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Purification Capacity and Oxygen Sag in Sringin River, Semarang

Churun Ain*1), Siti Rudiyanti*1), Haeruddin *1), Heppi Puspita Sari

**1)Program Study of Aquatic Resources Management,*
Fisheries and Marine Sciences Faculty – Diponegoro University

Abstract

Sringin River is located in Semarang city, Central Java. The river receives a varieties of domestic and industrial waste from settlements and industries located around the river. This can be potential of causing a decrease in water quality and affect the ability of self purification. The aim of this research is to know deoxygenation rate, reoxygenation rate, oxygen sag and selft purification of Sringin River with Streeter-Phelps equational. This research was conducted in March 2018 in Sringin River. The research used a survey method with purposive sampling. Sampling was repeated three times, each repetition once a week. The results were obtained that the theoretical DO values approached actual DO so it can be modeled using equations of the Streeter-Phelps. The river experienced purification with zones formed include degradation zone, decomposition zone and recovery zone of a point source. The reoxygenation rate is 0,3635/day, deoxygenation rate is 1,1117/day with a constant natural purification is 0,3269/day (Hydroscience equation) and 0,02259/day with natural purification rate is 22.789 (Streeter-Phelps equation).

Keywords: Purification Capacity, Oxygen Sag, Reoxygenation Rate, Deoxygenation Rate, Sringin River, Semarang

I. INTRODUCTION

Sringin River is located in Terboyo Industrial Area, Trimulyo Village, Genuk District, Semarang City. Sringin River receives various domestic and industrial wastes from settlements and factories located around the river. Such conditions have great potential in causing a decrease in water quality [1],[2] and affecting natural purification capabilities [3]. Organic and inorganic wastes that enter the river body before flowing into the sea experience a mixture of water masses, where the river itself has the ability to recover (self purification). This ability can be affected by dilution of waste that is mixed with river water, where the river is a lotic waters that is moving water and has a current velocity. The ability of the river to purify itself from waste naturally is produced by certain processes that work when the river moves downstream which can inform the dilution of water contaminated with the entry of surface and ground water or through hydrological, biological and chemical processes[4]. The physical and chemical processes of water purification are controlled and are very dependent on biological factors [5].

The river can purificate if the pollution entering the river body is not excessive so that it can still carry out the function and pollution of the sea can be minimized and even avoided. Water pollution can cause a decrease in environmental quality such as habitat damage, morphological or physiological disturbances in the organism, in addition to both long and short periods can cause disruption to human life such as health. Therefore river water quality plays an important role in life. Rivers play a strategic role as one of the natural resources that can support human's lives, and sustain water resources [6].

The oxygen sag curve can describe the decrease in oxygen that occurs. Data can be prediction self purification, how fast the Sringin River in purification, occurs due to the phenomenon of the process of reducing dissolved oxygen (deoxygenation) and the process of increasing dissolved oxygen (reoxygenation) to overcome pollution or the condition of the river is has exceeded the carrying capacity of the waters. This research can be seen that the sag oxygen curve, purification capabilities and the purification zone at Sringin River. Results of this study can provide information to the community and the government in managing the river and as a reference for further research. The variables measured in this study include BOD (Biochamical Oxygen Demand), and DO (Disolved Oxygen), current velocity, discharge and also supported by secondary variables including temperature, pH, brightness and depth. The purpose of this study was to determine the decreasing constants of dissolved oxygen (deoxygenation) and the increase in dissolved oxygen (reoxygenation), to know the sag oxygen and the ability of natural purification (self purification) in the waters of Sringin River Terboyo Industrial Area.

RESEARCH MATERIALS AND METHODS

A. Research Material and Variables

The material used in this research is the Sringin River water sample which is used to measure the DO and BOD variables, both of these variables are used to analyze the sag oxygen and purification zones that occur with the support of several environmental that affect the water quality in the Sringin River. Several physical and chemical factors in water ecosystems including temperature, current velocity, discharge, brightness, and depth and pH [7].

B. Research Methods

The method used in this study is a survey method that is analyzed quantitatively. The information obtained is the DO value measured by titration method, BOD analysis is carried out based on the SNI 6989.72.2009 method. Measurement of temperature, current velocity, discharge, brightness, and depth as well as pH are also carried out as secondary variables. For the purpose of estimating trophic conditions, purification capacity, degree of mineralization, biological depuration factors in waters, using spatial and temporal distribution of chemical and physical parameters that characterize water quality (temperature, pH, dissolved oxygen, transparency, chlorophyll-a, total phosphorus, TN / TP ratio) [8].

