Phosphate Distribution Model Of Cipicung River Water Affected By Sarimukti Landfill Leachate Discharge

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Phosphate distribution model of Cipicung River water affected by Sarimukti Landfill Leachate Discharge

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Abstract. This study aims to develop a phosphate distribution model up to the calibration stage in the Cipicung River. The model was simulated to determine the distribution of phosphates using a volume control approach so that the river is likened to an elongated reactor divided into several segments. Pollutant load entered is considered to be point source so the model does not take into account other loads that enter the river. Based on the results, the deviation or an error made in the calculation of the initial model at a distance of 40 m from the leachate outlet is 1.9%. The error results obtained in the calculation of the initial model are quite large; this is due to several factors that exist in the components of the model. The component model that influences the magnitude of the error is the decay rate (k). In the calibration process the model components that affect the magnitude of the error can be varied to find the best fit for the data in the field. The variations of k value were 10, 13, 15, 17 and 20/day. The closest model to the conditions in the field is using k value of 15/day with an error of 0.013%.

1. Introduction

Phosphate is an essential nutrient needed for the survival of aquatic life. The presence of phosphate compounds in water is very influential on the balance of the ecosystem. Dissolved phosphate is divided into organic phosphate and inorganic phosphate, which consists of orthophosphate and polyphosphate [1]. Organic phosphate in wastewater is produced from food, agriculture and domestic waste [2,3]. While inorganic phosphate mainly comes from the use of detergents. Low phosphate levels (<0.01 mg/L) in water can inhibit the growth of plants and algae. This situation is called oligotrophic. However, high phosphate levels in the waters will actually cause excessive growth of algae. Algae bloom that occurs in surface water bodies is caused by eutrophication [4].

Eutrophication causes the overgrowth of phytoplankton which results in an imbalance in productivity of the body of water, which is caused by the ingestion of nutrients in large quantities from agricultural runoff and other wastewater [5]. In other words, eutrophication is the result of water pollution caused by the emergence of excessive nutrients into the aquatic ecosystem. Water is said to be eutrophic if the total concentration of phosphorus (TP) in water is in the range of 35-100 µg/L [6]. Eutrophication occurs due to accumulation of household and agricultural waste that contains phosphate [7].

Phosphate compounds in wastewater can come from residents (domestic), industrial and agricultural waste. Waste entering the water can increase the concentration of phosphate and in sustainable conditions can lead to eutrophication. Leachate from landfills (TPA) generally contains high phosphate concentrations. Leachate is a liquid that seeps through a pile of garbage by carrying dissolved or suspended material, especially the result of the process of decomposition of waste material [8]. Cipicung

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River is a water body that receives leachate generated by Sarimukti Landfills and is also used as paddy fields irrigation by the surrounding community.

Modeling is a method to simulate the distribution of concentration of pollutant in the environment. This study aims to develop a phosphate distribution model up to the calibration stage in the Cipicung River.

2. Research methodology

In the process of preparing the model, it takes a number of data collecting, both primary and secondary types. In this study, sampling or primary data and secondary data collection were performed to determine the condition of the Cipicung River water body in terms of the phosphate parameters. Water samples were taken from Cipicung River. Concentrations of phosphate were analyzed in the laboratory. The data set were used to calibrate the distribution model of phosphate.

2.1. Secondary data and references collection

Literature study is conducted to get a strong theoretical basis so that it can be used as a reference in conducting research. Literature sources include journals, scientific articles, text books, and previous research related to this research. Secondary data and literature studies needed for the process of making a model especially to figure the behavior of phosphates in water. The source of phosphate load in this case is leachate generated from outlet of Sarimukti Landfill.

2.2. Primary data collection

The primary data collection is needed as initial data for the model equation, i.e. a river discharge that receives leachate, river discharge at the upstream part of the leachate outlet, concentration of leachate in the outlet, and phosphate concentration at a distance of 40 m from the leachate outlet. Sampling site can be seen in Figure 1. The symbol of Q_w is leachate discharge, C_w is phosphate concentration of leachate, Q_r is river discharge before leachate outlet and C_r is phosphate concentration in Cipicung River before leachate outlet.

Figure 1. Location of sampling points.

River water and leachate samples taken were then analyzed to measure the concentration of phosphate. The analytical method used in the laboratory is the Stannous Chloride method. The principle of the Stannous Chloride method is orthophosphate with Ammonium Molibdat forming the complex compound Ammonium phosphomolybdate. With the addition of the $SnCl_2$ reducing agent it will be reduced to form a blue complex [9]. The intensity of the blue color that occurs is measured by a spectrophotometer at a wavelength of 690 nm.

