







Water quality assessment in the Bedadung River using self-purification optimisation and water quality allocation in Indonesia

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Abstract: This research analyses the characteristics of pollution sources and evaluates the water quality of the Bedadung River at the Perumdam Tirta Pandalungan water intake, as a component of the municipal waterworks for the Jember Regency. Utilising self-purification optimisation with linear programming and the Indonesian water quality classification, the study unfolds in a systematic fashion. The research was broken down into the following stages: (1) analysis of the characteristics and distribution of pollution sources, (2) capacity determination using mass balance and the Streeter-Phelps method, and (3) optimisation of organic pollution sources. The input data for the study comprised biochemical oxygen demand (*BOD*), discharge, river profile, and dissolved oxygen (*DO*). The pollution source identification results around the Bedadung River segment showed that 13 wastewater monitoring points were dominated by domestic activities with quality (*BOD*) in the range 1.01–3.18 mg·dm⁻³. This did not exceed the established domestic wastewater quality standards in Indonesia. The total pollution load capacity – *BOD* at the Perumdam Tirta Pandalungan water intake in the Sumbersari (T2) and Kaliwates (T3) segments was determined using self-purification optimisation and it exceeded class I designation standard for river water quality established by the Indonesian government. The maximum *BOD* value using self-purification optimisation in the Sumbersari (T2) segment was 11.44 mg·dm⁻³ compared to 13.45 mg·dm⁻³ in the Kaliwates (T3) segment. The maximum *BOD* for class I water quality is 2 mg·dm⁻³. The class I water quality standard is thus more stringent in maintaining river water quality compared to self-purification.

Keywords: biochemical oxygen demand (*BOD*), Jember, urban area, wastewater management, water quality standard

INTRODUCTION

The abundance of water resources worldwide is now causing challenges. These include reduced carrying capacity, limited access to water resources, and increased pollution (David, 2006;

Rahayu, Rini and Soedwihajono, 2019; Wang *et al.*, 2023). Declining water quality adversely impacts living organisms. In 2015, around 663 mln people had no access to drinking water of acceptable quality (UNESCO, 2015). The water quality declines chiefly due to human and industrial activities (Ewaid, 2017; Long,

2020; Xu, Goa and Yuan, 2022). Declining water quality in large rivers has also been reported in tropical regions such as Indonesia (Ginting *et al.*, 2017; Sidabutar *et al.*, 2017; Novita *et al.*, 2020). Large rivers in Indonesia are generally the main sources of raw water for domestic consumption (Rahayu, Rini and Soedwihajono, 2019; Li *et al.*, 2022). The Bedadung River is among the surface water sources used by Perumdam Tirta Pandalungan, a municipal waterworks to meet the clean water needs of the Jember Regency. As such, Perumdam Tirta Pandalungan has a main water intake on the main Bedadung River in the Kaliwates District. The main Bedadung River passes through districts of Patrang, Sumbersari, and Kaliwates. These three areas comprise a designated urban system based on the Jember Regency Spatial Plan for 2015–2030 (Peraturan, 2015). However, the plan points to certain risks, including domestic sources of pollution and reduced water quality in the Bedadung River. Based on the pollution index and National Sanitation Foundation water quality index (NSF *WQI*), an evaluation of the water quality in urban area segments of the Bedadung River has shown the pollution status with phosphate, cyanide, total coliform, and faecal coliform parameters contributed to the poor water quality (Novita *et al.*, 2020; Novita, Firmansyah and Pradana, 2023). In line with the finding, anthropogenic activity in urban areas was found to positively correlate with the distribution of domestic pollution in urban areas (Li *et al.*, 2022; Xu, Goa and Yuan, 2022). Domestic pollution in urban areas is generally centralised as wastewater is drained through integrated drainage channels and discharged into rivers.

