Laundry wastewater characteristics and their relationship with river water quality as an indicator of water pollution. Case study: Code Watershed, Yogyakarta

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Abstract. Laundry services are rapidly becoming ubiquitous in rural and urban areas, generating high domestic waste volumes. Their growth has raised concerns about the quality of natural waters, particularly the rivers into which most laundry businesses discharge their wastewater. The research set out to study laundry wastewater characteristics and their relationship with the river water quality as water pollution indicators in Code Watershed (Indonesia). It lies in three administrative units where many human activities take place in the watershed's upper to the lower reaches. BOD and COD of 25 sampled laundry businesses were analyzed descriptively and compared to the laundry wastewater standards stipulated in Regulation No. 7 of 2016 and the class II water quality standards issued in Governor Regulation No. 20 of 2008. The results showed that the BOD of four laundry businesses and the COD of 18 laundry businesses exceeded the predetermined standards. Overall, rivers in Code Watershed meet the class II river water criteria for BOD at three of the seven sampling points and COD at all points.

1. Introduction

In the Special Region of Yogyakarta (SRY), Indonesia, increasing community activities along the Code River, mostly those of domestic and small-scale industrial sectors, have modified the water quality. Monitoring in 2013 confirms ammonia and COD are low at the inlet but high at the outlet, up to the point where the quality standards are exceeded. These findings indicate that the influence of waste disposal from, for instance, settlements, lodging, small-scale industries, and health services, becomes more significant downstream [1]. Meanwhile, another monitoring by the SRY Environment and Forestry Service reveals an increasing trend in detergent contents from 2017 through 2019 and 2020, above the class II water quality standards. A significant increase also appears in BOD. Accordingly, the source of pollutants in the Code River that passes through urban areas comes from domestic waste, e.g., greywater, soap, food wastes and scraps, and fecal wastes [2].

These contaminants can adversely affect river water and its surroundings, that the constantly decreasing water quality alters processes and mechanisms in abiotic, biotic, and social environments in Code River [3]. High nitrate and manganese concentrations indicate the abiotic environment's damaged functions, disrupting the other environmental constituents: reduced biota diversity and elevated community vulnerability to diseases caused by deteriorating river water quality and poor sanitation.

Laundry business constitutes a small-scale industry with a persistently growing number and economic significance in several countries, such as Indonesia, India, and China. Nevertheless, this industry's development raises various kinds of problems as it generates about 3.881 million liters of wastes per day, comprising 40% of the total industrial wastes, or 20,000–25,000 liters/person/year [4]. Meanwhile, in Turin, Italy, data shows that the laundry industry produces an average of 400 m^3 of wastewater per day for every 15 liters of water used. Because the wastewater consists of organic substances (soap, detergents, chlorinated solvents, aromatics, biological substances, fats, and grease) and inorganic substances (heavy metals, sand, silt, clay, metal ions, and particles), it makes the refining process intricate and highly time-consuming [5].

With the increasing use of chemicals in the industry, river water pollution has quickly become an alarming issue [6]. The characteristics of laundry wastewater are divided into three types, namely domestic laundry, industrial laundry and hospital laundry [7] (Table 1). Based on the table, it is known that the distribution of wastewater quality levels from the three activities. Laundry wastewater from laundry services (industry) has a higher level than other activities.

In this study, only selected parameters were used for analysis, only parameters that had a high content in laundry wastewater were selected. Wastewater from laundry activities still contains high concentrations of

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dissolved materials (TSS), BOD, COD, and also LAS (linear alkylbenzene sulphonate) [8,9]. The COD and MBAS content after leaving the washing machine were 186 - 2418 mg/L and 25.0 - 33.9 mg/L decreased slightly to 122 - 14488 mg/L for COD and 6.50-10.3 mg/L for MBAS in water bodies/rivers [10].

Table 1. Characterisation of domestic,industrial and hospital laundries wastewater

Parameters	Domestic laundry	Industrial laundry	Hospital laundry
pH	9.3 - 10	9.0 - 11	11.4 - 11.6
EC (µs/cm)	190-1400	640-3000	808-2000
TDS (mg/L)	400-6000	420	456-800
TSS (mg/L)	200-987	400-1000	66-71
TH (mg/L CaCO3)	-	44	53-68
TA (mg/L CaCO3)	83-200	128	302-375
TOG (mg/L)	8.0-35	71.5-11790	25-26
Phosphate (mg/L)	4-27.6	3.43	10.8-167
BOD5 (mg/L)	48-1200	218-9810	44-50
COD (mg/L)	375-4155	80-212000	477-876
Turbidity (NTU)	14-400	40-150	87.9

Source: (Lade & Zainab, 2018)

Based on the background, the purpose of this study was to determine the characteristics of the laundry business wastewater and its relationship to the water quality of the Code river. Where the current development of the laundry business is very large and has the potential to pollute the river environment.