Sampling

This research was carried out in March 2018. Sampling and measurement of physical parameters were carried out at nine sampling points. Sampling was carried out three times repetition with a span of one week one sampling. Sampling in this study was carried out by purposive sampling, based on certain considerations [9]. The location map of the data collection and the sample is presented in Figure

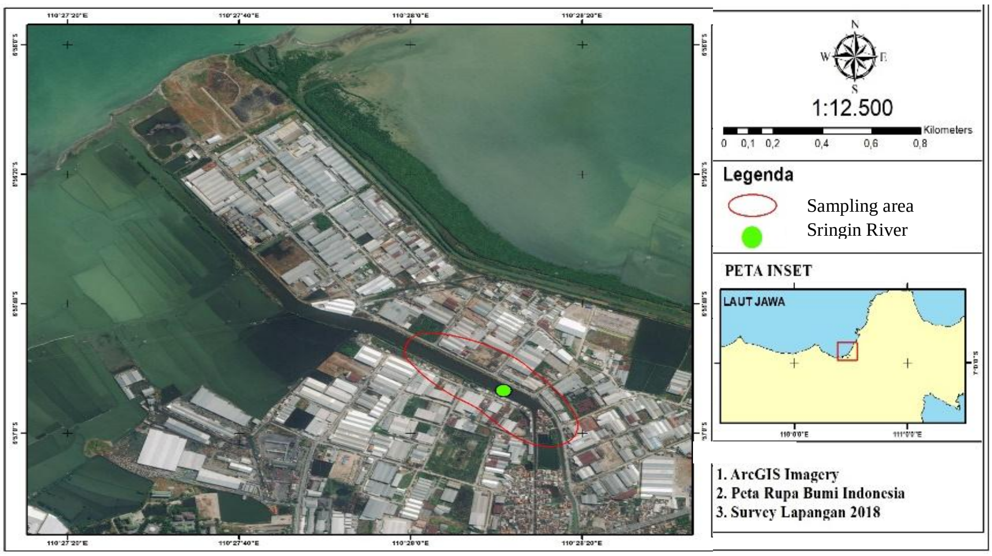

Figure 1. Map of Research Locations in Sringin River, Terboyo Industrial Area, Semarang

Data analysis method

Reduction of oxygen (deoxygenation) was analyzed using the Streeter Phelps method in 1925 which was contained in the Decree of the Minister of Environment No. 110 of 2003.

If it is assumed that the river and waste are completely mixed at the discharge point, then the concentration of the constituent in the mixture of water and waste at x = 0 is:

$$C_{\circ} = \frac{Q_r C_r + Q_w C_w}{Q_r + Q_w} \quad \text{...(1)}$$

Description:

$C_{\circ}$ = initial constituent concentration at the point of discharge after mixing (mg / l)

Qr = River debit (m3 / sec)

Cr = concentration of constituents in river water before mixing (mg / l)

Cw = concentration of constituents in wastewater (mg / l)

The saturated oxygen value is determined by the following equation:

$$Ds = 475/(33{,}3+t) \text{..(2)}$$

Description:

Ds = DO Saturation

t = Tempertur

Reduction of oxygen (deoxygenation)

$$\text{Log } \frac{L'}{L} = Kt \text{...(3)}$$

Description:

K = deoxygenation constant

L '= Upper BOD concentration (mg / l)

L = BOD concentration of last / down point (mg / l)

t = travel time between points (s)

The deoxygenation constant can also be obtained by the equation Hydroscience (1971) [10] as follows:

$$K\ (20°C) = 0{,}3\ (H/8)^{-0{,}434} \qquad (4)$$

$$K\ (T°C) = K(20°C) \times 1{,}047^{(T-20)} \qquad (5)$$

Description:

H = depth of river average (m)

U = average speed of river flow (m / s)

The addition of oxygen (reaeration) was analyzed using the O'Conner and Dobbin equations with the following equation [11]:

$$R = \frac{294\ (DL\ U)^{1/2}}{H^{3/2}} \qquad (6)$$

$$DL = 1{,}760 \times 10^{-4}\ m^2/d \times 1{,}037^{T-20} \qquad (7)$$

Description:

R = reaeration constant

H = depth of river average (m)

U = average river speed (m / s)