The monitoring of river water quality stands as a paramount consideration in controlling the impact of pollution in urban areas. In this regard, the water quality of the Bedadung River has been monitored utilising index evaluations such as the pollution index and water quality index, alongside the determination of pollution load carrying capacity employing the Streeter–Phelps method (Pradana *et al.*, 2019; Novita *et al.*, 2020; Novita, Pradana and Dwija, 2020). The results of this study reveal that the main Bedadung River exhibits a slight degree of pollution, while the accumulation of pollution load at the water intake of Tirta Pandalungan, serving as Municipal Waterworks of Jember Regency, is notably high. This assertion is supported by Pradana, Novita and Purnomo (2022), whose dynamic system model simulation highlights the substantial pressure exerted by accumulated domestic pollution on the capacity of the Bedadung River in urban areas. However, their study fails to delve into the impact of pollution source distribution and characteristics, necessitating consideration of self-purification as a reference for determining pollution load capacity.

In Indonesia, the determination of carrying capacity is generally based on the river class allocation standard outlines in the government regulation (Peraturan, 2021, Appendix VI), which categorises rivers into class I, II, III, or class IV. Nonetheless, not all major rivers in Indonesia are assigned a standardised class, and self-purification capacities vary. Self-purification concerns a river's inherent ability to naturally degrade easily decomposable pollutants, contingent upon factors such as dissolved oxygen (DO). This, in turn, is influenced by deoxygenation and reoxygenation rates (Higashino and Stefan, 2017; Long, 2020; Lung, 2023). Thus, for sustainable river water quality management, the control of river pollution sources necessitates consideration of natural river conditions, including

river profile and climate conditions to support self-purification processes (Mendivel-Garcia *et al.*, 2022).

In general, the concept of self-purification hinges on the dynamics of dissolved oxygen (DO) and biochemical oxygen demand (*BOD*), serving as indicators of organic compounds that undergo natural decomposition influenced by oxygen circulation and river profile (Arifin *et al.*, 2020). Considering that values of *BOD* and DO fluctuate, optimisation based on the characteristics of the pollution source and river capacity becomes imperative. Linear programming is a relevant optimisation method. This method enables quality management of water resources, particularly in reservoir operations in Indonesia, by considering objective factors and constraints to these water resources (Ginting *et al.*, 2017). Comprehensive pollution control necessitates a comprehensive approach that considers nature's ability to recover, ensuring sustainability of environmental interventions (David, 2006). This study aims to analyse the characteristics of pollution sources and evaluate water quality of the Bedadung River at the water intake of Perumdam Tirta Pandalungan, serving as the municipal waterworks for Jember Regency. It seeks to employ self-purification optimisation with linear programming and class of water quality standard allocation.

MATERIALS AND METHODS

STUDY AREA AND INPUT DATA

The focus of this research study is the Bedadung River that passes through the urban area of Jember Regency, encompassing the districts of Patrang, Sumbersari, and Patrang. The selection of the study area was determined by the assessment of the Bedadung River's water quality status and the location of the water intake for Perumdam Tirta Pandalungan, the municipal waterworks serving Jember Regency. According to Novita *et al.* (2020), pollution affecting the main Bedadung River in urban areas starts in the Patrang–Kaliwates sub-district segment. Furthermore, empirical findings obtained via a simulation of dynamic systems have shown a notable accumulation of pollution at the Perumdam Tirta Pandalungan water intake, attributable to domestic pollution of the Bedadung River in Jember Regency (Pradana, Novita and Purnomo, 2022). The land uses in the study area comprise residential, paddy fields, agricultural fields, and urban forests. Figure 1 shows a map of the study location.

Data collection for this study involved a survey and direct tracing of point pollution sources entering the Bedadung River, commencing from the Patrang, Sumbersari, and Kaliwates districts. Data on water quantity and quality were gathered using grab sampling or instantaneous water sampling (Piniewski *et al.*, 2019; Tadic *et al.*, 2022). Key parameters comprised wastewater discharge and river water characteristics, including DO and *BOD*. The field measurements entailed the use of a current meter for discharge and the DO meter employing the electricity method for DO level assessment in both wastewater and river water samples. Water discharge (Q , in $\text{m}^3 \cdot \text{s}^{-1}$) was calculated using Equation (1) (Lu *et al.*, 2022):

$$Q = v \cdot A \quad (1)$$

where: v = velocity ($\text{dm}^3 \cdot \text{s}^{-1}$), A = cross-section area of waterways or rivers.

