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Prediction of water pollution in Kali Surabaya river segment Karangpilang-Ngagel using stella model

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Prediction of water pollution in Kali Surabaya river segment Karangpilang-Ngagel using stella model

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Abstract. Kali Surabaya River is one of the river in Surabaya that use as the water source of PDAM Surabaya. Moreover, Kali Surabaya River takes an important role of society, industry, agriculture and economic commerce in its surrounding area. The increasing of industry and domestic waste that dispose to Kali Surabaya River, causing the degradation of its water quality. From parameters DO, BOD, and COD of Kali Surabaya River, we can look for relation and mutual attachment to determine the class of water body of Kali Surabaya. The method that use in this case is system dynamics using Stella Model. The purpose of this modelling is to identify and determine the relation of DO, BOD and COD value that contains in Kali Surabaya river segment Karangpilang-Ngagel Surabaya, and to determine the class of water body of Kali Surabaya River segment Karangpilang-Ngagel using dynamic system method. The result of this modelling is prediction of DO parameter value that decreasing in 2018 at all three segments. In December 2018, concentration of DO in segment 1 is 3.79 mg/L; in segment 2 is 4.34 mg/L and in segment 3 is 3.72 mg/L. According to the prediction result from this model, DO value at all segments in November and December is still exceed the standard value of class II river standard, which is 4 mg/L. In the other hand, in January until October DO value at all segments is under the standard of class II river standard. The average DO value of Kali Surabaya River in 2018 is in the range of 3.72-4.9 mg/L.

1. Introduction

Surabaya is a city of East Java Province government which is teeming with various activities. Domestic, industrial and governmental activities occur simultaneously. Each one of these activities requires water as a means of support. On the other hand, raw water for drinking water in Surabaya City is obtained from surface water (water body) flowing through the City of Surabaya. Surabaya River is one of several rivers being used as a source of raw water by PDAM Surabaya. Therefore, water quality control must be done to ensure that Surabaya River is up to the quality standards. Based on East Java Provincial Regulation No. 2 in 2008 regarding Water Quality Management and Water Pollution Control in East Java Province, waste water management must be conducted before discharge into Surabaya River water body. Water pollution control in Surabaya River has been implemented as one of many efforts to prevent water pollution from exceeding the class II water quality standard according to Governor Regulation No. 61 in 2010.

Dynamic systems modeling is one of several models used to determine the status of water quality used to model the water quality. From this dynamic system, pollution control effort options for Surabaya River can be determined. Surabaya River is currently polluted, because the water quality of the river has exceeded the quality standard of class II river. Quality monitoring has been conducted, however there is no further study on the relations of DO, BOD, and COD in Surabaya River utilizing dynamic systems. Based on the mentioned problems, relationships and mutual attachments of DO, BOD, and COD parameters in Surabaya River can be analyzed to establish a prediction of Surabaya River to then determine the water body class of Surabaya River. The method used in this research is dynamic systems utilizing STELLA model.

2. Methods

2.1. Research idea
The idea of this research is based on the numbers of pollution of Surabaya River from industrial wastes and household wastes. This causes a decrease in river water quality. Water from Surabaya River is used as a source of raw water by PDAM Karangpilang Surabaya, therefore an effort must be done to determine the relationship between DO, BOD, and COD parameters to predict the concentration of DO, BOD, and COD in Surabaya River in the next few years.

2.2. Literature study
Literature study is conducted from the beginning until the end of this research to obtain the basic theory related to this research so that it can be used as a reference in analysing data to attain a conclusion to this research. The sources of literature used in this research includes previous researches, text books, internet, etc. concerning Surabaya River, STELLA model, river water quality standards, water pollution as well as water quality parameters.

2.3. Data collection
The data used in this research includes secondary data and primary data. The primary data used are water quality data – i.e. DO, BOD, COD, temperature, pH, velocity and river water discharge. While the secondary data used are Surabaya River map and Surabaya River water quality data from the last 2 years – i.e. 2016 to 2017.

2.4. Research implementation

2.4.1. Research location determination. This research was conducted in the Surabaya River area, specifically Karangpilang-Ngagel segment. The selection of Surabaya River as the object of this research is based on the Surabaya River being the source of raw water for PDAM Surabaya where the water pollution increasingly worsens. Therefore, it is necessary to control water pollution in Surabaya River to ensure the safety of the environment and community around Surabaya River. In this research there are 3 segments with 4 points namely Karangpilang, Sepanjang, Gunungsari dan Ngagel. The segment distribution is based on the existing segments from obtained secondary data.

