumulate in the fatty tissue (lipophilicity) of living beings and can cause cancer. These compounds are belong to the group of unintentionally persistent organic pollutants (U-POPs) that can be harmful to the environment and human health.

The increasing of cement demand requires the availability of natural raw materials and non-renewable energy as a factor of cement production. Utilization of wastes as fuels and alternative materials in co-processing in the cement industry in addition to having a positive impact as the conservation of natural resources and reduction of waste disposal to an environmental, will also have a negative effect that is emissions of dioxins/furans. There is not currently many laboratory facilities capable to measure emissions of dioxins/furans and method of UNEP toolkits generates the high estimated value of dioxins/furans to the environment. The purpose of this research was (1) to identify factors which influence the formation of dioxins /furans emissions from the cement industry which use waste as an alternative fuel, (2) create a model calculation of estimated emissions of dioxins/furans. This study was a quantitative study which are in the form of statistical formulation. The research is part of non-experimental rearch with research survey sampling. The result of this research showed that there are four external factors that can influence the formation of dioxins/furans, namely the amount of waste that used as an alternative fuel and emission discharge from kiln to chimney after cement production process. These factors are the gas flow rate, temperature and moisture. Model calculation for estimated emission of dioxins/furans 0.0599 + 0.00097 ln moisture - 0.0065 ln temperature + 0.000510 ln gas flow rate -0.00318 ln AFR show accurate results and accuracy close to the results of laboratory analysis. The calculation models already meet the sufficiency of the model (goodness of fit) because it was close to 100% (R-sq adjective amounted to 91.7%) with an error value (s) of 0.000581460.
Keywords: *dioxins/furans, environment, persistent organic pollutant, model calculation*

Introduction

Cement production growth rate each year showed the upward trend, which is 62.89% (2003), 67.11% (2004), 66.25% (2005), 68% (2006) and 71.13% (2007). In general, the average production of cement in Indonesia was 67.08% of the installed capacity with the average of cement production growth was 3.5% (MoE, 2008). The increasing of cement demand requires the availability of natural raw materials and non-renewable energy as a factor of cement production.

The raw materials used to produce one ton of clinker is 1.5 tons to 1.6 tons consisting of limestone / lime (+ 80%), clay (+ 16%), silica sand (+ 3%) and sand iron (+ 1%) to be clinker (+ 96%) and mixed with gypsum (+ 4%) for the finished cement product (MoE, 2008). The cement industry requires very high energy in the production process, which is about 30-40% of the cost of production. The process of making cement with long dry kiln technology require energy of 700-800 kcal for one kilogram of clinker, whereas the wet process using long kiln requires energy consumption of 1500 kcal per kg of clinker.

Utilization of wastes as fuels and alternative materials in co-processing in the cement industry in addition to having a positive impact as the conservation of natural resources and reduction of waste disposal to an environmental, will also have a negative effect that is emissions of dioxins/furans. Co-processing is one of the alternative waste management in industrial processes to take back benefits (recovery) of energy or materials (recycling) of wastes to be reused in the production process as well as an alternative fuel in the the kiln.

Dioxins/furans are unintentional product, formed inadvertently produced from the incomplete combustion or chemical reactions involving organic matter and chlorine. Emissions of dioxins/furans in the the cement industry released through the chimney as part of the cement kiln unit and raw mill in the form of gases and particulates.

Besides toxic, dioxins/furans have properties not easily decompose in a long period of time (persisitent) and will accumulate in biological in the living body through the food chain (bio-accumulated). It also has properties not easily soluble in water, in the living body dioxins/furans accumulate in fatty tissue and eventually cause cancer. Furhter, it can be spread or move from one place to another either by wind, water or animals in low concentrations in the environment is part per trillion (Gorman and Tynan, 2003).

Since there is not many laboratory facilities capable to measure emissions of dioxins/furans and method of UNEP toolkits generates the high estimated value of dioxins/furans to the environment, there are lack of data quality status of dioxin/furan in the environment. This study aims to make a model calculation of estimated dioxin emissions/furans for the cement industry that utilizes the waste in the production process, in order to obtain accurate and precise data (precision) when compared with UNEP toolkits and results of laboratory analysis.