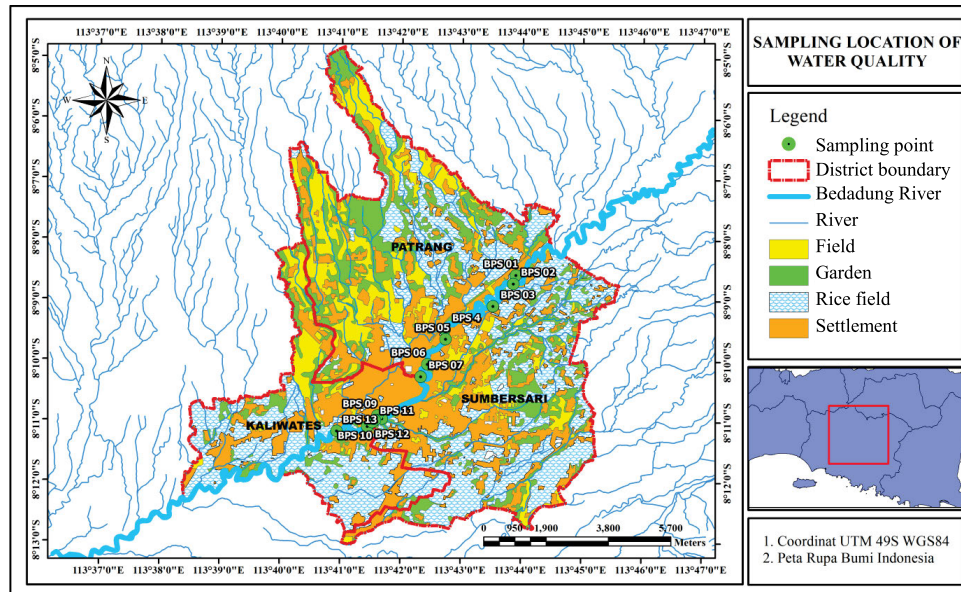


Fig. 1. Sampling location of point source pollution discharged into the Bedadung River in urban areas of Jember Regency; source: own elaboration based on Indonesia Geospatial Portal in coordinate UTM 49S WGS84 and Indonesian Earth Map in 2021 (<https://tanahair.indonesia.go.id/portal-web/downloadpetacetak>)

Water quality was measured based on DO and *BOD* using the titrimetric or volumetric Winkler method, in accordance with the 2017 standard (code APHA 5210 B 2017 (APHA-AWWA-WEF, 2017b) and APHA 4500-O B (APHA-AWWA-WEF, 2017a)) at the Water Quality Laboratory, Faculty of Agricultural Engineering, Faculty of Agricultural Technology, University of Jember. The study was conducted from July to September 2019, focusing on the Bedadung River. Sampling was conducted three times during the period, with the river divided into three segments for observation. These segments included the starting point (T1) in the Patrang District, the water intake area of Perumdam Tirta Pandalungan in Summersari as the second point (T2), and the water intake area of Perumdam Pandalungan in Kaliwates as the third point (T3). The sampling scheme was devised to assess the water quality of the Bedadung River based on source measurements derived from detailed survey results, as presented in Figure 2.

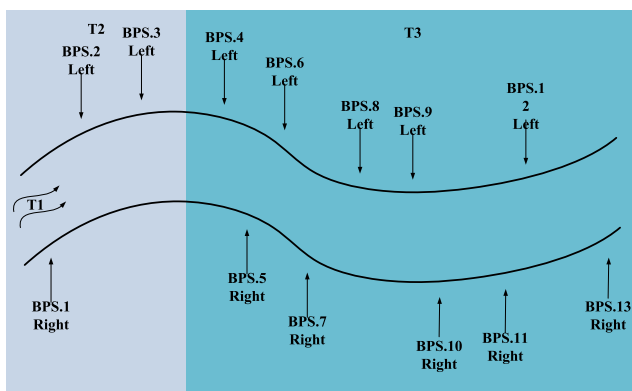


Fig. 2. Segment division of point source pollution discharged into the Bedadung River; T1 = the river water quality before the discharge of point source pollution (Patrang sub-district); T2 and T3 = water intake of Perumdam Tirta Pandalungan as the municipal waterworks at Summersari and Kaliwates (river water quality after point source pollution from BPS1 to BPS13 was discharged), BPS 01–13 = sources of point pollution; source: own elaboration