2.3. Model development

The preparation of the model is performed to determine the value of concentration in steady state conditions without time changes. The numerical solution uses a control volume approach so that the river is assumed to be a longitudinal reactor divided into several segments. Pollutant load entered is considered to be point source so the model does not take into account other loads that enter the river. The mass balance that occurs in each segment in a steady state in accordance with the equation, namely:

$$0 = W_i + Q_{i-1,i}c_{i-1} - Q_{i,i+1}c_i + E_{i-1,i}(c_{i-1} - c_i) + E_{i,i+1}(c_{i+1} - c_i) - k_iV_ic_i \quad (1)$$

By collecting the same variables the equation becomes:

$$-(\mathrm{Q}_{i-1,i} + \mathrm{E}'_{i-1,i})\mathrm{c}_{i-1} + (\mathrm{Q}_{i,i} + \mathrm{E}'_{i-1,i} + \mathrm{E}'_{i,i+1} + \mathrm{k}_i\mathrm{V}_i)\mathrm{c}_i - (\mathrm{E}'_{i,i+1})\mathrm{c}_{i+1} = \mathrm{W}_i \quad (2)$$

or

$$\mathrm{a}_{i,i-1}\mathrm{c}_{i-1} + \mathrm{a}_{i,i}\mathrm{c}_i + \mathrm{a}_{i,i+1}\mathrm{c}_{i+1} = \mathrm{W}_i \quad (3)$$

with each value a is as follows:

$$\mathrm{a}_{i,i-1} = -\mathrm{Q}_{i-1,i} - \mathrm{E}'_{i-1,i} \quad (4)$$

$$\mathrm{a}_{i,i} = \mathrm{Q}_{i,i+1} + \mathrm{E}'_{i-1,i} + \mathrm{E}'_{i,i+1} + \mathrm{k}_i\mathrm{V}_i \quad (5)$$

$$\mathrm{a}_{i,i-1} = -\mathrm{E}'_{i,i+1} \quad (6)$$

Finally, the solution to the equation is in the form of a matrix like in equation (7), which is:

$$[A]\{c\} = \{W\} \quad (7)$$

The number of segments in the preparation of the model is set at 20 units with the length of each segment which is 2 m. Leachate input entered in the segment is assumed to be only in the first segment as point source.

The limitations used in this study are (1) Model calculations are performed for rivers under steady state conditions (without changes in time) with a volume control approach, (2) Components of the dispersion, velocity and flowrate of the river are considered uniform in each segment and do not change with time, (3) The river length reviewed for the model is 40 m, with a total of 20 segments. The length of each segment is 2 m.

2.4. Calibration

The calibration process in modelling is one step to get the equation coefficient that best describes the field conditions, so that the model will be able to be applied for appropriate management actions [10]. This phase includes varying the parameters of the model to produce the optimum fit between the model count and the available data set. Model parameters that can be varied are the decay rate (k) with the k value obtained to find the most optimum suitability according to data in the field are 10, 13, 15, 17, and 20/day. The decay rate (k) of the literature is generally below 1/day [11]. This varied k value can be caused by the rate of decomposition of organic matter by aquatic organisms is large enough, this is in accordance with the statement that the greater the value of k, the decomposition process of organic matter will be faster, conversely the smaller the value of k the decomposition process will run slowly [12].

3. Results and discussion

3.1. River flow before leachate input point (Q_r)

The Cipicung River flowrate is determined using the following equation approach:

$$Q_r = U_r \times Ac_r \quad (8)$$

Velocity (U_r) measurement is done several times and the results are then averaged. This result aims to minimize errors. Then the wet height (H_r) and cross-sectional width (B_r) are measured, to determine the cross-sectional area of the leachate channel (Ac_r). The results of the measurements show that river flow velocity (U_r) is 0.2044 m/s, Average River Width (B_r) is 0.846 m, the average height of the river water (H_r) is 0.093 m, cross-sectional area (Ac_r) is 0.078 m^2, discharge (Q) is 0.0159 m^3/s.

3.2. Phosphate concentrations

The value of C_r represents the concentration of phosphate in the Cipicung River before receiving leachate input. Samples for determining the value of C_r are taken at the point before the landfill leacheat effluent. The result of the measurement of phosphate concentration in river water before leachate input is 0.574 mg/L.

The value of C_w represents the concentration of phosphate in leachate water. Samples for determining the value of C_w were taken at the landfill leach effluent point. The results of the measurement of phosphate concentrations in leachate are 2.87 mg/L.

Phosphate concentration at a distance of 40 m from the leachate outlet was determined to be a comparison of the results of the model in steady state conditions. Samples were taken at a point at a distance of 40 m from the leachate outlet. The result of the measurement of phosphate concentration at a distance of 40 m from the outlet is 1.51 mg/L.

3.3. Flow discharge (Q_w)

Sarimukti Landfill leachate discharge is determined using the following equation approach:

$$Q_w = U_w \times Ac_w \tag{9}$$

Flow velocity (U_w) is determined by conventional methods using ping pong balls and records how much time is needed to reach a certain distance (x). This is done according to the following equation:

$$U_w = x/t \tag{10}$$

U_w measurement is done several times and the results are then averaged. This result aims to minimize errors. Measurements of wet height (H_w) and cross-sectional width (B_w) are carried out to determine the cross-sectional area of the leachate channel (Ac_w). The results of the measurements show that leachate flow velocity (U_w) is 0.2896 m/s, average leachate channel width (B_w) is 0.08 m, average leachate channel height (H_w) is 0.48 m, cross-sectional area (Ac_w) is 0.0398 m^2, discharge (Q_w) is 0.0115 m^3/s.