Methodology

1. Research method

This study was a quantitative study that emphasizes the quantification of the data collection, the stages of data collection, processing and analysis of data. This quantitative research presented sample design, and testing hypotheses, all of which are in the form of statistical formulation. The applied research is part of a non-experimental research with the research survey sampling. Derivative quantitative approach/method applied in this study include exploratory research, explanation, prediction, and descriptive to identify factors which will influence to the quality of dioxins/furans emission.

Regression analysis is one of analysis to determine the effect of a variable against another. In regression analysis, the variables that affect the so-called independent variables and the variable that is affected is called the dependent variable. If the regression equation there is only one independent variable and the dependent variable, it is called a simple regression equation, whereas if more than one independent variable, it is called a multiple regression equation.

Regression analysis including data collection line pattern search (parameter estimation and testing of non barely models), the regression equation estimation (estimation and testing of parameters) as well as the interpretation of the model and parameters. Stages of formation and the regression model according Mattjik Sumertajaya 2006 through: (1) determination of the model, (2) estimated parameters, (3) verification of the model, (4) if the model is inaccurate or no assumptions are not met, then it will go back to step The first, and (5) inference and interpretation.

Multiple linear regression analysis is a statistical analysis tool in science to measure the mathematical relationship between more than two independent variables (X) with the explanatory variable (Y). The general form of multiple linear regression equation is as follows (Mattjik and Sumertajaya, 2006):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta k X_k + \varepsilon \quad \text{...(1)}$$

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Note:
βi: regression coefficient
The equation is suspected by the equation:

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_kX_k \quad \text{.....(2)}$$

Linear above means indicates that the regression equation is linear in the parameters. To find the values of the parameters of the multiple regression equation can be used Least Squares Method, but the multiple regression equation must satisfy the following assumptions:

1. Gauss-Markov conditions
   - E [εi] = 0, the value of hope / flats remnant = 0
   - E [εi2] = var [ε] = σ2, homogeneous residual variance for each value of x (homoskedastisitas)
   - E [ε i, ε j] = 0, i ≠ j, a remnant independent
2. Error normal spread
3. Error (ε) independent of the independent variable (x), cov (xi, εj) = 0, for every i
4. No multicollinearity in independent variables, cov (xi, xj) = 0, for any i ≠ j

Hypotheses used for this analysis are:
H0: free variables has no effect on emissions of dioxins / furans
H1: free variables affect the dioxin / furan
With the decision criteria reject H0 if the p-value is smaller than 5% alpha.

Multiple regression assumptions in this analysis is done through a test for normality, multicollinearity test, test and test heteroskadesitas autocorrelation.

2. *Research location*

This research was conducted in PT Holcim Indonesia Tbk-Narogong Plant that is located at Jl. Kingdom Nargong Kab. Bogor, West Java and PT Holcim Indonesia Tbk-Cilacap Plant domiciled in the Karangtalun, Kab. Cilacap, Central Java.

3. *Population and samples*

The population of this study is the number of the cement industry in Indonesia, today there are 9 companies spread in the Sumatra, Java, Kalimantan, Sulawesi and Nusa Tenggara. Samples of research conducted by purposive sampling through the establishment of criteria, namely cement industry that utilizes the waste in the production process through co-processing, representation of geographical location, and the ease of obtaining data and information. Acquired two companies as samples in this research, PT Holcim Indonesia Tbk Plant-Cilacap, Central Java and PT Holcim Indonesia Tbk-Narogong Plant, West Java.

Result and Discussion

The high demand for cement and the scarcity of raw materials and fuel to be used in the cement production process push the cement industry to look for alternative sources of energy and raw materials. In addition, the waste generated from industrial activities require proper handling, so no harm and pollute to the environment. Utilization of waste as raw material or fuel alternative in the co-procesing cement manufacturing will provide waste management solutions to reduce the waste generation and save the sustainability and the availability of fuels and raw materials that non-renewable resources. However, there is an environmental impact from cement industry used waste in their process as dioxins/furans air emissions. Dioxins/furans is formed at the temperatures between 200^{o}C up to 400 ^{o}C (the Department of the Energy of the United Kingdom (1995)

Co-processing is an alternative waste management industry efficiently and effectively both in terms of financing, conservation of natural resources and environment, which use waste in the cement industry by taking back the benefits (recovery) of energy and materials from waste (MoE Repuplic of Indonesia, 2008). This is because cement technology operates at high temperatures above 1400^{o}C thus able to process and destroy waste without any risk to environment or human health (UNEP, 2005). Waste treatment with co-processing is one of the waste reduction efforts and is part of the hierarchy of waste management through the application of the 3Rs principles (reuse, recycle and recovery) in order to obtain ecological and economic benefits in the waste utilization, without harming the environment. It will support the financial effectiveness through the energy efficiency by ensuring the use of energy energy consumed. This is an application of the principle of ecological economy that links between economic principles with the principles of ecology (Cunningham 2012).