DATA ANALYSIS

The data analysis in this study comprised a descriptive quantitative assessment of the river pollution load capacity, using the mass balance method and the Streeter–Phelps model. Additionally, the study optimised domestic pollution control through linear programming. The pollution load carrying capacity of water can be determined through the calculation of the mass balance of pollution sources or by utilising the Streeter–Phelps mathematical model. The mass balance enables to determine the average concentration of the downstream flows originating from point source pollutants. Whether considering multiple converging streams as a single final flow or calculating water and constituent masses separately (Yeon, Kim and Lee, 2016; Lahlo, Mackey and Al-Ansari, 2023; Tugiyono *et al.*, 2023), the following formula is used:

$$C_R = \left(\sum C_i Q_i \right) / \sum Q_i = \sum M_i / \sum Q_i \quad (2)$$

where: C_R = mean concentration of constituents for the combined flow, C_i = i -flow constituent, Q_i = i -flow, and M_i = i -flow constituent.

This method accounts for the accumulation of flow from several sources of point and non-point pollution that enter the main river flow (Yeon, Kim and Li, 2016; Angello, Behailu and Tranckner, 2020; Lahlo, Mackey and Al-Ansari, 2023). Subsequently, the pollution load capacity was calculated using the Streeter–Phelps method, which takes into account the balance or distribution of oxygen within water bodies based on the deoxygenation and reoxygenation rates (Long, 2020; Ejigu, 2021). Equation (3) was used to determine the pollution load capacity using the Streeter–Phelps method:

$$TPLC = VI - (VO + rD + rR) \quad (3)$$

where: $TPLC$ = total pollution load capacity ($\text{mg}\cdot\text{dm}^{-3}$), VI = input flow ($\text{mg}\cdot\text{dm}^{-3}$), VO = output flow ($\text{mg}\cdot\text{dm}^{-3}$), rD = deoxygenation rate, rR = reoxygenation rate.

Further analysis was conducted through the optimisation method using linear programming to establish alternative point source pollution controls based on the pollution load capacity of the Bedadung River (Inyim and Liengcharernsit, 2012; Zhang *et al.*, 2013; Mahlathi, Siyakatshana and Chirwa, 2016). The model incorporated three research variables: decision variables representing the pollution load of the Bedadung River segments T2 and T3, an objective function in the form of minimised decision variables or pollution load capacity in the Bedadung River segments T2 and T3, and limiting variables determining the maximum *BOD* value of 6 mg·dm⁻³, or the pollution load capacity value. The objective function equation in the linear programming method is as follows (Inyim and Liengcharernsit, 2012; Ginting *et al.*, 2017):

$$Z = TPLC T_2 + TPLC T_3 \quad (4)$$

where: *Z* = *BOD* optimisation objective function (kg·d⁻¹ or mg·dm⁻³), *TPLC T*₂ = total pollution load capacity at the second point (kg·d⁻¹ or mg·dm⁻³), *TPLC T*₃ = total pollution load capacity at the third point (kg·d⁻¹ or mg·dm⁻³).

This study aimed to generate data on the pollution load value of the point source inputs to determine the optimisation value of these inputs along the Bedadung River from Patrang to Kaliwates Districts. By assessing the optimisation value of pollution sources, informed decisions could be made regarding the treatment of wastewater flowing into the main Bedadung River. This was expected to reduce the concentration of pollution sources discharged into the river, especially with regards to aligning Perumdham Pandalungan, Summersari, and Kaliwates with the class I quality standard for rivers as a raw material sources for drinking water.