2. Research Area Description

Based on the inventory of laundry business locations in SRY, Code Watershed was selected as the research location because it is located in the middle of the region, dividing the City of Yogyakarta into two (Fig 1). It stretches as far as 45.58 km, traversing three administrative units: from Sleman Regency (precisely, Merapi Volcano National Park in Hargobinangun, Pakem) to the City of Yogyakarta then Bantul Regency (i.e., Jl. Imogiri Timur, Trimulyo, Jetis). Two main rivers flow in the watershed, namely Boyong and Code. Based on public knowledge, Boyong starts from Merapi Volcano to Jl. Ring Road Utara then continues downstream as Code River.

3. Methodology

The research began by taking 25 samples of laundry business wastewater and Code River water at ten observation points simultaneously. These samples were determined using purposive sampling, i.e., based on the distance between the laundry business and the river, while the observation points were selected based on the laundry sample density. The research tools included 500 ml water sample bottles to safely store and transport the collected water to the laboratory and a Global Positioning System (GPS) to determine the location. The laboratory analysis results were analyzed descriptively and compared with the wastewater standards and the class II river water quality standards based on the predetermined stream order. The parameters observed were Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

3.1 Laundry Wastewater Characterization

The wastewater quality test results were analyzed and observed side-by-side with the wastewater standards issued in Regulation No. 7 of 2016 [11], where the highest allowable BOD and COD levels are 75 mg/L and 159 mg/L, respectively (Table 2).

Table 2. Wastewater Parameter Standards for Laundry Industries

Parameters	Maximum Allowable Presence (mg/L)	Highest Pollution Loads (kg/ton)
BOD_5	75	1.5
COD	150	3
TSS	100	2
TDS	2,000	40
Detergent	5	0.1
Temperature	± 3°C of air temperature	
pH	6.0–9.0	
Largest wastewater discharge (L/kg)	20	

Source: SRY Regulation No. 7 of 2016

3.2. Code River Water Quality Analysis

The river water quality characteristics were compared with the SRY Government's Regulation No. 20 of 2008 [12] (Table 3), which classifies the quality based on a predefined stream order. Based on the SRY Government's Regulation No. 22 of 2007 [13], the Boyong River (upper reach of the watershed) is a first-order stream, while the Code River (middle and lower reaches) is second-order.

Table 3. BOD and COD Standards by Stream Orders

Parameters	Units	First	Second	Third	Fourth
BOD	mg/L	2	3	6	12
COD	mg/L	10	25	50	100

Source: SRY Government's Regulation No. 20 of 2008

3.3. Comparative Analysis of Laundry Wastewater and River Water Quality

The relationship between laundry wastewater and Code River water quality was analyzed descriptively using tables and graphics. Code Watershed was divided into ten segments; each had a water quality observation point. These segments were also identified as experiencing point source pollution from the wastewater generated by laundry businesses.