2.4.2. Sampling. [1] The sampling of the river water is determined based on river water discharge. Sampling is done with a frequency of 3 with the same condition for 3 days. Sampling starts from headwaters at 08.00 IWST. The timing of this sampling is based on the water usage activity along the research segment which are mostly residential, office complex, commercial and warehousing areas.

2.5. Data processing
Based on the standard method, the tools and materials to support the measurement of the test parameters are as follows: Winkler bottle or plastic bottle to store the sample so that no contaminants or oxygen tampers the sample, chemicals used for preservation, measuring devices for meticulous measurements, thermometer to measure water temperature, cooling box to store sample containers, camera to document sampling activities, rope to ease sampling process, sampling tools to take water from river, plastic bucket to collect sample water.

2.6. STELLA modelling

STELLA (Structural Thinking, Experiential Learning Laboratory with Animation) is an automated software designed to operationalize various input problems translated in model form. The STELLA program is used to build and then experiment with various creative models to illustrate the important concepts of dynamic systems to predict cases or situations through research data input or literature data.

3. Results and discussion

3.1. Model variation

Model structure validation is the main validation process in system thinking. Validation aims to see the extent to which the model structure equals with the real structure, which is related to the limits of the syntax, forming variables and assumptions about the interactions that occur within the system. The results of this model when compared with the actual model is not much different, so it can be interpreted that the model has been validated.

Parameter testing in this model is done by looking at three different variables that are interconnected with each other and by comparing the actual logic with the simulation results. In this research, the model parameters are based on the main parameters of DO, BOD and COD. Techniques for checking the consistency of the model outputs to actual data can be done by statistical tests and visual comparisons (graphs) of model outputs with actual data [2]. Mean Absolute Percentage Error (MAPE) value is the absolute average of error against model prediction.

MAPE < 5% : Very accurate
5%<MAPE<10% : Accurate
MAPE>10% : Not accurate

The MAPE value of DO on segment 1 to segment 3 is less than 10%. This indicates that the value of this model is accurate.

Table 1. MAPE DO in segment 1.

Month	Forecast (F) DO1 (mg/l)	Actual (A) DO1 (mg/l)	Akurasi	A-F	|A-F|	Error (%)
1	4.91	5.1	96.28	0.19	0.19	3.72
2	4.88	4.2	116.20	-0.68	0.68	16.20
3	4.84	3.8	127.24	-1.04	1.04	27.24
4	4.77	5.1	93.57	0.33	0.33	6.43
5	4.69	4.9	95.81	0.21	0.21	4.19
6	4.60	4.7	97.97	0.10	0.10	2.03
7	4.50	5	90.01	0.50	0.50	9.99
8	4.38	4.8	91.28	0.42	0.42	8.72
9	4.25	4.4	96.56	0.15	0.15	3.44
10	4.11	4.4	93.32	0.29	0.29	6.68
11	3.95	3.7	106.74	-0.25	0.25	6.74
12	3.78	4.7	80.33	0.92	0.92	19.67
		MAPE				**9.59**

Table 2. MAPE DO in segment 2.

Month	Forecast (F) DO1 (mg/l)	Actual (A) DO1 (mg/l)	Akurasi	A-F	|A-F|	Error (%)
1	4.44	4.6	96.62	0.16	0.16	3.38
2	4.43	4.2	105.53	-0.23	0.23	5.53
3	4.42	4.1	107.81	-0.32	0.32	7.81
4	4.41	4.8	91.88	0.39	0.39	8.12
5	4.40	4.9	89.76	0.50	0.50	10.24
6	4.38	4.9	89.48	0.52	0.52	10.52
7	4.37	5.1	85.71	0.73	0.73	14.29
8	4.36	4.9	88.96	0.54	0.54	11.04
9	4.35	4.4	98.81	0.05	0.05	1.19
10	4.34	4.7	92.32	0.36	0.36	7.68
11	4.33	3.8	113.94	-0.53	0.53	13.94
12	4.32	4.7	92.00	0.38	0.38	8.00
		MAPE				**8.5**

Table 3. MAPE DO in segment 3.

