Research article

Evaluation of Textile Industry Wastewater Treatment as an Effort to Control River Water Pollution in Central Java

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Abstract.
There is an increasing need for clean water because of the growing population. However, the amount of clean water is decreasing due to poor water resource management. Several textile industry processes result in waste. Color, alkalinity, high TSS, high BOD, and some dyes are known to contain chromium elements and are all common characteristics of liquid waste produced by the textile industry. The goal of this study was to assess the performance of textile waste treatment units in Pringsurat Subdistrict, Magelang Regency, Central Java Province, as part of an effort to reduce river water pollution. Quantitative and qualitative methods were used including through surveys and mapping. Groundwater flow maps, and river water and wastewater levels of BOD, COD, TSS, phenol, chromium, ammonia, and sulfide were used as primary data. Unpleasant odors and discoloration of the river were observed. It is recommended that, to reduce the impact of the wastewater, a constructed wetland with a combination of two types of plants, *Iris pseudacorus* and *Thypa angustifolia*, should be used.

Keywords: Pollution Control, River Pollution, Textile Industry, Wastewater treatment, and Wetland

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1. Introduction

Textile industry located in Pringsurat Subdistrict, Temanggung Regency, Central Java Province is a textile factory that has been established in 2015. The textile industry produces textile fabrics from plain materials to ready-to-sell textile fabrics. The waste from textile industry generates from several process activities such as stenter (precision process), dyeing, printing (giving motif), Steamer (ripening colors), Washing (re-washing) and finishing (packaging and distribution). Wastewater produced by the textile industry generally has characteristics such as colored, alkaline, high TSS value, high BOD and high temperature [1]. Some dyes also contain chrome (Cr), such as $Na_2Cr_2O_7$ or $Na_2Cr_3O_7$ [2].

Production activities carried out wastewater that directly discharge through the river located in the south of the factory. Elo River is a sub-watershed of Progo River used by Kebumen villagers as an irrigation, but its existence is precisely watered by textile industry wastewater. Based on the results of interviews with residents around the river, the waste dumped by the textile industry has colour characteristics and causes odors on the surface of the river water. Local residents living around the sewers complained of an unpleasant smell and discoloration of the river water. In addition to that, in October 2020, many dead fish were found along the Elo River. According to previous research, the high human activity to be able to meet the needs of his life stemming from agricultural, industrial, and household activities will potentially produce waste that will have a direct impact on the decline in river water quality [3].

The textile industry in Pringsurat Sub-district is known to already have wastewater treatment plant (WWTP) to process wastewater resulting from production activities. Constraints are known based on the company that the performance of WWTP itself has not been feasible or has not been able to process waste properly to produce waste quality in accordance with the specified quality standards. This is also supported by tests conducted by the surrounding environment agency shows that there are still some parameters that exceed the quality standards.

The quality of river water bodies that receive water produced by textile activities is not carried out regular monitoring or control. It is necessary to assess the impact of pollution and evaluate the function of WWTP to determine the level of pollution due to waste that has not been in accordance with the criteria and. Furthermore, this evaluation is needed to assess the performance of the final treatment and wastewater unit whether it is in accordance with the criteria of quality standards. In this study will be conducted analysis and evaluation of the quality of wastewater processing unit. The results of this evaluation can be a recommendation for WWTP rehabilitation and optimization [4].

The potential for pollution by wastewater against river water and water needs to be controlled so as not to cause problems for the biotic environment, biotic, as well as cultural. One of the methods of treating water It uses constructed wetland. Constructed wetland is one of the alternatives to planned and controlled water treatment using natural processes involving vegetation, media, and microorganisms to treat wastewater [5]. Constructed wetland system used is constructed wetland type Horizontal Sub-surface Flow because has advantages such as simple construction, so it is easy to make; flexible in the selection of placement locations; flexibility in the operating system; cost cheap. The objective of this research is to evaluate the performance of textile industry waste treatment units as an effort in controlling river water pollution in Pringsurat Subdistrict, Magelang Regency, Central Java Province.

