Effect of Change in Rate of Emissions Furan/Dioxin of Public Health Risk on WTE Gede Bage

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Abstract: Bandung, adopted a policy to build Waste to Energy (WTE) systems with a combustion capacity of 500 tons/day. WTE technologies will burn waste that is fed and utilized energy generated to be converted into electrical energy. This technology has the potential to reduce the volume of waste more effectively, but WTE also emit various harmful contaminants, including Polychlorinated Dibenzofurans (PCDF) and Polychlorinated Dibenzo-p-Dioxins (PCDDs). WTE equipped with air pollution control, so that the emission of harmful contaminants can be controlled and detected continuously. This study only discusses contaminants PCDF and PCDDs, and the effect of air pollution control work against public health risks. In this study, the efficiency of air pollution control is assumed at 0%, 25%, 50%, 75%, 90% and 99%, while the public health risk assessment carried out for the projected 15 years into the future. Public health risk assessment carried out by the calculation of the health risk of carcinogenic (liver cancer). A causal relationship between the independent variable efficiency of air pollution control with one dependent variable number of liver cancer patients, obtained the simple linear regression equation $Y = 76.4592 - 0.7692X$.

Key words: WTE, APC efficiency, atmospheric dispersion, human health, environmental toxins.

1. Introduction

WTE is a waste incinerator technology, and utilize energy generated to produce electricity. The technology has the potential to reduce the volume of waste more effectively.

WTE has the potential to emit contaminants that have a negative impact on the environment, especially public health. The particulate contaminants such as dust, heavy metals, acid-forming gases chlorides, fluorides, and sulfur dioxide, volatile organic carbon also forming furans (polychlorinated dibenzofurans, PCDF) and dioxins (polychlorinated dibenzo-p-dioxins, PCDDs). All pollutants that easily spread in all directions through the air.

Contaminants generated and has become a public

concern is furan and dioxin. Furans and dioxin causes effects in a especially form of the disease is carcinogenic form of liver cancer. Waste to energy is equipped with an Air Pollution Control (APC), so that toxic contaminants could be controlled and detected continuously. The efficiency of air pollution control will determine the rate of contaminant emissions are dispersed into the environment [1-4].

In an effort to conduct an assessment of public health risks as a result of dispersed PCDF/PCDDs, the study titled "the effect of rate changes furan emissions/dioxin against public health risks on WTE Gede Bage" needs to be done. This study will calculate the rate of change in emissions PCDF/PCDDs due to changes in the efficiency of the APC. Emission rate change is expected to affect the number of people affected by diseases such as liver cancer.

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2. Methodology

The release of contaminants into the environment cause the risk in its vast dimensions, one such risk is the human health effects. The purpose of the risk calculation process is to produce a quantitative estimate of the risk to human health posed by the release of contaminants into the environment [1, 5-7]. In this study, presented as a four step sequence shown in Fig. 1, which release assessment, transport assessment, assessment of exposure, and assessment consequences. Each of these steps has a component of qualitative and quantitative components [1].

The quantification of these externalities depends on the prediction rate of emission of contaminants. Referral popular is document used emission factors which are derived from the USEPA. The value of emission factors used as the basis for calculating the rate of emission by using the Eq. (1) [1, 4, 7, 8].

$$Q = EF \times A \times (1 - ER/100) \quad (1)$$

Where, Q (emission rate) is the amount of pollutants emitted per unit of time, EF is emission factor, A (rate of activity) is the intensity per unit time, and ER (Emission Reduction efficiency, in %) is the efficiency of APC.

Forecasts dispersion of emissions is determined at the beginning of this activity. The calculation results are used to create a model of contaminant dispersion pattern point source, which required a meteorological data. This meteorological data are wind speed and atmospheric stability.

The following illustration shows the Gaussian dispersion formula. The resulting expression shows the concentrations of pollutants at any point for review. The points indicate the position located in a line and drawn from the point of discharge of pollutants into a wind direction [1, 9].

$$C(x, y, z) = \frac{S_0}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left\{ \exp\left[-\frac{(z-h)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+h)^2}{2\sigma_z^2}\right] \right\} \quad (2)$$

Although the Gaussian dispersion formulas seem complicated, manual calculation is still possible. But in this study, it is done repeatedly until the 4,320 time calculation, because it consists of 16 points of the compass, 45 point review, 1 kind of pollutants, and 6 conditions the efficiency of the APC. Effort to speed up the calculation process, so in this study, it will utilize pollutant dispersion modeling program and a spreadsheet program—the authors utilize disperse pollutants program SCREEN3.