DL = molecular diffusion coefficient of oxygen at temperature T (m2 / day)

The estimated value of R by the Engineering Board of Review for the Sanitary District of Chicago is as follows:

Table 1. Reoxygenation constants [11]

Water Body	Range of R
Small ponds and backwaters	0.10-0.23
Sluggish streams and large lake	0.23-0.35
Large streams of low velocity	0.35-0.46
Large streams of normal velocity	0.46-0.69
Swift streams	0.69-1.15
Rapid and waterfalls	>1.15

Natural purification (River purification) is obtained by the following equation:

$$f = R/K \quad (8)$$

Description:

f = natural purification constant

R = reoxigenation constant

K = deoxygenation constant

The values of natural purification constants according to are presented in Table 2 as follows:

Table 2. Constant Purification Value [12]

Water Body	*Range of f*
Small ponds and backwaters	0,5 – 1,0
Sluggish streams, large lakes, and impounding reservoirs	1,0 – 1,5
Large stream of low velocity	1,5 – 2,0
Large stream of normal velocity	2,0 – 3,0
Swift streams	3,0 – 5,0
Rapids and water falls	≥ 5,0

Sag oxygen modeling uses the 1925 Streeter Phelps equation [13] contained in the Decree of the State Minister for the Environment Number 110 of 2003 commonly used in river analysis as follows:

$$Dt = \frac{KL_o}{R-K}\left[10^{-Kt} - 10^{-Rt}\right] + D_{\circ}\, 10^{-Rt} \quad (9)$$

Description:

K = deoxygenation constant (/ day)

R = reoxigenation constant (/ day)

Dt = the oxygen deficit point of source of pollutant at time t (mg / l)

L ^ = ultimate BOD concentration after the point after mixing (mg / l)

D◦ = initial oxygen deficit at waste point (mg / l)

RESULTS AND DISCUSSION

A. Research Results

1. Description of Location

Sringin River is used by the surrounding community to carry out various daily activities, one of which is to be used as a fisherman by road to go fishing using boats and as a fishing location. The location of the water quality measurement and sampling of the Sringin River was carried out at the coordinate points described in Table 3.

Table 3. Coordinate Points of Research Locations

No	Coordinate	River Width
1	S06°57’ 07.5’’ - E110°28’17.9’’	±8 m
2	S06°56’56.6’’ - E110°28’15.7’’	±8 m
3	S06°57’07.4’’ - E110°28’14.4’’	±8 m
4	S06°56’57.0’’ - E110° 28’14.3’’	±8 m
5	S06°56’51.9’’ - E110°28’13.2’’	±50 m
6	S06°56’51.9’’- E110°28’07.8’’	±50 m
7	S06°56’48.1’’- E110°28’03.1’’	±50 m
8	S06°56’44.9’’ - E110°27’57.7’’	±50 m
9	S06°56’42.4’’ - E110°27’50.7’’	±50 m

2. Laboratory Analysis and Measurement of the chemical parameters of the Sringin River

Laboratory analysis and measurement of Sungin's chemical and physical parameters are as follows (Table 4)

Table 4. Results of Measurement of Chemical and Physical Parameters of the Sringin River

Parameters	Replication	Sampling Point									WQ
		1	2	3	4	5	6	7	8	9	
pH water	I	7	7	7	7	7	7	7	6	7	
	II	6	6	6	6	6	6	6	6	6	6-9
	III	6	6	6	6	6	6	6	6	6	
DO (mg/l)	I	2	3,2	1,6	2,8	2,4	2,4	2,8	2,4	3,2	
	II	2	1,6	1,6	1,6	1,2	2,4	2,4	2	2,4	4
	III	1,4	2,4	2	2,4	1,6	0,8	2,4	2,4	2	
BOD (mg/l) **	I	5	4	52	5	6	8	11	6	14	
	II	8	6	10	14	17	7	10	18	49	3
	III	21	231	8	192	172	76	122	57	124	
Brightness (m)	I	0,42	0,45	0,46	0,63	0,42	0,64	0,57	0,53	0,45	-
	II	0,42	0,44	0,46	0,63	0,42	0,40	0,42	0,41	0,44	
	III	0,25	0,41	0,45	0,41	0,42	0,38	0,48	0,42	0,49	
Depth (m)	I	1	1,55	0,9	1,33	1	1,14	1,19	1,20	1,11	-
	II	0,95	1,22	1	0,99	0,96	1,10	1,20	1,16	1	
	III	1,05	1,60	1,15	1,30	0,95	0,96	1,17	1,10	1,15	
Current Velocity (m/s)	I	0,0061	0,0074	0,0067	0,0074	0,0051	0,0093	0,0091	0,0145	0,0137	-
	II	0,0051	0,0061	0,0064	0,0057	0,0071	0,0069	0,0071	0,0072	0,0071	
	III	0,0093	0,0095	0,0125	0,0133	0,0175	0,0074	0,0077	0,0087	0,0095	
Tempera-tur (°C)	I	29	29	29	29	30	30	30	28	29	-
	II	30	31	30	31	30	30	30	30	30	
	III	30	30	30	29	29	29	29	29	30	
Discharget (m^3/s)	I	0,0072	0,0475	0,0526	0,0395	0,3641	0,5554	0,6347	0,6715	0,6541	-
	II	0,0075	0,0451	0,0546	0,0429	0,2882	0,3726	0,3983	0,3897	0,3976	
	III	0,0234	0,0837	0,0983	0,0936	0,5217	0,444	0,427	0,4614	0,4547	

