Regional Detection Polluted with Diffusion and Convection Models in Banten Province

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Regional Detection Polluted with Diffusion and Convection Models in Banten Province

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Abstract. Numerical convection and diffusion models can be used to predict air pollutant concentrations in an area. Changes in air pollutant concentration can be analyzed using diffusion equations which depend on the coefficient of intra-particle diffusivity (D). Whereas to find out the changes in air quality categories become polluted using a convection equation which depends on the diffusivity coefficient between particles (Γ). The combination of the two equations can be used to estimate the polluted areas of a region. The results of the climate analysis indicate that Banten Province if viewed from the direction of the wind, is very potential for the development of increased fish production. Meanwhile, if viewed from the temperature and rainfall of Banten Province the potential for agriculture. However, considering that in the western part of the region there is a large industry with a chimney height of 275 meters, so based on atmospheric stability, the distribution of air pollutants spread far outside the industrial area. This will have implications for other regions so that at high concentrations (with diffusion equations) it will change the air quality (with the convection equation) so that in certain regions and at certain times it will become a polluted area.

1. Introduction

Air pollutants are substances in the atmosphere which under certain conditions will endanger humans, animals, plants or microbial life and building materials [1]. Air pollutants are produced by nature and mostly by human activities. Air pollution caused by human activities is the result of transportation, industry, and urbanization. The concentration of major pollutants (SO_2, NO_2, CO, and SPM) increased due to a combination of contaminants due to warming, geographic conditions and meteorological conditions. About concerning air pollutants produced from different industries, depending on the fuel used. Air pollutants are divided into: carbon oxides (CO, CO_2), sulfur oxides (SO_2, SO_3), nitrous oxide (N_2O, NO, NO_2), hydrocarbons (CH_4, C_4H_{10}, C_6H_6), photochemical oxidants (O_3, PAN and aldehydes), particles (smoke, dust, soot, asbestos, metals, oils and salts), inorganic compounds (asbestos, HF, H_2S, NH_3, H_2SO_4, H_2NO_3), other inorganic compounds (pesticides, herbicides, alcohols, acids and other chemicals), radioactive substances, heat, and noise [2]. A significant influence of air pollutants on humans, especially on aspects of health, comfort, safety, aesthetics, and economy. Table 1 shows some types of air pollutants and their effects on humans.

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Table 1 . Several types of air pollutants and their effects on humans

Types of air pollutants	Influence on humans
Carbon monoxide (CO)	Reducing the ability of the blood to carry oxygen, weaken thinking, heart disease, dizziness, fatigue, headaches and death
Sulfur dioxide (SO_2)	Exacerbating respiratory diseases, weaken respiratory and eye irritation
Nitrous oxide (NO_x)	Exacerbating heart and respiratory disease, and lung irritation
Hydrocarbons	Affecting the respiratory system, several types can cause cancer
Photochemical oxygen (O_3)	Exacerbating heart and respiratory disease, eye irritation, irritation of the esophagus and respiratory tract
Dust	Cancer, aggravating heart and respiratory disease, coughing, irritation of the throat and chest discomfort
Ammonia (NH_3)	Respiratory irritation
Hydrogen sulfide (H_2S)	Drunk (dizziness), eye irritation and esophagus and toxins at high levels
Metals and metal compounds	Causes respiratory illness, cancer, nerve damage and death

Criteria for the impact of air pollution, refer to Government Regulation No. 27 of 1999 and Decree of the Head of the Environmental Impact Management Agency Number: KEP-056/1994 regarding: (1) the number of people affected, (2) the extent of the impact distribution, (3) the duration of the impact, (4) the intensity of the impact, (5) the number of other environmental components affected, (6) the cumulative nature of the impact, and (7) reversible or irreversible of the impact. Therefore, in analyzing air pollution in an area, it is necessary to know the climatic conditions and land functions of the region. Climatic conditions are needed to detect the distribution of pollutants that are spreading in the region.