The application of co-processing in the cement industry has to be able to process and use waste by using high technology with temperature above 900^{o}C and retention time of more than 2 seconds, in addition determination of waste feeding in the cement plants has to be considered. There are some criterias of waste before processed and used in co-processing (MoE Republic of Indonesia, 2008);

1. fairly high energy content, so the thermal can be recovered as an alternative fuel,
2. mineral composition recovery as an alternative raw material for cement production,
3. besides those two criterias above, waste can be burnt in the cement kilns as waste destruction facility. Table 1 describes the temperature and residence time in the cement kilns

Table 1. Temperature and Retention Time at the Cement Kiln

Location	Temperature (^{o}C)	Gas Retention Time (second)
Main burner	>1450 (material) >1800 combustion)	>12-15 seconds for the temperature of >1200^{o}C >5-6 seconds for the temperature of >1800 ^{o}C
Precalciner	>850 (material) >1000 (combustion)	>2-6 seconds for the temperature of >800^{o}C

Result and Discussion

The use of waste as raw materials or fuels containing chlorine in the cement process will produce dioxin/furan emissions to environment. Emissions of dioxins/furans produced when cooling the gas phase or in the combustion zone and then discharged through the chimney into the environment. Due to sufficient the retention time in the kiln (more than two minutes) and the high temperature to make the cement product, it makes waste perfectly burnt and dioxin/furan emissions into the environment is very low.

Factors that will influence to the formation of dioxins/furans from combustion processes include the residence time, temperature in the secondary combustion zone, concentration of sulfur in the combustion process, fluctuations during the combustion, and the chlorine content in material and waste (Aurell, 2008). In addition the increasing of moisture and metal catalysts in the thermal process will increase the concentration of dioxins/furans emission. In these conditions the concentration of dioxins/furans will increase in line with the increase of chlorine contained both in raw materials and fuels (UNEP, 2005). Kardono, 2002 stated that the copper catalyst (Cu) in the combustion process will trigger a reaction formation of dioxins/furans. According to UNEP (2005), the use of raw materials, the application of best technology are considered to control in order to reduce the formation of dioxins/furans to environment.

Measurement of dioxin/furan emissions have become very important in view of the status dioxins/furan in the environment and to see the health impact caused of dioxins/furans exposure in the human body. UNEP toolkits (2005) is one method for measuring the estimation dioxins/furans to environment. Emissions of dioxins/furans is calculated by using the total unit equivalent (TEQ), where the value is the sum TEQ concentrations of all components of dioxin/furans either from air, water, soil, products and residue that has been multiplied by the toxic equivalent factor (TEF). TEF is the level of toxicity of dioxins/furans to the toxicity of 2,3,7,8-TCDD levels. Estimates of emissions of dioxins/furans into the environment annually expressed in g TEQ per year, is the result of multiplying the production activity data that multiplied by the emission factor of each industrial activity. Emission factors used in this calculation is the result of research according to the standard of the UNEP-Chemical.

There are significant differences in the data between the estimation of dioxin/furan by UNEP toolkits and the results of measurements in the the laboratory. There should be an appropriate method to calculate the estimated emissions of dioxins/furans to the environment as an alternative to measure the emissions of dioxins/furans accurately, considering the cost is quite expensive and time consuming to perform measurements of dioxin emissions/furans in the laboratory due to the unavailability of laboratory facilities able to measure dioxins/furans.