* Water Quality Criteria Based on Class II, Government Regulation No. 82 of 2001[14]

** Test Results of the Laboratory of the Environment Office of the City of Semarang

pH value of river water in this study ranges from 6-7 indicating that the water is neutral towards acid. Based on these results DO on the Sringin River is below the class II quality standard, which is 4 mg / l. BOD values also exceeded the class II quality of 3 mg / l. The brightness of the Sringin River is in the range of 0.41-0.64 m with a depth range of 0.9-1.60 m. The difference in depth of each point can be influenced by the morphology of the Sringin River. In addition, the presence of precipitating solid waste can cause morphological changes because of an increase in the river bed. In addition to the sludge, dissolved and suspended material can cause the waters to become cloudy and have an impact on the reduced oxygen content of the water, the presence of sludge and sediment is also a cause of silting of the river [15].

Temperature of the Sringin River ranges from 28-31˚C, apart from being caused by weather conditions when sampling water, the river temperature can be affected by entering waste. The waste discharged into a hot river the river waters will become hot too, the increase in temperature that occurs in river waters can disrupt the life of aquatic biota and other aquatic organisms because the level of dissolved oxygen will decrease in line with the increase in temperature, the more the high temperature rise of oxygen solubility in water decreases [16].

The current velocity influenced by the movement of water due to wind factors, besides that river bathymetry also affects, where the higher the tilt of the slope will increase the current velocity. This discharge value is related to the current velocity and morphology of the river. Debit can also affect other water parameters, one of which is the river sediment content that plays a role in trapping nutrients and organic matter. According to research [17] that the increasing river water debit will also increase the sediment content in the river.

3. Deoxygenation, Reagent and Self Purification Constants

The results of deoxygenation, reaeration and self-purification constant on Sringin River are presented in Table 5.

Table 5. Results of Deoxygenation Constant, Reactive and Self Purification Analysis

Process	Equation	Constanta
Deoxygenation	Streeter dan Phelps (Decree of the Minister of Environment No. 110 of 2003) [11]	0,02259/day
	Hydroscience (1971) [10]	1,1117/ day
Reoxygenation	O'Conner dan Dobbins (Decree of the Minister of Environment No. 110 of 2003) [11]	0,3635/ day
Self Purification	K based on Streeter dan Phelps (Decree of the Minister of Environment No. 110 of 2003) [11]	22,789/ day
	K based on Hydroscience (1971) *in* Ramadhani *et al.* (2013) [10]	0,3269/ day

The results in Table 5 show that the Sringin River experienced natural purification with a constant self purification of 22.789 / day (K using equation 3) and 0.3269 / day (K using equation 5). The deoxygenation and reoxygenation constants are then used to determine the deficit value of theoretical oxygen and oxygen using the Streeter Phelp equation. The oxygen deficit that occurs in the River illustrated by the Graph of Oxygen Sag (Oxygen Sag Curve) with the starting point is the mixing point presented in Figure 2.