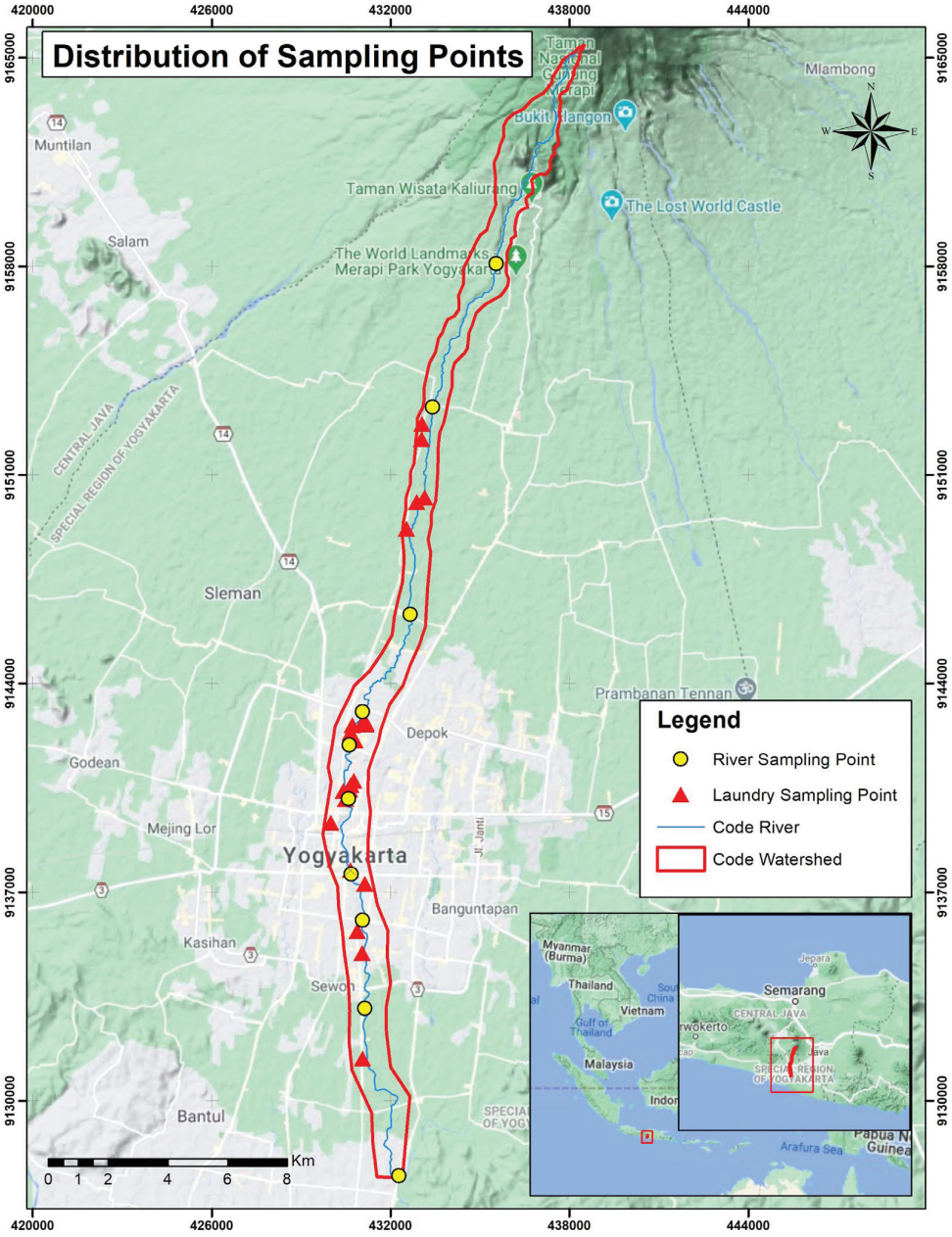

Fig 1. Water Sampling Points in the Code River

4. Results and Discussion

4.1. Laundry Wastewater Characteristics

Table 4 shows the laboratory test results of 25 laundry wastewater samples. Compared with the wastewater quality standards set in Regulation No. 7 of 2016, five samples contained high BOD levels exceeding the upper threshold, 75 mg/L. These five samples were that of Rumah Cuci (165 mg/L), Malika (93.3 mg/L), Ceria (141 mg/L), Hayu (125 mg/L), and Icigo (264 mg/L). As indicated by the bold figures in Table 4, 18 samples had COD in the range of 136–366 mg/L, exceeding the laundry wastewater quality standard, 150 mg/L.

High BOD and COD levels are in line with previous research in India that found high levels of BOD (230–626 mg/L), COD (376–910 mg/L), and suspended solids (445–1,550 mg/L) in laundry wastewater [9], and these conditions are believed to be due to the use of various detergents [14]. The interview with laundry owners revealed that cloth washing requires different types of detergents, increasing the presence of surfactants (complex organic compounds) in the liquid waste and the amount of oxygen required by

microorganisms to break down organic matters in the water.

4.2. Code River Water Quality

Table 5 shows the BOD and COD levels of the Code River water samples. Sampling points S1-S3 and S4-S10 were, respectively, compared with class I and class II water quality standards issued in the SRY Government's Regulation No. 20 of 2008. Five samples contained high BOD levels exceeding the predetermined standard: S2 (Pulowatu Bridge, 2.14 mg/L), S4 (Ring Road Utara Bridge, 6.99 mg/L), S7 (Sayidan Bridge, 4.76 mg/L), S8 (Lowanu Bridge, 5.63 mg/L), and S10 (Kembangsong Bridge, 3.33 mg/L). Meanwhile, the COD levels varied from 6.32 to 11.4 mg/L, meaning that none of the COD in all ten river segments is above the class I and class II water quality standards.