Result and Discussion

Utilization of waste as material and fuel alternative in the cement plants is one way the application of ecological principles to preserve the environment by reducing waste directly into the environment and maintain the availability non-renewable resources. Waste used as a substitute for raw materials in the cement manufacturing process must have the characteristics such as cement raw materials (SiO2, Al2O3, Fe2O3 and CaO) and waste used as fuel substitution should it has a calories 2500 kcal / kg, content of organic halide (TOX) is less than 2% by weight of wet and PCB maximum of 30% of TOX and also content of heavy metals in waste, because it can be a precursor to the formation of dioxins/furans. Fiedler (2003) states that dioxins/furans can be formed from the incoming input during combustion processes, such as PVC residues, including chloroparaffins contained in waste oil (sludge oi or slope oill) or inorganic chloride.

Table 2. Type of Wastes Utilized in co-processing in the Cement Industry

Type of Wastes	Co-Processing	
	Raw Material Substituion	Fuel Alternative
Hazardous Wastes	Fly ash, bottom ash, EAF dust from steel smelting, slag from iron smelting	sludge oil, slope oil dan WWTP sludge
Non-Hazardous Waste	-	Sugarcane bagasse, palm shell, palm kernel, rice husk, solid expired product, secondhand cigarete, waste grain, scrap tires and sawdust

The amount of waste that used in co-processing will also determine the quality of dioxin emissions/furans because of the content of pollutants in the effluent as the content of heavy metals, organic content and PCBs that known to be precursors of the formation of dioxins/ furans. Waste can be categorized as non-B3 and B3 waste. B3 waste it has a greater potential to generate dioxins/furans for the content of pollutants in the waste B3, such as chlorine, heavy metals, organic compounds, and so forth. Therefore, setting the amount of waste that can be used will affect the quality of the emissions of dioxins/furans to environment. The percentage utilization of waste as material and fuel alternative in the cement manufacturing process was 4.09% in accordance with the provisions of the permit, which is not more than 5%. This is to avoid the formation of dioxins/furans.

Table 4. Total Waste Utilization in Co-processing in Cement Manufacturing Process Year 2005-2013

Year	Alternative Waste Utilization (Ton)				
	Raw material	Fuel	Total	Cement Production	%of Waste Utilization
2005	31,484.72	1,657.15	42,141.87	3,320,216	1.27
2006	46.652,80	31,601.22	78,254.02	2,797,871	2.80
2007	110,732.66	56,112.81	166,845.47	3,516,999	4.74
2008	127,972.63	77,675.13	205,647.76	3,735,762	5.50
2009	59,695.61	116,919.22	176,614.83	3,667,567	4.82
2010				3,809,986	5.89

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	79,018.77	145,561.28	224,580.05		
2011	140,566.36	107,581.03	248,147.39	4,609,264	5.38
2012	149,610.27	117,927.99	267,538.26	5,155,536	5.19
2013	121,398.26	108,076.86	229,475.13	4,566,496	5.02

The fuel composition used in the cement manufacturing process is dominated by fosil fuel, ie 95.01% of fine coal and IDO 0.90%, only 4.09% of fuel derived from waste. Waste fuel alternative is potential to produce calories in the process of combustion in the cement plants compared with IDO, visible from 43986.58 tons of waste fuel alternative can generate heat energy of 304,887,941.92 MJ. Utilization of waste below 5% as an alternative fuel is proven to provide high energy and emit dioxins/furans into the environment is very low. The results of laboratory analysis of dioxin/furan emissions in year 2010 showed very good value that well below the quality standards specified in the license, which is 0.01 ng TEQ/Nm^3, while the quality standards for emissions of dioxins/furans is 0.1 ng TEQ/Nm^3.

Table 5. Fuel Composition on Cement Production Process

Clinker Production	Ton	2,203,158	MJ/Ton-clinker	Total (Ton)	% Energy Utilization
Fine Coal	MJ	7.089,517,960.87	3,217.89	343,476.69	95.01
IDO	MJ	67,330,047.54	30.56	1,737,101.33	0.90
Waste Fuel Alternative	MJ	304,887,941.92	138.39	43,986.58	4.09
Total	MJ	7,461,735,950.33	3,386.84		100

Hazardous waste utilization as an alternative raw material for cement is implemented in the the beginning, where the waste is mixed with other raw materials to be heated in the preheater and burnt in the rotary kiln at temperatures between 1400^o-1600^{o}C and suddenly cooled in the the clinker cooler to produce clinker. Henceforth it will be ground clinker in the cement mill or mill finish. Hazardous waste can also be used directly in the the cement mill or mill finish, if it has a characteristics as gypsum or lime and the lost of ignition (LoI) is less than or equal to 3%. It is intended to maintain the quality of the cement produced in accordance with the Indonesian National Standard (SNI).