There are several models of the distribution of air pollutants including the Travel Activity Scheduler for Household Agents (TASHA) used to model and map atmospheric emissions and dispersion traffic in the Toronto area . The polluter that is focused is NO_x[3]. Then there are The National Pollutant Models that are made to improve the measurement of pollution exposure compared to traditional methods that only capture images locally and regionally [4]. TASHA and The National Pollutant Models are similar to Land-use Regression (LUR) [4][5], which focus on calculating the exposure of polluters to individuals. However, these models have limitations especially with regard to the need for data for monitoring large areas. In contrast, SIRANE is a polluter distribution model in urban areas based on a simplified description of urban geometry that adopts parametric relationships for the phenomenon of polluter transfer inside and outside urban areas [6]. Therefore, from the exposure to the types of models needed a model that can reach a wide area and can provide data as detailed as possible, especially for the measurement of pollutant distribution in Banten province.

Banten Province has an area of 9662.92 km^2 which consists of four districts and four cities. The area of the regency / city is between 147.19-3426.56 km^2. Each regency/ city has different astronomical boundaries, climatic conditions, and land functions. The distribution of pollutants emitted from industry, depends on the height of the chimney used. The higher the chimney used, the further the pollutant distance emitted. Meanwhile, related to climatic conditions, the distribution of pollutants depends on atmospheric stability, temperature and wind direction.

2. Method

This research was conducted with three stages, first, collection of reviews literature related theory of diffusion and convection. Second, to build models of the distribution of air pollutants by combining the theory of diffusion and convection. The last to simulate the data using distribution models derived contaminants.

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2.1. Diffusion Theory

In physics, chemistry, and engineering, the phenomenon of displacement is one of the various mechanisms of particles or physical quantities moving from one place to another. Displacement of these particles, can be through the process of convection and diffusion. Diffusion, or conduction is a form of gradual transfer events from one point to another point [7]. Diffusion is a phenomenon of mass, momentum, and energy transfer with intra-molecular mechanisms [8]

Diffusion equation

$$\nabla^2\phi = \frac{1}{D}\frac{\partial\phi}{\partial t} \tag{1}$$

To find out the change in density of a material undergoing a diffusion process , it is analyzed by equation (1). In one dimension of the equation, it is written as follows.

$$\frac{\partial\phi}{\partial t} = D\frac{\partial^2\phi}{\partial x^2} \tag{2}$$

Where D is the intra-particle diffusivity coefficient which is multiplied every two times the change in density with space. But at every time change, does not change the shape of its density (fixed), what changes is only the magnitude.

2.2. Convection Theory

Convection (heat transfer in fluid) is a phenomenon where when the fluid is heated, the fluid will experience movement. The process of transfer by convection occurs in two ways, namely natural convection and forced convection. Natural convexation or free convection, occurs in the fluid due to the heating process so that its density changes with the direction of moving up. Fluid displacement due to natural covection processes and forced convection is inseparable from the diffusivity coefficient between particles (Γ). To examine the process of convection of a fluid, use equation (3).

$$\frac{d}{dt}(\rho u\phi) = \frac{d}{dx}\left(\Gamma\frac{d\phi}{dx}\right) \tag{3}$$

With Γ the diffusivity coefficient *between particles* , the coefficient is a function of the pressure, temperature, and mass of each particle. These variables, in the concept of thermodynamics, include equality of states that influence each other.