RESULTS AND DISCUSSION

POLLUTION LOAD CHARACTERISTICS

Pollutants, by definition, are substances that are alien to the natural environment. They are classified as natural or anthropogenic pollutants based on their origin and entry into the environment. This section presents the findings from the analysis of pollutants stemming from anthropogenic activities.

BOD is the quantity of oxygen necessary for the aerobic microbial oxidation of organic matter into the carbon dioxide and water. According to Prambudy, Supriyatin and Setiawan (2019), elevated *BOD* values are caused by domestic waste discharge, which increases the organic content in rivers. The *BOD* concentrations originating from pollution sources ranged from 1.01 to 3.18 mg·dm⁻³ (Tab. 1), falling below the maximum limit for domestic waste quality, set at 30 mg·dm⁻³ (Peraturan, 2016). The discharge values of pollutant sources at their respective points of origin varied from 0.03 to 121.65 dm³·s⁻¹. The pollution load values ranging from 0.01 to 25.44 kg·d⁻¹. Notably, the highest pollution load value of 25.44 kg·dm⁻³ stemmed from domestic waste. This high pollution burden resulted from the significant load of contaminants present in wastewater, wastewater discharge, and untreated wastewater discharged directly into river bodies (Xu *et al.*, 2018; Widyarani *et al.*, 2022). The pressure exerted by a source of point pollution has the potential

to lower DO levels in a body of water. In tandem with this phenomenon, the prevalence of pathogenic microorganisms such as faecal coliform also increases (Novita *et al.*, 2020; Li *et al.*, 2022; Xu, Goa and Yuan, 2022).

Table 1. Point source pollution characteristics

Point source	Point source pollution type	Biological oxygen demand (mg·dm ⁻³)	Discharge (dm ³ ·s ⁻¹)	Waste polluting load (kg·d ⁻¹)
1	agriculture	2.01	11.88	2.06
2	domestic	2.75	14.94	3.55
3	municipal waterworks effluent	2.57	0.19	0.04
4	domestic	3.18	0.03	0.01
5	domestic	1.72	1.85	0.27
6	domestic	1.53	9.90	1.31
7	domestic	2.57	15.73	3.49
8	domestic	2.42	121.65	25.44
9	domestic	1.29	95.78	10.70
10	agriculture	1.07	54.51	5.02
11	domestic	1.01	39.50	3.45
12	agriculture and domestic	2.48	41.89	8.98
13	domestic	2.26	14.22	2.77

Source: own study.

Organic matter present in water bodies is typically discerned based on *BOD*. Dissolved organic matter stemming from the source of point pollution can impede self-purification. The accumulation of *BOD* values originating from such point sources of pollution contributes to increased deoxygenation levels, as microorganisms utilise oxygen to degrade biodegradable organic matter. Furthermore, the characteristics of point sources of pollution is part of comprehensive strategies aimed at controlling pollution in urban and industrial areas.

POLLUTION LOADS AND TOTAL POLLUTION LOAD CAPACITY

Rivers have a finite capacity to accommodate pollution loads, and exceeding this capacity can disrupt the river's assimilative conditions. The analysis of mass balance aimed to determine the average downstream flow concentration stemming from point sources pollution. Figure 3 shows the results of the pollution load and river capacity analysis. The determination of pollution load capacity involves establishing the maximum pollution load based on *BOD* values in accordance with class I provisions outlined in Peraturan (2021), subtracted from the actual pollution load. In the urban segment of Jember Regency along the main Bedadung River, the range of maximum and actual pollution load values sequentially spans from 363.13 to 430.97 kg·d⁻¹ and from 613.94 to 1,312.6 kg·d⁻¹. Negative results from the pollution load capacity calculation indicate that the Bedadung River in