Utilization of waste as fuel alternative intended to replace a small portion of heat energy generated from coal fuel and IDO and must be fed in the the preheater and/or the main combustion process (kiln). Hazardous waste liquid containing organic compounds halide (TOX) and the PCB should be fed to the main combustion process in the kiln and is equipped with interlock system according to standards set to prevent leakage when feeding the waste in the kiln, it is because the temperature in the the kiln is very high, above 1400^{o}C and will burn perfectly the waste. It also can prevent the formation of dioxins/furans. This is in line with the statement of the Department of the Energy of the United Kingdom (1995) that dioxins/furans will be formed at temperatures between 200^{o}C burning up to 400^{o}C.

Result and Discussion

Many factors can influence the formation of dioxins/furans, beside the low temperature the DOE of the United Kingdom (1995) stated that the presence of chlorine compounds or organic halide compounds, combustion technology and air emission control devices on the thermal process can also affect the quality of the emissions of dioxins/furans to the environment. UNEP (2005) has stated that the emissions from the cement industry is largely determined by the cement manufacturing technology, high temperature, and retention time in the main combustion process in the kiln.

Technology cemen in Indonesia is quite advanced, ie long dry kiln at very high temperatures in the kiln reaches 2000^{o}C and long residence time (more than 2 minutes) which can reduce the potential for formation of dioxins/furans. In addition, air emissions control technology tool that is used also to prevent or reduce emissions of dioxins/furans to environment. Air emissions control devices used in cement manufacturing consist of dust collector/bag filter in or fly as well as the lowering temperature of the dust that will go into the electrostatic precipitator (EP) by using a water spray , so that the EP can work optimally to capture the dust. Use of water spray is also intended to drastically lower the temperature in the the chimney, so the formation of dioxins/furans can be avoided. Other air emission control device is a gas analyzer that serves to monitor the operating parameters of the kiln burning among CO, NO and O2. Continuous emission monitoring (CEM) is a tool used to monitor the emissions of gases that come out into the environment continuously.

Aurell (2008) stated that the other factors will influence the formation of dioxins/furans in the combustion process include; residence time, temperature in the secondary combustion zone, the concentration of sulfur during combustion process, the current fluctuations in the combustion process and the chlorine content in the raw materials and waste. Setting a high temperature consistency and residence time during the cement manufacturing process will result in burning waste perfectly.

Increased humidity on thermal processes may also influence the formation of dioxins/furans, therefore setting the temperature at the post combustion zone or in the processing phase in the air emission control device becomes very important to prevent the formation of dioxins/furans, because dioxins/furans will be formed at a temperature of 200^o-400^oC (UNEP, 2005). Setting very low temperatures at the end of the combustion zone (160 ^{o}C) can prevent the re-establishment of dioxins/furans.

Air sampling technique by using US EPA Method 0023A (1996) for parameter dioxins/furans emission is to be concerned by researcher. Based on observations in the field, there are two factors that are expected to determine the quality of dioxin emissions/furans in the chimney before the emissions discharged into the environment; the internal factors and external factors.

a. Internal factors

Internal factors when measuring dioxin/furan in cement factory chimney includes time sampling, contamination and pendigingan flue gas.

- Sampling Time

The concentration of dioxins/furans are very small in units of pico grams, require samples taken should be high enough so that it can be detected accurately. Generally the duration of sampling dioxins/furans between 4-8 hours, but in the implementation of sampling it is performed for 6 hours. Based on experience, time is enough to detect dioxins/furans in the cement factory.

- Contamination Dioxin / Furan

Pre-treatment of the sampling equipment by cleaning all laboratory equipment is done to avoid the contamination of dioxins/furans during the sampling. Test leak test done to ensure that there are no leaks in the sampling equipment. Once the sample is obtained, hygiene and procedures established performed on samples in the laboratory before the sample is ready to be sent to a laboratory to be analyzed concentrations of dioxins / furannya.