Output predicted impacts can be displayed as maps isopleth dispersion region, this map was made to show an increase in the concentration of pollutants and an increase in the dispersion of pollutants in average conditions across the region dispersion. Gradation increase in average concentrations that may occur will be visualized on the map isopleth [1, 3, 7, 9].

Isopleth map is overlaid into thematic maps with demographic information. Results of these efforts are as basic data, which determine the health risk estimates on the distribution of impact across the region.

These are described as the way in which exposure to contaminants move, ranging from environmental media into the body of a man who exposed. Exposure assessment in human populations exposed to be identified (receptors) as well as estimates of the rate at which humans exposed to contaminants. In this study, contaminants can enter the body and cause toxic effects simply through breathing. Intake levels of contaminants are mass or activity of contaminants entering the body per unit time [7, 8].

$$I = \frac{C \times R \times t_E \times f_E \times D_t}{W_b \times t_{avg}} \quad (3)$$

Where, I is intake, mg/kg/day, C is risk agent concentration, mg/m³, R is the rate of intake or consumption, m³/hr for inhalation, t_E is exposure time, hours/day, f_E is frequency of exposure, day/year, D_t is the duration of exposure, years, W_b is weight, kg, t_{avg} is the average period of time ($D_t \times 365$ days/year, 70 years $\times 365$ days/year for carcinogens)

Fig. 1 Risk calculation component of the risk assessment process.

The estimated incidence of cancer uses a linear approach or nonthreshold approach to exposure to carcinogenic chemicals. The functional form of this relationship is given in Eq. (4) [7, 8].

$$ECR = I_k(mg/kg/day) \times CSF(mg/kg/day)^{-1} \quad (4)$$

Carcinogenic risks expressed as Excess Cancer Risk (ECR) and Cancer Slope Factor (CSF). Slope factor is usually derived from experimental animal data. Slope factor is published by the US EPA, based on a Linear Multistage (LMS).

Public health risk assessment is due to changes in the efficiency of the APC, followed by a simple linear regression. A simple linear regression equation is in Eq. (5) [10]:

$$Y = a + bX \quad (5)$$

Where, Y is the subject of the dependent variable, in the form of a public health risk, X is subject to independent variables, such as the efficiency of APC, a is the intercept, b is the regression coefficient.

In addition the price of a and b can be searched by Eqs. (6) and (7):

$$a = \frac{(\sum Y_i)(\sum X_i^2) - (\sum X_i)(\sum X_i Y_i)}{n \sum X_i^2 - (\sum X_i)^2} \quad (6)$$

$$b = \frac{n \sum X_i Y_i - (\sum X_i)(\sum Y_i)}{n \sum X_i^2 - (\sum X_i)^2} \quad (7)$$

3. Results and Discussion

WTE plant general arrangement of the components is shown in Fig. 2. The waste has been collected at the polling station which will be transported by truck to the WTE plant. Waste is prepared to be burned in a furnace. Burning stove designed specifically so that waste can be burned at high temperatures (between 800 °C-1,000 °C). Combustion in the form of bottom ash (bottom ash) can be issued automatically and collected for easy transport. Hot gases of combustion

are then used to evaporate the water that is in the pipes boiler. Temperature and high-pressure steam produced by the boiler is used to turn turbines, to further connect with generators.

After the hot gas is used to evaporate the water that is in the boiler, then, it is poured into Air Pollution Control (APC). Air pollution control will reduce acid gases, heavy metals, dioxins and particulates. Remaining combustion irreducible APC discharged into the environment via the chimney.

Whatever the depth of the impact assessment is chosen, it must begin by simulating disperse pollutants. Pollutant dispersion modeling effort required information about the source of the emissions. WTE Gede Bage have emission source does not move (stationary source), controlled release pattern point source (point source) in the form of a chimney (stack). The technical specifications of the chimney are 120 m high chimney, chimney inside diameter of 1.5 m, speed bursts of 20 m/s and temperatures 403 K bursts. The study was planned over a span of 15 years, to the time where the emission sources are planned during the study period.