Month	Forecast (F) DO1 (mg/l)	Actual (A) DO1 (mg/l)	Akurasi	A-F	|A-F|	Error (%)
1	4.70	4.9	95.86	0.20	0.20	4.14
2	4.68	4.65	100.66	-0.03	0.03	0.66
3	4.65	4.65	99.99	0.00	0.00	0.01
4	4.60	4.75	96.92	0.15	0.15	3.08
5	4.54	4.8	94.65	0.26	0.26	5.35
6	4.47	4.7	95.05	0.23	0.23	4.95
7	4.38	4.8	91.20	0.42	0.42	8.80
8	4.27	5.1	83.78	0.83	0.83	16.22
9	4.15	3.75	110.78	-0.40	0.40	10.78
10	4.02	4.5	89.38	0.48	0.48	10.62
11	3.88	4.3	90.13	0.42	0.42	9.87
12	3.72	4.4	84.45	0.68	0.68	15.55
		MAPE				**7.50**

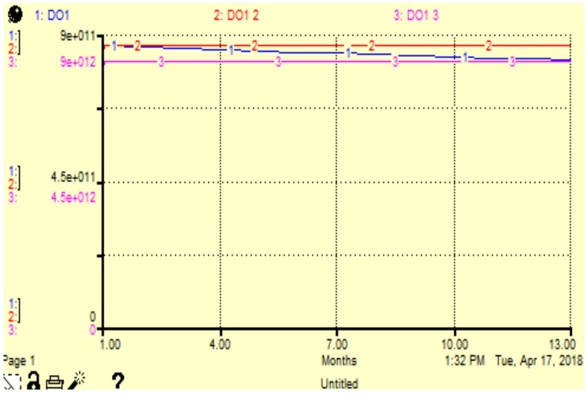

Figure 1. The model results of DO parameter

The model results of DO parameter in Figure 1 shows that DO in all the three segments are still high. In segment 2, the value of DO is higher than segment 1 and segment 3. This could be the result of segment 2 having a higher flow rate compared to the other segments. In rivers with high flow velocities, the oxygen in the water surface layer will rapidly exchange with the lower layers. This exchange occurs because of the rotation in the flow of the river. Dissolved Oxygen (DO) plays an important role as an indicator of water quality, because dissolved oxygen has a role in the oxidation process and reduction of organic and inorganic materials. In Figure 1 the value of DO in segment 3 is the lowest compared to segment 1 and segment 2, this is due to the large amounts of organic waste originating from domestic waste and industrial waste entering the river containing an abundance of biodegradable materials. This causes an increase of oxygen demand, therefore the dissolved oxygen in the river will decrease rapidly. The decrease in DO indicates that the water quality of Surabaya River has been polluted, because the amount of dissolved oxygen in the water body is an indication of the freshness of the water. So, if the level of dissolved oxygen is low then it can be indicated that there has been contamination by organic substances. This can occur because the more organic substances that the microorganisms break down, the more oxygen the microorganisms need.

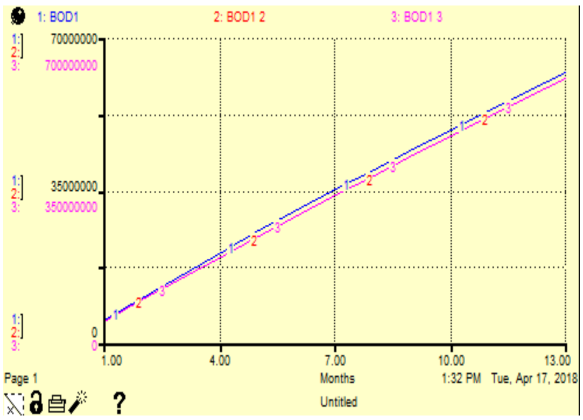

Figure 2. The model results of BOD parameter

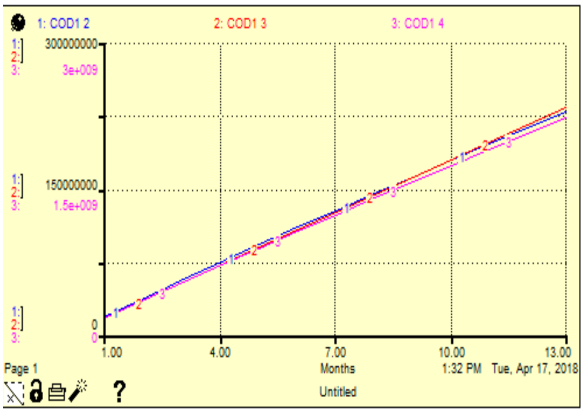

Figure 3. The model results of COD parameter

The model results of BOD parameter in Figure 2 shows that the model looks increasingly higher. Figure 2 shows that the BOD value going downstream increases over distance [3]. BOD quantities are used to indicate organic pollution in the water. The more organic matter contained in the water, the greater the amount of oxygen needed, so the BOD value is greater indicating high levels of pollution. The model results of COD parameter in Figure 3 shows that the model looks increasingly higher.