- Flue Gas Cooling Proses

Flue gas cooling process in the chimney must be ensured that the cooling equipment during the sampling run correctly. It is considered that the samples obtained in the form of condensate from the chimney

According to UNEP (2005), dioxins/furans released into the air is determined by the flue gas and the amount of gas produced per unit production. The highest gas volume resulting from the type of wet kilns. Cement manufacturing industry which is using technology long dry kiln, where the temperature is stable in the main burner and a long residence time makes the emissions of dioxins/furans produced very small although using waste as fuel alternative in the cement manufacturing process.

The concentration of dioxins/furans in the flue gas is also strongly influenced by temperature in air emission control devices. The use of gas conditioning tower to control dust prior to the EP with using water spray will catch dust with dust collector to the maximum and drastically lower the temperature in the chimney. Sudden Low temperature (<200^{o}C) can prevent the formation of dioxins/furans. Since the cement manufacturing can keep the temperature in the chimney is always below 160^{o}C, so the quality of the emissions of dioxins/furans produced was far below the standards.

b. External factors

External factors concerned during the sampling dioxins/furans are fluctuations in flow rate of the flue gas, so during the measurement Isokinetic conditions must be met. For setting Isokinetic condition done by measuring temperature, pressure, humidity and flue gas conditions in the chimney periodically during the sampling. In addition to the four factors mentioned above, the process conditions in the factory during the sampling dioxins/furans must be in a steady state. In accordance with the sampling method issued 0023A by the US EPA (1996) for dioxin/furan that the temperature, the pressure in the chimney, the gas flow into the chimney, and the humidity in the chimney should be recorded during sampling.

The use of kinetic models to decrease the formation of dioxins in the gas kiln waste incinerators can be done by controlling the residence time of more than 2 seconds, the setting temperature during combustion and the incoming gas flow to keep the turbulence in the flue gas after combustion (Ficarella and Laforgia,1999). In addition Fiedler (2003) states that dioxins/furans from thermal processes can be contained in the flue gas, the botom ashes/fly ashes and water from the scrubber, although the content of dioxins/furans smallest in the flue gas due to the use of modern technology for gas cleaning in air emissions control devices, high temperatures and long residence time.

Determination of moisture in the chimney as one factor for the formation of dioxins/furans. It is supported by a statement from Fiedler (2003) that some parameters should be concerned for the dioxins/furans formation in the thermal process such as oxygen, moisture, and temperature, because the moisture will decrease the temperature for both thermal in the main burner and temperature in the chimney. Dioxins/furans will be formed at a temperature of 450^o-250^o C.

Based on the above description and observations in the field, researchers decided on four factors that affect the quality of dioxin/furan emissions to be used as a variable in the estimations model of dioxin emissions/furans releases from the cement industry. The fourth variable is the amount of waste that is used in the co-processing, the gas flow rate, temperature and moisture/humidity in the chimney. Determination of these four external factors should be based on a fairly advanced cement technology (long dry kiln), high temperatures in the main combustion zone, a long residence time, and control the use of catalysts in the cement manufacturing process (Fiedler, 2003).

c. Emission Estimation Model of Dioxin/Furan

This study uses more than one independent variable, therefore the approach of analysis using multiple linear regression equation to examine the factors that affect the dioxins/furans emission. Multiple regression equation model estimated dioxin emissions/furans to the environment are as follows:

Emissions of dioxins/furans = a + b1 humidity + b2 temperature + b3 gas flow rate + b4 amount of wastes (AFR) + ε.. (1)

Based on four independent variables that have been set for the above, then the regression equation dioxin /furans emission based on models mentioned above are as follows:

Emissions of dioxins / furans = 0,0599 + 0,00097 ln humidity – 0,0065 ln temperature + 0,000510 ln gas flow rate -0,00318 ln AFR..(2)

The hypothesis of the above equation is as follows;
H0 = variable X has no effect on emissions of dioxins / furans
H1 = at least one variable X that have a significant effect on the emissions of dioxins / furans

The probability value of calculation model estimates of dioxins/furans is 0.016 less than alpha (0.05), meaning that the hypothesis H0 is rejected. It is clear that at least one variable X (independent variable) having a significant effect on the emissions of dioxins/furans. R-sq adjective in this model is equal to 91.7% means that values diversity dioxins/furans can be explained by variables or factors mentioned above amounted to 91.7% while the remaining 8.3% is explained by other factors. According to Mattjik (2006) that the calculation model already meets the criteria of adequacy of the model (goodness of fit) because it was close to 100% with the value of the error /failure standard (S) equal to 0.000581460.