WTE plant incineration capacity in this is as much as 500 tons of waste per day. Utilizing the data emission factor will estimate the magnitude of the rate of emission of each chemical. Calculating the emission rate should use variable efficiency Air Pollution Control (APC). The calculation result emission rate various components of contaminants in a variety of APC efficiency can be seen in Table 1.

This modeling effort, meteorological data used is data with an average time of 1 hour of recording time for 2 years and the data taken from the nearby station (BMKG Geophysics Station Class I Bandung). The data is divided into two time measurements:

Fig. 2 Structure of components waste to energy plant in general [11].

Table 1 The rate of emission of PCDF/PCDDs in several of the efficiency of the APC.

Efficiency of APC	Emission rate gr/s
0%	4.83E-06
25%	3.62E-06
50%	2.42E-06
75%	1.21E-06
90%	4.83E-07
99%	4.83E-08

measurements of day and night measurements. Complete data on wind speed and direction need to make isopleth map regional distribution. All the wind direction should be taken into account in making these maps, as well as the average speed in each direction of the wind.

To speed up the calculation process, in this study, it will utilize pollutant dispersion modeling program and a spreadsheet program. In this study, the authors

utilize disperse pollutants program SCREEN3. This model does not require extensive meteorological data. Enough with just one set of data for each wind speed, atmospheric stability, and the ambient air temperature around the point of emission releases. This model will perform their own calculations by combining various wind speed and atmospheric stability classes that may occur. SCREEN3 count results indicated the average results of calculations per 1 hour.

The first step to do is enter the data rate of emissions, for example, for pollutants PCDF/PCDDs of 4.83E-06 g/s, 120 m high chimney, chimney inside diameter of 1.5 m, gas velocity out of the chimney 20 m/s, temperature gas from chimney 403 K, ambient air temperature of 293 K. Additional data such as wind speed, atmospheric stability class, topography and distance information point for review. Calculation begins by choosing one of the wind direction, and

Table 2 Average speed and wind direction.

Direction	Time measurement (average speed)	
	Night	Day
	m/s	m/s
N	1.608009	1.884279
NNE	1.827736	2.065283
NE	1.735566	1.960605
ENE	1.748105	2.029694
E	1.675337	2.026544
ESE	1.684302	2.020109
SE	1.720983	1.932123
SSE	1.609503	1.927389
S	1.658464	1.869783
SSW	1.652034	1.750865
SW	1.632574	1.801452
WSW	1.673069	1.844106
W	1.806336	2.030414
WNW	1.831250	2.004615
NW	1.733099	1.949205
NNW	1.879268	1.981259

been a blow, an example of the east wind blows at night. Table 2 shows that the average speed east wind that blows at night is 1.675337 m/s. In determining atmospheric stability class, it can be seen on the classification Pasquill stability. Atmospheric stability classes at night time can be specified as a class E or slightly stable. In the same way in determining atmospheric stability classes in the daytime, it can use the classification Pasquill stability.

The calculation will result in the concentration of pollutant dispersion in the direction of the east wind blows. Repeat these calculations for the wind direction to another. Such a move would be obtained contaminant concentration distribution of PCDF/PCDDs in the 16 direction of the wind, and with 45 points of the review (the distance to the source of pollutants).

In the case of the assessment of the influence of emission sources, it is not enough to just do an assessment disperse pollutants. In this study, the authors also forecast ambient air quality. Results of measurements of ambient air quality indicate that the contaminant PCDF/PCDDs are undetected. Ambient air quality is assumed to remain the same throughout

the projection period of 15 years.

The results of these calculations will be made in isopleth dispersion region map. This map was made to show the pattern of increase in the dispersion of pollutants in all regions of the dispersion. Gradation increase in average concentrations that may occur will be visualized on the map. Values increased concentration is calculated based on the average scene. Such information is needed to determine the impact of output forecasts. Isopleths dispersion region map that has been made can be seen in Fig. 3.

Isopleth resulting map consists of 8 regions, and as a whole, consists of 292 villages. Externalities calculation is done by reduction of public health risk assessment. In this activity, forecast the number of people affected, further data required number of population in each area isopleths. It is known that the rate of population growth in West Java is 1.72%, then the sum of the number of people in the 8 regions isopleths and the estimated number of population projections for the period up to 15 years can be seen in Table 3.