Figure 3 shows that the value of COD going downstream increases over distance. Chemical Oxygen Demand (COD) indicates the total amount of oxygen needed to oxidize materials chemically, both degradable biologically (biodegradable) as well as undegradable biologically (non-biodegradable) [4]. This shows that in addition to the presence of organic biodegradable materials by microorganisms, non-biodegradable materials are also present [5]. COD values that are higher than BOD values indicate the presence of chemically oxidizable substances are primarily non-biodegradable materials.

The behavior of DO has increased in the beginning and tends to decrease as seen in Figure 4. Whereas parameters BOD and COD has increased up to the last point. All three parameters have been in accordance with the actual logic of each parameter.

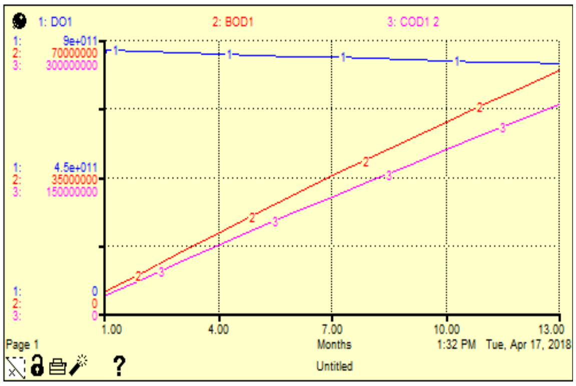

Figure 4. The simulation results in segment 1

The simulation results in Figure 4 shows that the condition of DO in segment 1 decreases at the end of the segment, specifically in November and December at 3.9 mg/L and 3.78 mg/L respectively. This is consistent with the increase in BOD and COD with BOD values of 5.77 mg/L and 6.27 mg/L and COD values of 19.72 mg/L and 21.42 mg/L. Throughout segment 1, there are activities that causes drops in DO levels in the river due to the inflow of domestic waste into the river. This causes the BOD and COD levels to rise causing the DO level in the water to decrease.

Similarly, the behavior of DO has increased in the beginning in segment 1 and tends to decrease as seen in Figure 4. Whereas BOD and COD parameters has increased up to the last point. All three parameters have been in accordance with the actual logic of each parameter.

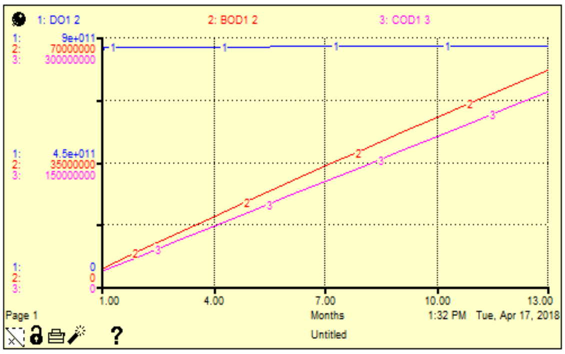

Figure 5. The simulation results in segment 2

The simulation results in Figure 5 shows that the condition of DO in segment 2 decreases at the end of the segment, specifically in November and December at 4.33 mg/L and 4.32 mg/L respectively. This is consistent with the increase in BOD and COD with BOD values of 5.18 mg/L and 5.64 mg/L and COD values of 18.81 mg/L and 20.46 mg/L. Throughout segment 2, there are activities that causes drops in DO levels in the river due to the inflow of domestic waste into the river. This causes the BOD and COD levels to rise causing the DO level in the water to decrease. In segment 2, the levels of BOD and COD are significantly lower than segment 1. This is due to segment 2 having greater flow velocity compared to segment 1. This results in saturated oxygen rapidly mixing with the entire river flow to supply the oxygen demand for microorganisms.

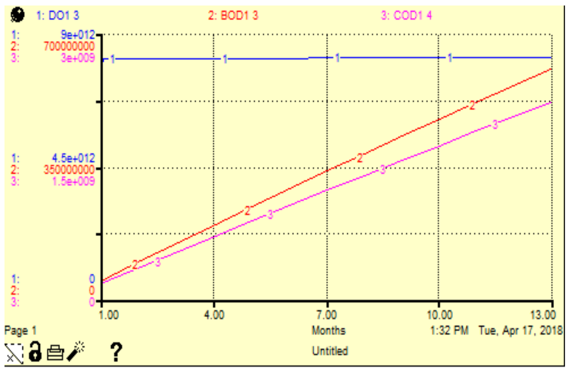

Figure 6. The simulation results in segment 3

Similarly, the behavior of DO has increased in the beginning and tends to decrease as seen in Figure 4.30 above. Whereas BOD and COD parameters has increased up to the last point. All three parameters have been in accordance with the actual logic of each parameter.