S2 (Pulowatu Bridge), where the BOD exceeded its allowable level in class I water, is located in the upper reach of the Code River. Similarly, S4 (Ring Road Utara Bridge) is in the middle segment, i.e., the center of the economic growth in the Sleman Regency. Meanwhile, the other three sampling points (S7, S8, and S10) are located in the lower reach, and the excessively high BOD levels at these points are potentially caused by the accumulation of pollutants upstream. A previous study found that the Code River segment in Kotabaru (City of Yogyakarta) had a high BOD level, i.e., 100.1 mg/L [15], and it is located close to the lower reach of the river.

Table 4. BOD and COD Levels of the Sampled Laundry Business Wastewater in the Code River

No	Laundry Business Names	Coordinates		Wastewater Quality (mg/L)	
		X	Y	BOD	COD
1	Gading Laundry	433056.53	9152706.17	10.2	**272**
2	Nabila Laundry	432870.02	9150095.37	13.4	**158**
3	Amanah Laundry	433136.02	9150236.97	14.3	**253**
4	Djamil Laundry	432537.89	9149194.23	14.3	**136**
5	Rumah Cuci Laundry	433040.64	9152194.03	**165**	**354**
6	Purple Bubble Laundry	431077.00	9142700.00	19.4	107
7	Medio Laundry	431167.00	9142670.00	5.64	**190**
8	Omah Degan Laundry	430711.05	9142590.74	27.4	78.8
9	Spongebob Laundry	431179.00	9142616.00	51.6	**392**
10	Express Laundry	431073.95	9142652.43	1.56	**183**
11	Kawankoe Laundry	430759.00	9142175.00	6.54	50.6
12	Mom's Laundry	430653.00	9142337.00	20.6	**259**
13	B & K Laundry	430750.00	9142136.00	14.4	**253**
14	Icigo Laundry	430803.00	9142081.00	**264**	**334**
15	Pelangi Laundry	430764.00	9140728.00	19.8	69.5
16	Nana Laundry	430631.00	9140432.00	23.5	44.2
17	Malika Laundry	430405.00	9140384.00	**93.3**	101
18	Laundry 31 C	430669.85	9140591.29	20.1	75.8
19	Laundry Kiloan 34	430492.00	9140124.00	23.8	**171**
20	Ceria Laundry	429996.00	9139322.00	**141**	**348**
21	Hayu Laundry	430650.00	9137731.00	**125**	**366**
22	Gangsar Laundry	431137.00	9137274.00	41.1	**341**
23	Barokah Laundry	430884.00	9135680.00	12.0	**221**
24	Youshan Laundry	431050.00	9134953.00	3.98	**240**
25	Uno Fresh Laundry	431053.00	9131401.00	70.4	**240**

Source: Laboratory test results, 2020

Table 5. BOD and COD Levels of the Sampled Water in the Code River

Codes	Sampling Points	Coordinates		Measured Parameter Levels (mg/L)		Water Quality Standard (mg/L)	
		X	Y	BOD	COD	BOD	COD
S1	Gantung Boyong Bridge	435443.24	9158022.7	0.19	5.69	2	10
S2	Pulowatu Bridge	433451.18	9153253.9	**2.14**	3.16	2	10
S3	Kamdanen Bridge	432545.7	9146251.5	1.33	9.48	2	10
S4	Ring Road Utara Bridge	431096.92	9143052.1	**6.99**	8.85	3	25
S5	New UGM Bridge	430553.64	9141844.8	0.71	7.58	3	25
S6	Sardjito Bridge	430674.37	9140154.6	0.71	10.7	3	25
S7	Sayidan Bridge	430614	9137619.2	**4.76**	7.58	3	25
S8	Lowanu Bridge	431036.56	9136049.7	**5.63**	11.4	3	25
S9	Pandeyan Bridge	431157.29	9132850.3	2.14	6.32	3	25
S10	Kembangsongo Bridge	432424.97	9127538.2	**3.33**	9.48	3	25

Source: Laboratory test results, 2020

Table 6. BOD and COD Level Comparison of the Laundry Wastewater and River Water Samples in the Code River