In order to find out what the X variables having a significant effect on dioxins/furans emission the *t*-student test has been conducted. The smallest alpha value is ln AFR (0.007), meaning that the logarithm of the amount of waste is a significant effect on the emissions of dioxins/furans with -0.0031812 coefficient value, meaning that the negative effect in every one unit increase in the logarithm In AFR will lower the value of dioxins/furans as 0.003182.

Table 6. *t*-student Results of Multiple Regression Model Dioxin Emissions/Furan

Prediction	Coefficient (Coef)	Coefficient Standard Error (SE Coef)	*T*	Probability (p)	Variance Inflation Factor (VIF)
Constanta	0.05989	0.06879	0.87	0.448	
ln humidity	0.000972	0.001562	0.62	0.578	2.789
ln temperature	-0.00645	0.01381	-0.47	0.672	1.820
Ln gas flow rate	0.0005104	0.0007991	0.64	0.568	2.570
ln AFR	-0.0031812	0.0004831	-6.59	0.007	1.545

The limitation of waste amount of 5% from total used fuel and selection of the waste type will affect the formation of dioxins/furans. The use of advanced air emission control technology can also reduce emissions of dioxins/furans to the environment.

Other variables that make negative is the logarithm In temperatures of 0.00645, while the humidity and gas flow rate have a positive influence. This is consistent with the statement of UNEP (2005) and Fiedler (2003) that the humidity and the gas flow rate will affect the formation of dioxins/furans in the thermal process, because the rate of gas flow into the chimney containing dioxins/furans, while humidity will decrease the temperature in the chimney that potential formation of dioxins/furans.

Based on the previous value *t*-student test, the Variance Inflation Factor (VIF) for each variable 1n humidity (2,789), 1n temperature (1.82), 1n gas flow rate (2.57) and 1n AFR (1.545). The VIF value is necessary to measure the presence or absence of multikol. From the overall of the VIF value, there are nothing more than 10, which means it does not happen multicollinearity in the regression equation. Normal probability graph shows the probability value (p-value) is greater (0.15) than the value of alpha (0.05), which means the data is spread normal and already meet the assumptions of linear regression.

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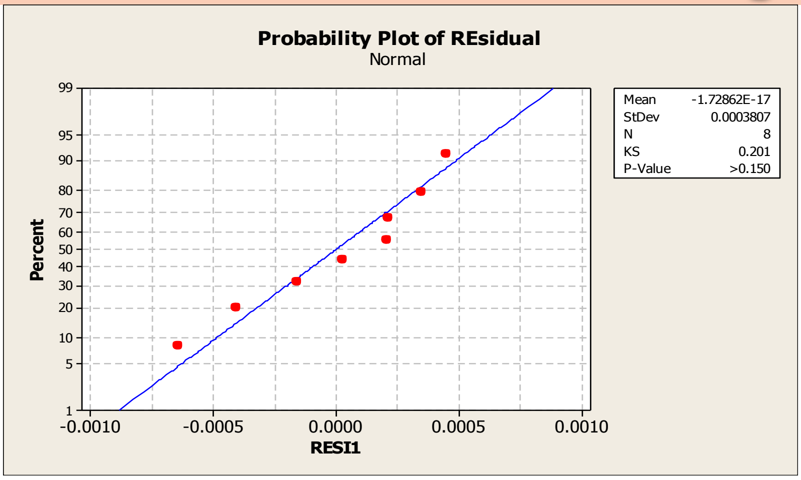

The autocorrelation test shows that the value of the Durbin-Watson is 2.22 which is met to the Durbin-Watson standard, ie 2.22793. It means that there is no autocorrelation and met the regression assumptions. Based on the test results heteroskedasticity: Breusch-Pagan-Godfrey obtained value 0.9932 is greater than the alpha value of 0.05, meaning that a remnant has been homogeneous and meet multiple regression assumptions.