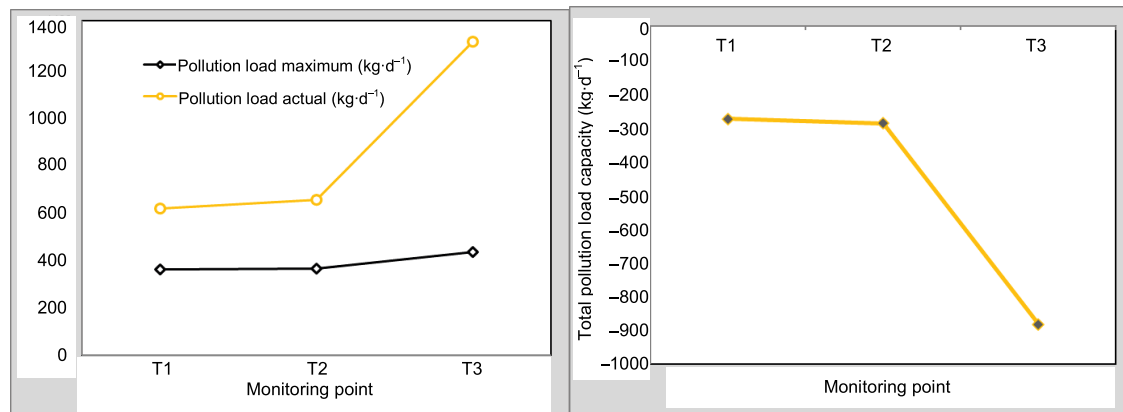


Fig. 3. Pollution load on the Bedadung River: A) pollution loads corresponding to class I river water quality allocation, B) actual pollution loads or pollution loads after the discharge of point source pollution; T1–T3 as in Fig. 2; source: own study

the urban area segment can no longer receive waste without causing pollution, based on class I water quality standard designation.

The *BOD* pollution load on the Bedadung River, which serves as a water intake for Perumdam Tirta Pandalungan, fluctuated, as shown for T2 and T3 in Figure 3. In both points, the pollution load exceeded capacity and tended to escalate within a range of values (from -881.63 to -287.47 $\text{kg}\cdot\text{d}^{-1}$). The contribution of point source pollution or addition pollutants from anthropogenic activities is expected to further exacerbate the pollution burden and degrade river water quality (Solihu and Solomo, 2022; Ngatia, Shadrack and Mihai, 2023). The pollution load entering the river has exceeded the river's capacity to degrade organic matter, especially in terms of the biochemical oxygen demand (*BOD*). This aligns with the study by Pradana *et al.* (2019), indicating that although the Bedadung River has a relatively strong ability to degrade organic matter, the high concentration of pollutants entering the river leads to a decline in water quality. Therefore, in the water intake segment for Perumdam Pandalungan, the river water quality is deemed unsuitable as a raw water source. The accumulated pollution load makes it difficult to purify the river water as a source of clean water for domestic use in Jember. Considering the exposure conditions of easily digestible organic matter or *BOD*, the water intake in the Bedadung River fails to meet class I allocation standards in Indonesia as a raw water source, as per Peraturan (2021). Several factors affect the capacity of the river, including its width, discharge, surrounding conditions, and most importantly, the input of pollution sources. In the absence of any initial waste handling, the latter can jeopardise the river's self-purification capacity (Pradana *et al.*, 2019; Long, 2020).

ANALYSIS OF TOTAL POLLUTION LOAD CAPACITY USING THE STREETER-PHELPS METHOD

The total pollution load capacity was assessed using the Streeter-Phelps model based on the deoxygenation and reoxygenation rates. The results obtained indicate the maximum pollution loads, i.e. 13.45 and 11.44 $\text{mg}\cdot\text{dm}^{-3}$, at points T2 and T3, respectively, as presented in Table 2. These values are influenced by the natural conditions of the Bedadung River, shaped by the self-purification mechanism. The latter is influenced by factors such as DO, staging distance, and river profile.