No	Laundry Business Names	Laundry Wastewater Quality (mg/L)		Stream Section with Suspected Point Source Pollution	River Water Quality Downstream of the Laundry Wastewater Outlet (mg/L)	
		BOD	COD		BOD	COD
1	Gading Laundry	10.2	**272**	Kamdanen Bridge	1.33	9.48
2	Nabila Laundry	13.4	**158**			
3	Amanah Laundry	14.3	**253**			
4	Djamil Laundry	14.3	**136**			
5	Rumah Cuci Laundry	**165**	**354**			
6	Purple Bubble Laundry	19.4	107	New UGM Bridge	0.71	7.58
7	Medio Laundry	5.64	**190**			
8	Omah Degan Laundry	27.4	78.8			
9	Spongebob Laundry	51.6	**392**			
10	Express Laundry	1.56	**183**			
11	Kawankoe Laundry	6.54	50.6			
12	Mom's Laundry	20.6	**259**			
13	B & K Laundry	14.4	**253**			
14	Icigo Laundry	264	**334**			
15	Pelangi Laundry	19.8	69.5	Sardjito Bridge	0.71	10.7
16	Nana Laundry	23.5	44.2			
17	Malika Laundry	**93.3**	101			
18	Laundry 31 C	20.1	75.8			
19	Laundry Kiloan 34	23.8	**171**	Sayidan Bridge	**4.76**	7.58
20	Ceria Laundry	**141**	**348**			
21	Hayu Laundry	**125**	**366**			

No	Laundry Business Names	Laundry Wastewater Quality (mg/L)		Stream Section with Suspected Point Source Pollution	River Water Quality Downstream of the Laundry Wastewater Outlet (mg/L)	
		BOD	COD		BOD	COD
22	Gangsar Laundry	41.1	**341**	Lowanu Bridge	**5.63**	11.4
23	Barokah Laundry	12.0	**221**	Pandeyan Bridge	2.14	6.32
24	Youshan Laundry	3.98	**240**			
25	Uno Fresh Laundry	70.4	**240**	Kembangsongo Bridge	**3.33**	9.48

Notes: bold figures indicate exceeded quality standards

4.3. Comparison between Laundry Wastewater and River Water Quality

Table 6 shows the spatial distribution of the wastewater and river water quality samples at seven sampling points: S3 (Kamdanen Bridge), S5 (New UGM Bridge), S6 (Sarjito Bridge), S7 (Sayidan Bridge), S8 (Lowanu Bridge), S9 (Pandeyan Bridge), and S10 (Kembangsongo Bridge). Fig. 3 and Fig. 4 illustrate the distribution of BOD and COD levels of the laundry wastewater and Code River water quality. Nearly all of the wastewater samples showed that BOD and COD decreased downstream when Boyong River reaches Code River. Spatially, in the Kamdanen Bridge segment, there was a waste input from five laundry businesses, with BOD levels varying from 10.2 to 165 mg/L and COD in the range of 136–354 mg/L. At the point where Boyong River stops and continues as Code River, the BOD and COD levels lowered to 1.33 mg/L and 9.48 mg/L, below the class 2 river water quality standards.

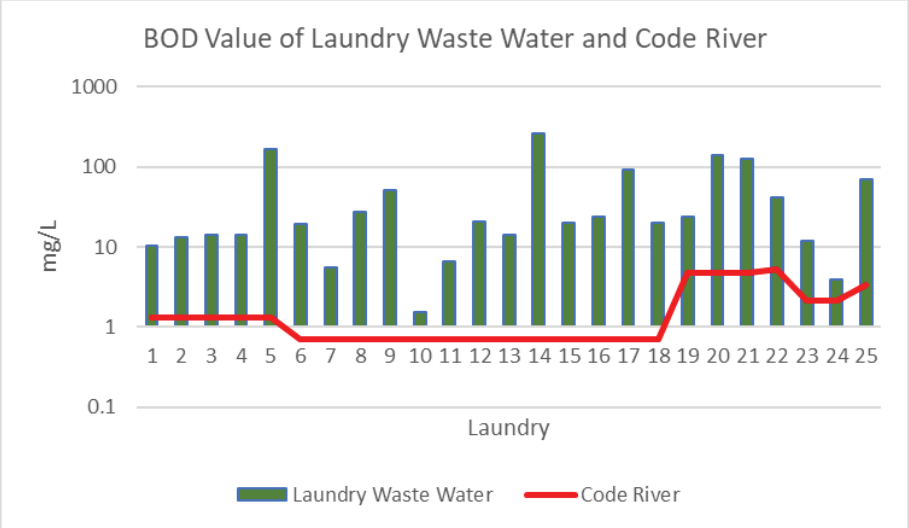

Fig 2. BOD Levels of Laundry Business Wastewater and Code River Water (25 Samples)