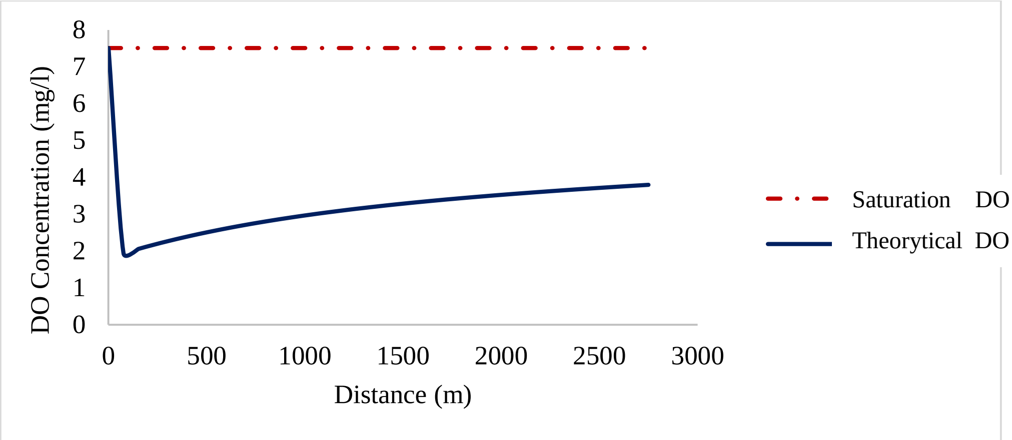

Figure 2. Oxygen Graph Sag on the Sringin River

Comparison of the average actual oxygen value with theoretical oxygen at the mixing point up to point 9 has the difference presented in the following graph (Figure 3):

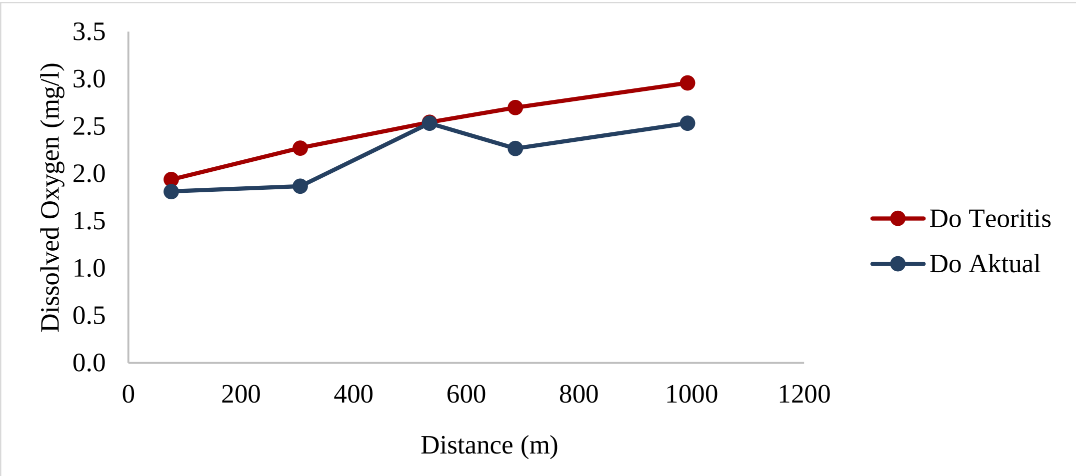

Figure 3. Graph of Comparison of Actual Oxygen and Theoretical Oxygen of the Sringin River

The purification zone formed in this study are the degradation zone, decomposition zone and purification zone. The purification zone is presented in Figure 4.