3. Results and Discussion

The air pollutant distribution pattern is developed from equations (2) and (3) for the two-dimensional case the equation is obtained as follows:

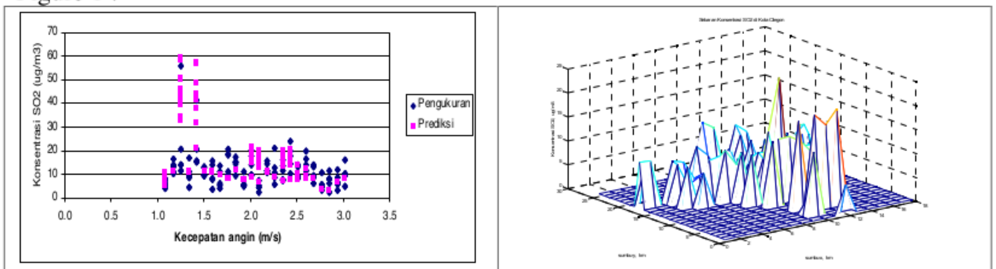
$$a_P\phi_P = a_W\phi_W + a_E\phi_E + a_S\phi_S + a_N\phi_N + a_P^o\phi_P^o + S_u \tag{4}$$

With: $a_P = a_W + a_E + a_S + a_N + a_P^0 + \Delta F - S_P$; $a_W = \frac{\Gamma_w A_w}{\delta x_{WP}}$; $a_E = \frac{\Gamma_e A_e}{\delta x_{PE}}$; $a_S = \frac{\Gamma_s A_s}{\delta x_{SP}}$; and $a_N = \frac{\Gamma_n A_n}{\delta x_{PN}}$;

and for the two-dimensional case, it applies: $A_w = A_e = \Delta y$ and $A_n = A_s = \Delta x$ [9]

By using equation (4), it will be known the concentration of air pollutants in an area. By comparing the threshold, if it exceeds the threshold, the area is categorized as polluted. Model analysis to develop (4), indicate that the stability of the A (very unstable) distribution of air pollutants occurs around the source. Pollutant distribution far from the source, occurs in the unstable stability (B) medium to somewhat stable (E). To find out the polluted area, a simulation is carried out using two scenarios, namely: a scenario with a source and no source.

The difference in pollutant distribution results based on the two scenarios, shown in Figure 1 .



(a) (b)

Figure 1. Distribution of model pollutants at wind speeds of 1-3 m / s (a) 2-dimensions (b) 3-dimensions

Based on the scenario there is a source, from four periods in three months there is a decrease in concentration. From the four analysis periods pollutant concentrations from the range of 6.065 $\mu g / m^3$ decreased to 5,411 $\mu g / m^3$. Pollutants spread from West to East in the direction of the wind. This model is in accordance with reality or data obtained from Badan Meteorologi, Klimatologi dan Geofisika (BMKG) [10]. Based on the analysis of climate data from 2005 to 2015, the average monthly wind speed in Banten Province ranged from 0.2 m / s in January, to 4.0 m / s in December. To find out the distribution of wind frequency, wind data were analyzed and a wind rose map was made. Based on the analysis of wind roses shows patterns that vary between morning, afternoon, evening and night. In general, in November to March the wind generally moves from West to East. The lowest frequency of Western winds was 36.7% in November, and the highest was 87.1% in December. Meanwhile in April to October the wind generally moves from North to South. The lowest North Wind frequency was 46.7% in June, and the highest was 67.7% in August. Referring to the wind data, the distribution of pollutants in Banten Province from November to March moves from West to East. If you look at the position of Banten, the wind is the wind that blows from sea to land. The wind can be used by traditional fishermen to catch fish. Furthermore, if viewed from the temperature and rainfall conditions, Banten Province can be utilized for agricultural development. However, considering that in the West in Banten Province, namely in the City of Cilegon there is an industrial area with a chimney height of up to 275 meters. The high chimney, will have implications for the distribution of air pollutants to other districts / cities in the province of Banten.

4. Conclusion

The results of climate analysis show that Banten Province, based on wind direction, has the potential to produce fish. Based on temperature and rainfall, Banten Province has the potential to become agricultural land. However, in the west, there is a large industrial area with a chimney height reaching 275 meters, which causes the spread of pollutants to expand. This spread has implications for the surrounding area so that at high concentrations (with the diffusion equation) will change the air quality (with the convection equation) so that in the area around the industry, it will become a polluted area.

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