Anthropometric variables and patterns of activity consists of weight, time of exposure, exposure frequency and duration of exposure. Anthropometric

Fig. 3 Map isopleths dispersion region.

Table 3 The estimated population in 8 regions isopleths during years 1-15.

Region	Total population	
	Now	15 years later
	People	People
1	13,949	17,711
2	35,380	44,921
3	53,469	67,888
4	241,817	307,026
5	355,318	451,135
6	464,860	590,216
7	515,119	654,028
8	2,085,035	2,647,295
Total	3,764,947	4,780,220

variables refer to the US EPA standards. Exposure object assumed to be static, and never considered anywhere. An understanding of these assumptions are considered equal weight of 70 kg, the rate of inhalation (standard US EPA) are considered equal to 15.2 m³/day, the daily exposure is 24 hours per day, frequency of exposure is 365 days per year and the duration of exposure to 15 years.

Changing the air quality for pollutants PCDF/PCDDs cause an impact on public health. Pollutants PCDF/PCDDs cause impacts that are carcinogenic form of liver cancer.

From isopleths dispersion region map for pollutants PCDF/PCDDs, it will be known concentration of pollutant dispersion pattern of the increase in average conditions across the region dispersion effect. Isopleths map of the study area is divided into eight regions based on the level of similarity of dispersion

of pollutants. Data on the concentration of the pollutant dispersion PCDF/PCDDs the dispersion region 8 and coupled with ambient air measurement data is shown in Table 4. Table 4 shows that the highest concentration of the dispersion of pollutants PCDF/PCDDs located in the region of 4, with a concentration of PCDF/PCDDs surface soil at 3.13E-09 mg/m³. Region 4 has a distance between 3 km to 5 km from the center of emission.

Regions obtained from the isopleths map as well as the assumption of anthropometric characteristics and patterns of activity can be calculated intake PCDF/PCDDs the exposure object. Results intake calculations for PCDF/PCDDs can be seen in Table 5. Table 5 shows that the highest intake of 1.44E-10 mg/kg/day, the highest intake due to exposure PCDF/PCDDs that afflict people living in the area isopleths 4.

Once known intake of PCDF/PCDDs, then the next is the calculation of the health risks. Carcinogenic risks expressed as Excess Cancer Risk (ECR). Referring to the US-EPA, the value of Cancer Slope Factor (CSF) PCDF/PCDDs is at 1.5E-05 (mg/kg/d). ECR calculation results due to exposure PCDF/PCDDs in 8 regions isopleths and projection exposure time of up to 15 years can be seen in Table 6. Table 6 shows that the highest ECR obtained by 2.16E-05. The highest risk of liver cancer pain affected due to exposure PCDF/PCDDs obtained by people who live in the area isopleths 4.

Table 4 Concentration CDD in 8 regions.

Region	PCDF/PCDDs concentration					
	0%	25%	50%	75%	90%	99%
	mg/m ³	mg/m ³	mg/m ³	mg/m ³	mg/m ³	mg/m ³
1	2.53E-09	1.90E-09	1.27E-09	6.33E-10	2.53E-10	2.53E-11
2	2.25E-09	1.69E-09	1.13E-09	5.63E-10	2.25E-10	2.25E-11
3	2.86E-09	2.15E-09	1.43E-09	7.15E-10	2.86E-10	2.86E-11
4	3.13E-09	2.35E-09	1.57E-09	7.83E-10	3.13E-10	3.13E-11
5	2.93E-09	2.20E-09	1.47E-09	7.33E-10	2.93E-10	2.93E-11
6	2.58E-09	1.94E-09	1.29E-09	6.45E-10	2.58E-10	2.58E-11
7	2.26E-09	1.70E-09	1.13E-09	5.65E-10	2.26E-10	2.26E-11
8	2.08E-09	1.56E-09	1.04E-09	5.20E-10	2.08E-10	2.08E-11

Table 5 Calculation intake.