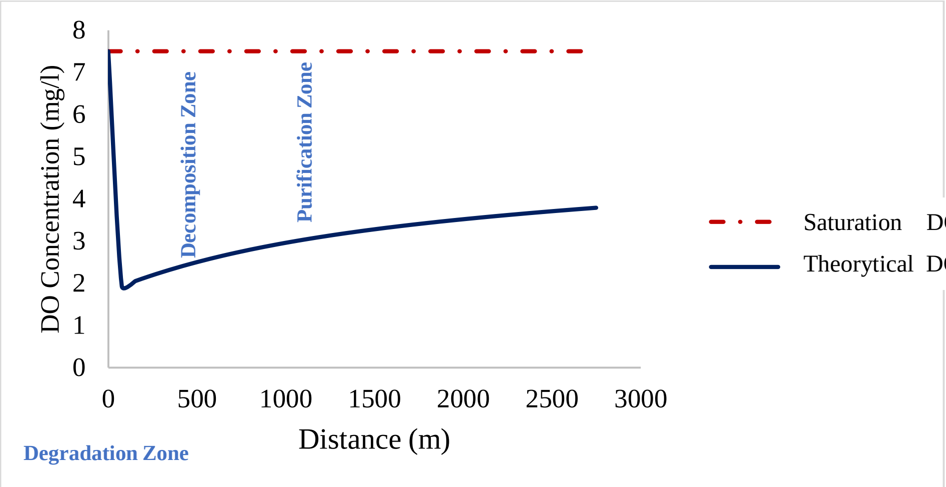

Figure 4. Self Purification Process Zone on Srigin River

B. Discussion

1. Oxygen Sag

The theoretical oxygen in the Sringin River had a significant decrease in the location after point source mixing, at a distance of 76.38 m from the mixing point (point 2.4, and 5) then a gradual increase in the next distance. The theoretical oxygen on the Sringin River after mixing cannot reach saturation conditions. Such depictions certainly occur if there is no waste input back along the river or at the distance studied. At the sampling location the actual DO and theoretical DO values show differences even though in a relatively narrow range. This relatively narrow difference (Actual DO 2,533 mg / l vs. theoretical DO 2,543 mg / l: 0,01 mg / l). This difference is caused by the entry of point sources that are not only from one source. Streeter Phelps equation in this study can be used because the difference in actual and theoretical oxygen values is relatively narrow. According to research [17] concluded that the natural purification capability of the river would be better if in conditions without input from the outside and with a longer distance.

Actual oxygen at point 2 and 4 showed increasing than point 1 and 3. This can be caused by the pumping process of river water before heading to point 2 and point 4, so there is also an aeration process that can increase oxygen. The process of entering oxygen from the air (reaeration) can be caused by water interaction such as agitation, the increase of oxygen in the water is very influential on the improvement of water quality [18]. Actual oxygen has decreased again, that is point 2 and point 4 towards point 5, where at that location is the meeting point of river branching flow so that the material carried by the current is mixed with waste waste at that point. This location is suspected to have the greatest effluent compared to other points. So it is assumed that the location of point source entry in this study is assumed. It is also suspected that the area is rich in bacteria and microorganisms. This is also supported by the results of measurements of BOD, COD, and organic materials [19] that tend to be high or experience an increase from the previous point. Pollutants in a waters primarily on the surface of the water can prevent the diffusion of oxygen from the air and can increase the number of aquatic organisms [20][21]. The low DO is possible because of the high organic matter that enters the waters, which is the amount of oxygen consumed by microorganisms in the process of metabolizing organic matter is greater [22].

The actual oxygen content at point 6 has begun to increase, it is possible to still be affected by waste at the point of mixing. In addition to being affected by incoming waste, this increase and decrease is due to the river's purification process. Then at point 7 actual oxygen also tends to rise in line with theoretical oxygen. This happens in addition to the mixture that occurs in it, it is suspected that at this point the waste input also begins to decline until the BOD and COD values at this point also decrease on average. Point 8 actual oxygen tends to decrease again not in line with theoretical oxygen which tends to rise. This decrease can be caused by the discharge of waste from fish ponds located around point 8. Disposal of wastewater from the pond is carried out directly to the Sringin River. Waste from ponds that contain leftovers and metabolic results of organisms cause increased waste. Internally, ponds produce high organic waste and can even adversely affect the environment of the pond itself [23].

The oxygen value of 9 points rises again in line with the theoretical oxygen value. The increase can be due to the absence of effluent from both industrial and domestic waste that is channeled to the location. However, the effluent still flows from the previous point supported by a very low current speed. Overall purification has occurred in the Sringin River, where the mixing point compared to point 9 of oxygen tends to have increased, although the increase occurred is not significant. The current pattern is relatively calm and there is no turbulence causing the reaeration process of air into the water to be reduced so that the river's purification ability is not optimal [24].

2. Self Purification

The waste entering the Sringin River can still be tolerated by the river in conducting self-purification as seen from the results of the constant obtained. Self purification ability of river waters occurs due to the addition of dissolved oxygen concentration in water, this addition can come from air and rainwater [25]. Such self-purification ability can also be influenced by environmental factors along the river flow. These factors include current velocity which also influences river discharge, changes in pollutant waste entering river waters, changes in temperature, deoxygenation constants and reaerations and other environmental factors. river indicators in purified conditioning approved in the river increased DO and decreased BOD and COD [26].