Table 2. Total pollution load capacity using the Streeter-Phelps method

Point	Critical times (day)	Critical distance (km)	Applicable DO deficit ($\text{mg}\cdot\text{dm}^{-3}$)	Critical DO deficit exists ($\text{mg}\cdot\text{dm}^{-3}$)	<i>BOD</i> maximum ($\text{mg}\cdot\text{dm}^{-3}$)
T1	–	–	1.72	0.11	–
T2	1.33	0.21	1.72	0.08	13.45
T3	1.33	0.21	1.72	0.16	11.44

Explanations: DO = dissolved oxygen, *BOD* = biological oxygen demand. Source: own study.

The *BOD* value permitted in the Bedadung River body is classified as high according to Peraturan (2021) and exceeds the class IV quality standards. As noted by David (2006), waters with a *BOD* value of more than 10 $\text{mg}\cdot\text{dm}^{-3}$ are considered polluted and are under significant pressure. Consistent with this, the dissolved organic matter concentration results show that the Bedadung River is no longer in its natural state, with the *BOD* values ranging from 0.5 to 7.0 $\text{mg}\cdot\text{dm}^{-3}$ (Novita, Firmansyah and Pradana, 2023). The high *BOD* value stems from intensive anthropogenic activities, leading to increased consumption of DO for organic matter oxidation and cellular synthesis (Prambody, Supriyatin and Setiawan, 2019). High exposure to organic matter in rivers can increase water treatment costs (Pradana, Novita and Purnomo, 2022). The approach to managing river pollution may involve consistent water quality monitoring, waste generation reduction, enhancing community sanitation (infrastructure and behaviour), urban planning improvement, ensuring the enforcement of policy and legal sanctions, as well as augmenting the capacity of local institutions. This approach, especially in urban areas continually discharging domestic wastewater into water bodies, involves restricting waste disposal into water bodies and implementing regulations outlined in Peraturan (2021) (Li *et al.*, 2022; Pradana, Novita and Purnomo, 2022).

OPTIMISATION OF POLLUTION CONTROLLING RECOMMENDATION USING LINEAR PROGRAMMING

The optimisation calculation results indicate that sections T2 to T3 of the Bedadung River can still accommodate the burden of pollution. Initially, the river exhibited a critical DO value of

0.11 mg-dm⁻³, with a DO deficit limit of 1.72 mg-dm⁻³. However, at T2, the pollution level decreased to 0.08 mg-dm⁻³, indicating a favourable purification process. This is supported by the DO value which tends to increase from T1, T2, and T3 with sequential values of 5.6, 5.4 and 5.4 mg-dm⁻³, respectively. Despite these improvements, the river has not yet reached a clean state (Zubaidah, Nieke and Agus, 2019).

During the dry season, substantial point sources of pollution reduce the self-purification capacity of the Bedadung River. Linear programming modelling indicates that, despite a total input of 13 points sources of pollution, the river can still accommodate a pollution load of 774.55 mg-dm⁻³ in T2 and 53.35 mg-dm⁻³ in T3. Referring to Table 3, the maximum *BOD* value shows a decreasing trend, namely 13.45 mg-dm⁻³ at T2 and 11.44 mg-dm⁻³ at T3. This decline is influenced by the downstream accumulation of pollution load, resulting in reduced capacity (Zhang *et al.*, 2022). Notably, the maximum *BOD* value obtained exceeds the class I allocation standard of 2 mg-dm⁻³ (Fig. 4).

Table 3. Data optimisation result for maximum biological oxygen demand (*BOD*) using linear programming and the Streeter-Phelps method

Point	Discharge (dm ³ .s ⁻¹)	<i>BOD</i> real (mg-dm ⁻³)	<i>BOD</i> maximum (mg-dm ⁻³)
T1	2072,00	3.53	–
T2	27,00	7.33	13.45
T3	395,05	19.52	11.44

Explanation: T1–T3 as in Fig. 2.

Source: own study.