Region	I PCDF/PCDDs					
	0%	25%	50%	75%	90%	99%
	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day
1	1.16E-10	8.74E-11	5.84E-11	2.91E-11	1.16E-11	1.16E-12
2	1.04E-10	7.77E-11	5.20E-11	2.59E-11	1.04E-11	1.04E-12
3	1.32E-10	9.89E-11	6.58E-11	3.29E-11	1.32E-11	1.32E-12
4	1.44E-10	1.08E-10	7.22E-11	3.60E-11	1.44E-11	1.44E-12
5	1.35E-10	1.01E-10	6.76E-11	3.37E-11	1.35E-11	1.35E-12
6	1.19E-10	8.92E-11	5.93E-11	2.97E-11	1.19E-11	1.19E-12
7	1.04E-10	7.82E-11	5.20E-11	2.60E-11	1.04E-11	1.04E-12
8	9.57E-11	7.18E-11	4.78E-11	2.39E-11	9.57E-12	9.57E-13

Table 6 Calculation ERC.

Region	ECR PCDF/PCDDs					
	0%	25%	50%	75%	90%	99%
1	1.75E-05	1.31E-05	8.76E-06	4.37E-06	1.75E-06	1.75E-07
2	1.55E-05	1.17E-05	7.80E-06	3.88E-06	1.55E-06	1.55E-07
3	1.97E-05	1.48E-05	9.87E-06	4.93E-06	1.97E-06	1.97E-07
4	2.16E-05	1.62E-05	1.08E-05	5.40E-06	2.16E-06	2.16E-07
5	2.02E-05	1.52E-05	1.01E-05	5.06E-06	2.02E-06	2.02E-07
6	1.78E-05	1.34E-05	8.90E-06	4.45E-06	1.78E-06	1.78E-07
7	1.56E-05	1.17E-05	7.80E-06	3.90E-06	1.56E-06	1.56E-07
8	1.44E-05	1.08E-05	7.18E-06	3.59E-06	1.44E-06	1.44E-07

Table 7 Results of the public health risk assessment.

Region	Liver cancer on the condition of efficiency APC					
	0%	25%	50%	75%	90%	99%
	People	People	People	People	People	People
1	0	0	0	0	0	0
2	1	0	0	0	0	0
3	1	1	1	0	0	0
4	7	5	3	2	1	0
5	9	7	5	2	1	0
6	10	8	5	3	1	0
7	10	8	5	2	1	0
8	38	29	19	9	4	0
Total	76	58	38	18	8	0

ECR forecast results will be determined number of cases of liver cancer patients in every region isopleths. For example, ECR at 2.02E-05 showed that out of a population of 100,000 people obtained forecasts the number of people potentially affected by liver cancer disease as much as 2 people. Complete forecasts liver cancer patients can be seen in Table 7. Table 7 shows that the highest number of liver cancer patients by 38

people. The highest number is located in the region of isopleths 8, it can be described as the largest population in the region 8.

Public health risk assessment results are shown in Table 7. In this study, it is necessary to determine the effect of changes in the efficiency of the air pollution control to the number of patients with liver cancer. That effort is obtained by regression analysis. The

Fig. 4 APC efficiency effect on the number of liver cancer patients.

functional relationship between independent variables with the dependent variable, is obtained in the form of a simple linear regression equation $Y = a + bX$.

Looking for an intercept value by using the Eq. (6), and the obtained value of $a = 76.4592$. Calculation followed by calculating a regression coefficient b using Eq. (7), and the obtained value $b = -0.7692$.

From the calculation of intercept a and the regression coefficient b , they can be used to determine the regression equation. The regression equation obtained in the form of $Y = 76.4592 - 0.7692X$. It can be mapped in a graph as shown in Fig. 4.

The graph shows a linear shape and the higher the efficiency of air pollution control, the number of patients with liver cancer due to exposure PCDF/PCDDs would be lower. At the time of the air pollution control at 100% efficiency, will ensure no pollutants are emitted into the environment. The Fig. 4 confirms that the efficiency of the air pollution control at 100% has no risk for liver cancer.

4. Conclusion

(1) Region 4 (distance between 3 km to 5 km from

the center of emission) is the region at highest risk of exposure PCDF/PCDDs. From the results of the calculations in the region 4, it showed the highest concentration of the pollutant dispersion ($3.13E-09$ mg/m³), the highest intake ($1.44E-10$ mg/kg/day), and the highest ECR ($2.16E-05$);

(2) Regional isopleths 8 shows the most number of liver cancer patients, it is because this region has the highest population;

(3) Functional or causal relationship between the independent variable efficiency of APC with one dependent variable number of liver cancer patients is obtained in the form of a simple linear regression equation $Y = 76.4592 - 0.7692X$.

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