Current velocity can affect the ability of water bodies to assimilate and transport pollutants [27]. Therefore, how long does it take for a pollutant to arrive at a specific location that you want to know can be estimated. Water temperature plays a role in increasing biological activities such as accelerating the rate of decomposition of organic matter, increasing the speed of metabolism and respiration, which also increases the consumption of oxygen so that dissolved oxygen is reduced (deoxygenation). Whereas the higher the oxygen reaeration constant, the greater the reaeration rate and the better the oxygen recirculation process [28]. The reoxygenation constant obtained in this study of 0.3635 / day shows that the Sringin River is included in a large flow with a low speed (Engineering Board of Review for the Sanitary District of Chicago in the Minister of Environment Decree No. 110 of 2003). Whereas the deoxygenation constant obtained in this study shows that the K value using the hydroscience equation (equation 5) can better describe the field conditions. Because using this equation is obtained natural purification constants of 0.3269 / day which in the range of river body types with the type of small ponds and backwater, which means that the river body has a tendency to be calm, so that the mixture is not so large. While using the Streeter Phelps equation (equation 3) the K value tends to be small and the natural purification constants are 22.789 / day which shows the type of river body with the Rapids and water fall type, which means the waters have a very large process resulting in large mixing, so natural purification runs faster. However, this is not in accordance with the conditions in the Sringin River, but this does not rule out the possibility of occurring at a certain time. One of them is when there is waste disposal, the water body gets pressure from the process of entering the waste. This can move the water body and increase reaerasi. Using the Streeter Phelps equation (equation 3) can also be used to determine the deficit value of oxygen and obtain a theoretical oxygen value that can describe the oxygen graph of sag. So that the purification zone can be determined. The following comparison is the result of the deoxygenation and reaeration constants obtained in a similar study (Table 9).

Table 9. Results of Deoxygenation and Reactivation Constants in Other Research

Researcher	Location	Deoxygenation constanta (K)	Reoxygenation constanta (R)	Purification constanta (f)
Dewi *et al.* (2017)[29]	Kali Wonokromo River, Surabaya	0,69-0,98/day	0,26-0,97/day	0,377-0,99/day
Arbie *et al.* (2015)	Progo River, D.I. Yogyakarta	0,013/menit	0,0287/menit	2,207/menit
Ramadhani *et al.* (2013)	Jawi River, Pontianak at tidal	0,64-0,84/ day 0,95-1,32/ day	0,32-1,34/ day 1,8-4,3/ day	0,5-1,595/ day 1,89-3,257/ day

The purification zone formed in the Sringin River includes the degradation zone, active decomposition zone and purification zone. The degradation zone is just below the sewerage channel, in this zone DO concentration decreases ± 40% of the saturation value, while the active decomposition zone is characterized by heavy pollution with very low DO even reaching 0, at the end of this zone there will be a 40% increase in DO From the initial value, the recovery zone was in a DO condition that had started to rise by more than 40% [30]. The degradation zone of the Sringin River is at point 0, which is the point of mixing point source with the water body up to a distance of 76.38 m. The lowest oxygen deficit occurred at this distance, DO concentration dropped to reach 75% of saturation conditions. Then theoretical DO gradually increased again and entered the decomposition zone up to a distance of 763,817 m, where at that distance an increase in theoretical DO had occurred up to 40% of the original concentration. Furthermore the theoretical DO concentration has increased by more than 40% from the original concentration and is in the purification zone. The purification ability of this river cannot reach the clean water zone. The reduction and addition of oxygen to the Sringin River in the range of other research results (Table 9), with a low tendency to reoxygenation. Such conditions are also supported by the condition of the Sringin River which has low current and discharge speeds. So that the addition of oxygen from the air through this mechanism is slow and cannot run optimally. In addition, the mixing of waste from the point source with the water body also runs slowly which affects the natural purification of the river. While the waste entering the river body with a large amount is seen from the measured variables, so that it requires a lot of oxygen for the decomposition process. The ability of the river to be recovered will be disrupted by the burden of polluters from the accumulation of BOD from pollutant sources [31].

4. CONCLUSION

The conclusion that can be drawn based on the research that has been carried out in the Sringin River Semarang is as follows:

1. The deoxygenation constant value of 0.02259 / day using the Streeter Phelps equation and 1.1117 / day using the hydroscience equation, the reoxygenation constant value is 0.3635 / day using the O'Conner and Dobbin equations.
2. The Sringin River has a natural purification capability with the zones formed covering the degradation zone, decomposition zone and purification zone from the point source. The natural purification constant was obtained at 22.789 / day using the Streeter Phelps equation.

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