3.4. Loading pollutants (W)

From the results of laboratory examinations, the value of phosphate concentration in leachate (C_w) was 2.87 mg/L P or 2.87g/m^3 P and the initial concentration value (C_r) was 0.574 mg/L or 0.574 g/m^3 P. While the measurement results of leachate flow (Q_w) is 0.0115 m^3/s or 993.6 m^3/day and river flow discharge (Q_r) is 0.0159 m^3/s or 1373.76 m^3/day. Then the pollutant load value can be calculated as follows.

$$W = (Q_w \times C_w) + (Q_r \times C_r) = (993.6 \times 2.87) + (1373.76 \times 1.574) = 3646.13 \text{ g/day}$$

3.5. Coefficient of dispersion (E and E ')

The E value represents the river longitudinal dispersion coefficient, which is determined using the following equation:

$$E = 0{,}05937 \frac{Q_0}{SB_r} \tag{11}$$

Q_0 value is the discharge at the time of mixing that is equal to 0.0274 m^3/s or equal to 2364.36 m^3/day. To calculate the slope of the river or slope (S), the elevation or elevation of the location of the study object, the Cipicung River, is observed through Google Earth. The length of the river (L) to be observed and modelled was predetermined at 40 m. The elevation difference between upstream and downstream

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of the river along the 40 m (L) is known to be 0.5 m (ΔH). Then the value of the slope or river slope that will be observed is:

$$Slope = \Delta H / L \quad (12)$$

Slope = 0.5/40 = 0.0125

River width (B_r) is known by direct measurement at several points. The average width of the river is 0.846 m. Thus, the value of E can be calculated as follows:

$$E = 0.05937 \times (2367.36 / (0.0125 \times 0.846)) = = 13290.8 \ m^2/day$$

Whereas the value of E 'is then calculated using the following equation:

$$E' = (EAcr) / \Delta x \quad (13)$$

The value of the cross-sectional area of the river (Ac_r) is determined by direct measurement of the depth and width of the river at several points. The measurement results are then averaged to get the value of Ac_r of 0.078 m^2. The value (Δx) in the above equation expresses the length of each segment of the river being reviewed. For the calculation of this model, the length of the river under review is 40 m and is divided into 20 segments. Thus, the length of each segment (Δx) is 2 m. Then the calculation of E 'is as follows:

$$E' = (13290.8 \times 0.078) / 2 = 518,341 \ m^3/day$$

3.6. Model calibration

Model calibration is conducted by comparing the results of the phosphate concentration measured in the field with the phosphate concentration modelled by distance. This phase includes varying the parameters of the model to produce the optimum fit between the model count and the available data set. The calculation uses the volume control approach. Phosphate concentration based on the results of lab calculations in the 20th segment or a distance of 40 m from the leachate output is 1.51 mg P /L that give 1.9% deviation. The calibration process is carried out in the initial model calculation to see the magnitude of the error at a distance of 40 m.

Based on the results of deviations or errors made in the initial model calculation at a distance of 40 m from the leachate outlet is 1.9%. The error results obtained in the initial model calculation are quite large. This is due to several factors that exist in the component model. The component model that influences the magnitude of the error is the decay rate (k). In the calibration process the model components that affect the magnitude of the error can be varied to find the closest match to the data in the field. The k values varied were 10, 13, 15, 17 and 20/day. Calibration results from the specified variations can be seen in figure 2.

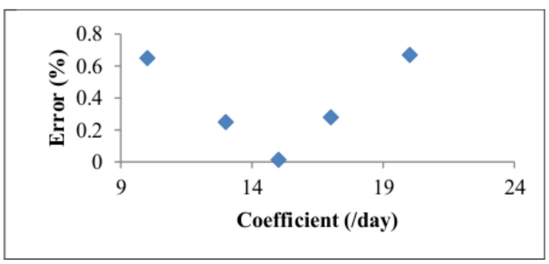

Figure 2. Calibration results graph at a distance of 40 m.

After the variation process, the model is chosen according to the conditions that are close to the data in the field. The closest model to the conditions in the field is using 15/day as coefficient value with an error value of 0.013%. The large k value can be caused by the large decomposition rate of organic matter by aquatic organisms and other processes [13]. This is in accordance with the statement that the greater the value of k, the decomposition process of organic matter will be faster, conversely the smaller the value of k, the decomposition process will run slowly [14,15]. Another factor that influences the value of k is also due to the fact that in the approach model with volume control the coefficient of deposition of organic matter is not taken into account this is estimated to cause the magnitude of the k value obtained. Attached in particle, phosphorus concentration in water may decrease rapidly due to deposition [16].

4. Conclusion

Based on the results of the simulation model, the following conclusions can be drawn, based on the results of deviations or errors made in the initial model calculation at a distance of 40 m from the leachate outlet is 1.9% and The closest model to field conditions is using a variation of k 15/day with an error value of 0.013%.

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