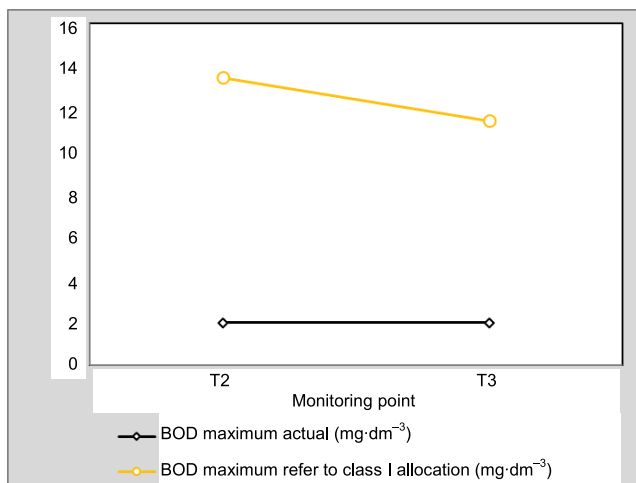


Fig. 4. Comparison of actual maximum biological oxygen demand (*BOD*) and maximum *BOD* for class I allocation acc. to Peraturan (2021); T2 and T3 as in Fig. 2; source: own study

Concerning the maximum value of the optimisation results obtained through linear programming, the objective function (*Z*) takes the form of a DO optimisation value aligning with class I allocation standards for water quality, i.e. 6 mg-dm⁻³ according to Peraturan (2021) as the benchmark for clean water quality. The difference in results is influenced by the self-purification

mechanism, which, in turn, is affected by the river's characteristics in terms of its profile and water quality. Factors such as depth, width, and flow velocity of tropical rivers play a significant role in oxygen intake from the atmosphere and the demand for DO to naturally degrade pollutants (David, 2006; Pradana *et al.*, 2019). Thus, the decrease in *BOD* levels from T2 and T3 indicates that although the Bedadung River maintains a purification process, it falls short of optimal efficiency.

The reduction in the pollution load values due to purification is suboptimal, primarily because during the dry season pollutants are not fully diluted. This compromises the river's ability to accommodate the pollution burden, exacerbated by a high deoxygenation rate (Novita, Septian and Pradana, 2022). This condition is influenced by various factors such as river discharge, depth, flow velocity, water temperature, and natural river conditions, necessitating an increased purification distance to replenish dissolved oxygen and restore the river to its original state (Zhang *et al.*, 2022). Table 3 shows variations in the *BOD* content and discharge at each point, reflecting differences attributable to point source pollution in terms of input quantity and pollutant content in the Bedadung River. Efforts to mitigate the *BOD* content should focus on enhancing the self-purification capacity of water bodies. One approach involves increasing turbulent flow by installing stone wall breakers along riverbanks. Alternatively, turbulence can be introduced by strategically placing large stones in shallow streams (Nugraha, Sarminingsih and Alfisya, 2020).

The results of this study serve as valuable reference points for understanding the self-purification process in rivers in tropical regions, contributing to sustainable environmental management. However, regulations in Indonesia (Peraturan, 2021), continue to serve as crucial and stringent guidelines for allocating water resources for anthropogenic activities while maintaining environmental sustainability.

CONCLUSIONS

The investigation into pollution sources along the Bedadung River segment revealed that domestic activities were predominant contributors among the 13 wastewater monitoring points, with a range of 1.01 to 3.18 mg-dm⁻³ biological oxygen demand (*BOD*). These values have not exceeded the domestic wastewater quality standards in Indonesia. Furthermore, the total pollution load capacity – *BOD* at the Perumdam Tirta Pandalungan water intake in the Summersari (T2) and Kaliwates (T3) segments was assessed using self-purification optimisation and exceeded the class I designation standard for river water quality set by the Indonesian government. The maximum *BOD* value achieved through self-purification optimisation is 11.44 mg-dm⁻³ in the Summersari (T2) segment and 13.45 mg-dm⁻³ in the Kaliwates (T3) segment, surpassing the maximum *BOD* value for class I water quality allocation, which is 2 mg-dm⁻³. The river's self-purification process denotes its inherent capability to naturally reduce pollutants, influenced by the river profile. However, despite the Bedadung River's potential to diminish pollution load through the self-purification process, emphasis should be placed on preventing pollution caused by domestic and other human activities from entering the river.

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CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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