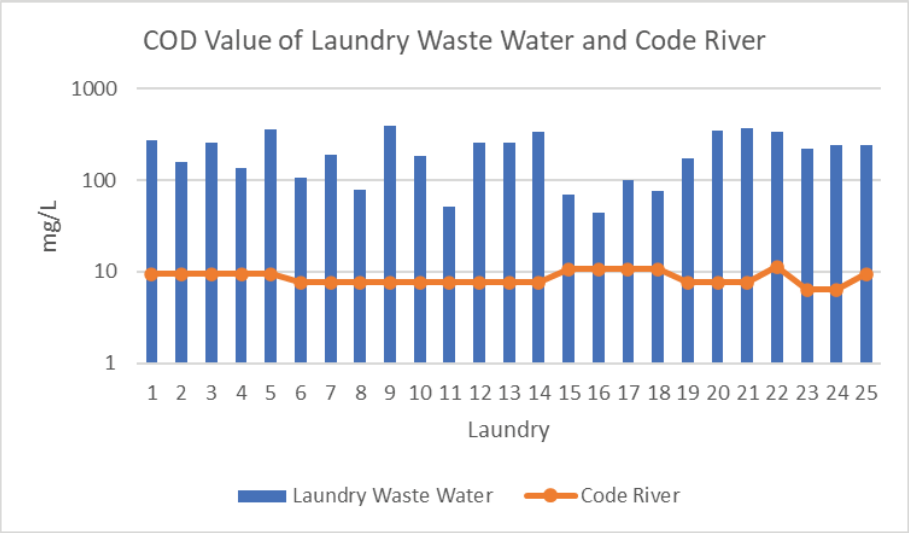

Fig 3. COD Levels of Laundry Business Wastewater and Code River Water (25 Samples)

S5 (New UGM Bridge segment) received waste input from nine laundry businesses and, therefore, had BOD in the range of 1.56–264 mg/L and COD between 50.6 and 392 mg/L. At the point where Boyong continues as Code River, the BOD and COD lowered to 0.71 mg/L and 7.58 mg/L, respectively, below the class II river water quality standard. The same case applies to S6 (Sardjito Bridge segment), which received wastewater from four laundry businesses; BOD and COD levels decreased from 19.8–93.3 mg/L and 44.2–75.8 mg/L to 0.71 mg/L and 10.7 mg/L, below the quality standards. Three laundry businesses disposed of their wastewater in S7 (Sayidan Bridge segment), leading to high BOD (23.8–141 mg/L) and COD (171–366 mg/L) that later decreased to 4.76 mg/L and 7.58 mg/L, respectively, where the Code River channel begins. At this point, the BOD is still above the specified river water quality standard, while the COD is below it.

S8 (Lowanu Bridge segment) received waste input from one laundry business, and like the previous three sampling points, its BOD and COD lowered from 41.1 mg/L and 341 mg/L to 5.63 mg/L and 11.4 mg/L, respectively, where the Code River channel starts. These BOD levels are above the predetermined standard. The same case applies to S9 (Pandeyan Bridge segment) that received wastewater from two laundry businesses; BOD and COD levels decreased from 3.98–12.0 mg/L and 221–240 mg/L to 2.14 mg/L and 6.32 mg/L. One laundry business discharged its wastewater into S10 (Kembangsongo Bridge segment), leading to high BOD (70.4 mg/L) and COD (240 mg/L) that later decreased to 3.3 mg/L and 9.48 mg/L, respectively, where Boyong continues as Code River. The BOD levels in this segment have exceeded the predefined class II river water quality standard.

5. Conclusion

The wastewater disposed of laundry businesses around the Code River has high levels of BOD and COD at several sampling points because the various detergents used in cloth washing elevate the amount of oxygen needed by microorganisms to break down organic matter. Based on the Code River water quality test results, the BOD at some sampling points has exceeded its allowable level in river water, but the COD is below the predetermined quality standard. The point at which Boyong River stops and Code River channel starts is marked by lowered BOD and COD levels because of many factors. Further research is required to explain this relationship in more detail.

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