The simulation results in Figure 6 shows that the condition of DO in segment 3 decreases at the end of the segment, specifically in November and December at 3.88 mg/L and 3.72 mg/L respectively. This is consistent with the increase in BOD and COD with BOD values of 5.69 mg/L and 6.21 mg/L and COD values of 19.72 mg/L and 21.42 mg/L. Throughout segment 3, there are activities that causes drops in DO levels in the river due to the inflow of domestic waste into the river. This causes the BOD and COD levels to rise causing the DO level in the water to decrease.

Throughout segment 3, there are activities that causes drops in DO levels in the river due to the inflow of domestic waste into the river. This causes the BOD and COD levels to rise causing the DO level in the water to decrease. In this segment, it is known that in November and December BOD and COD levels increase and the level of DO decreases. This may occur because in the rain season resuspension will occur which will increase turbidity in the water and will increase BOD levels, so if BOD levels increase DO levels will decrease.

Based on the above simulation results it can be concluded that if the value of DO in a waterbody is high, it can be caused by low levels of BOD and COD, and vice versa.

3.2. Preditction of next year

In this model, DO is used as a parameter for prediction, because the value of DO affects the value of BOD and COD values in the river.

[6] One of the indicators of river health status to note is the DO indicator. DO reflects the ability of waterbodies to adjust the presence of pollutant load, DO is used as a requirement for food availability in aquatic ecosystems and the main limiting or regulatory factors for the health and survival of aquatic organisms. The dissolved oxygen in a waterbody can be defined as the amount of oxygen in an amount of water that will be used by water organisms for respiration, reproduction and fertility. DO levels indicate that the water is fresh or not to fulfill the necessities. DO levels usually comes from the decomposition of organic substances in water, which is the release of foul-smelling gases that can endanger health.

This model can be used to predict DO levels in 2018. The data used should be primary data that meets the time series and has a high degree of validation. The predicted value of DO for the next year (2018) can be seen in Table 4.

Table 4. The predicted value of DO for the next year.

DO1 (mg/l)	DO2 (mg/l)	DO3 (mg/l)
4.91	4.44	4.70
4.88	4.43	4.68
4.83	4.42	4.65
4.77	4.41	4.60
4.70	4.40	4.54
4.61	4.39	4.47
4.51	4.38	4.38
4.39	4.37	4.27
4.26	4.36	4.16
4.12	4.35	4.02
3.96	4.35	3.88
3.79	4.34	3.72

By entering data from 2016-2017, it can be predicted that the DO parameter for the next year or 2018 is as shown in Table 4. From the results of the prediction, in 2018 the levels of DO will decrease in all three segments. In December of 2018, the DO concentration in segment 1, segment 2, and segment 3 is 3.79 mg/L, 4.34 mg/L, and 3.72 mg/L respectively.

According to the Regulation of Governor No. 61 in 2010, it is known that Surabaya River is classified as class II river. According to the predictions of this model, the value of DO in segments 1 and 3 in November and December exceeds the quality standard of class II river of 4 mg/L. While segment 2, as well as segments 1 and 3 in January to October meets the quality standard of class II river. The DO value of Surabaya River in 2018 ranges from 3.72-4.9 mg/L. After the simulation of existing as well as prediction for one year ahead, the quality status of Surabaya River is classified polluted.

4. Conclusions

From the results of the research analysis, the following can be concluded that parameter values of DO, BOD, and COD of Surabaya River segment Karangpilang-Ngagel obtained with dynamic systems using STELLA model for DO, BOD, and COD are 4.4 mg/L, 3.3 mg/L and 19.57 mg/L respectively. In 2017, the values of DO, BOD, and COD are 4.4 mg/L, 4.76 mg/L and 18.9 mg/L respectively. It is predicted by 2018 the value of DO will decrease by 8.5% or 3.72 mg/L, the value of BOD and COD will increase by 23.35% or 11.76 mg/L and 21.42 mg/L and the quality status of Surabaya River segment Karangpilang-Ngagel is contaminated.

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