Table 7. The assumption of Homogeneity Variety of Regression Equations of Dioxin/Furan

F-statistic	0.550448	Prob. F(4,3)	0.7161
Obs*R-squared	3.386204	Prob. Chi-Square(4)	0.4954
Scaled explained SS	0.242540	Prob. Chi-Square(4)	0.9932

Based on a multiple regression model dioxin emissions/furans above, indicate the estimation value of dioxin/furan emissions in the cement manufacturing is far below the estimated value by UNEP Toolkits and the quality standard by permit issued of the Ministry of the Environment Republic of Indonesia. The estimated value of dioxin/furan emissions by the model is closer to the actual value by the laboratory analysis

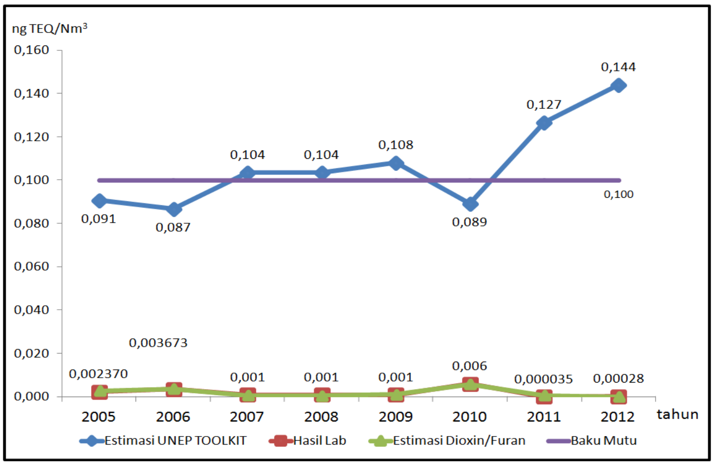

Figure 8. Estimated Emissions of Dioxin/Furan at Cilacap Cement Plant by Multiple Regression Model

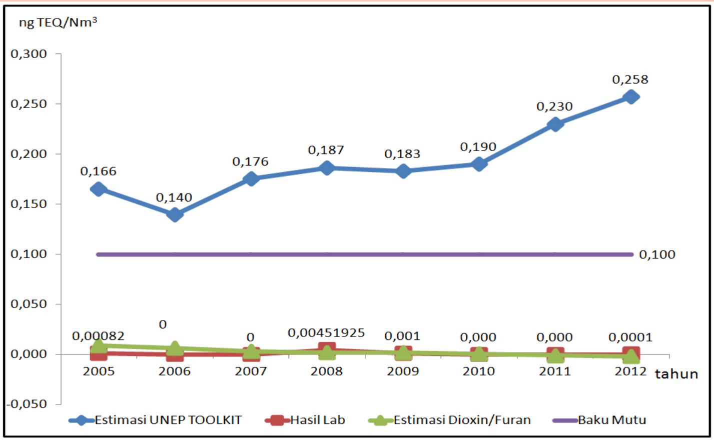

Figure 9. Estimated Emissions of Dioxin/Furan at Cilacap Cement Plant by Multiple Regression Model

From the both graphs above show there is difference quality of dioxin/furans emission, between UNEP Toolkit (2005), the results of the analysis in the laboratory and using multiple regression equation models. This can occur due to the use of different types of waste, the production capacity of each plant or when sampling dioxin emissions/furan done. The use of air emission control devices can also affect the quality of dioxin/furans emission to the environment.

In accordance with statistical tests were done before, it can be concluded that the model calculation of estimated emissions of dioxins/furans can be used as an alternative for measuring the emission of dioxins/furans in cement plants that use waste as substitution material and fuel alternative.

Conclusion

There are four factors can influence the formation of dioxins/furans in the cement manufacturing used waste in the co-processing, namely as an internal factor of the amount of waste used as an alternative fuel and the external factors since the gas emission flow into the chimney after burner process in the kiln, namely gas glow rate, temperature and moisture or humidity.

Model calculations estimate dioxin /furan emission 0,0599 + 0,00097 ln humidity – 0,0065 ln temperature + 0,000510 ln gas flow rate -0,00318 ln AFR show the accurate results and accuracy close to the results of laboratory analysis . The calculation models already meet the sufficiency of the model (goodness of fit) because it was close to 100% (R-sq adjective amounted to 91.7%) with a value of error / failure standard (S) equal to 0.000581460.

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