2. Methodology

2.1. Data Collecting

Data for this this research consist of primary and secondary data. Primary data is actual data obtained directly at the time of research in the field, both observational data and calculation data. For the determination of water quality analysis required test results from the laboratory as data on the characteristics of wastewater and river water in the research area. The parameters are biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), total phenol, total chrome, ammonia (NH_3), and sulfide (S). The selection of parameters used refers to Central Java Provincial Regulation No. 5 of 2012 on Wastewater Quality Standards. Parameters and quality of textile wastewater can be seen in **Table 1.**

Table 1: Water Quality Method Analysis.

No	Parameter	Unit	Methods
1	BOD	mg/L	SNI 6989.72-2009
2	COD	mg/L	SNI 6989.2-2019
3	TSS	mg/L	SNI 06-6989.21-2004
4	Total Phenol	mg/L	SNI 6989.17-2009
5	Total Chromium	mg/L	SNI 06-6989.30-2005
6	Ammonia (NH_3 as N)	mgL	SNI 6989.70-2009
7	Sulphide (as S)	mg/L	In House Methode

2.2. Sampling

Sampling of groundwater, river water and wastewater produced at some point in order to get water quality data. Sampling points are taken at 10 points. Sampling conducted in the research area are carried out with purposive sampling. Purposive sampling techniques are carried out intentionally in areas that have the potential of textile industry wastewater pollution in accordance with research objectives. The water sampling point can be seen at **Figure 1.**

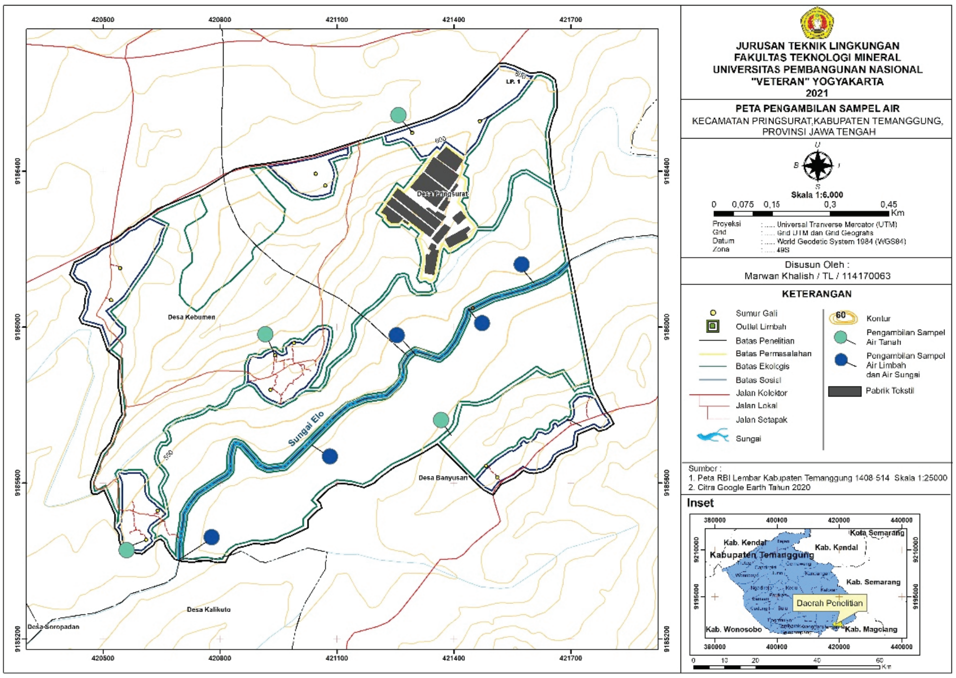

Figure 1: Sampling Point at the Research Area.

2.3. Pollution Index (IP) Calculation

Analysis of the level of water quality status of rivers and groundwater will be conducted using the pollution index method according to the Decree of the Minister of Environment No. 115 of 2003 on Determining water quality status, determination of pollution levels is carried out using the following formula [6]:

Where: IPj = pollution index for j Ci = water quality concentration in parameter i Lij = standard water quality concentration in parameter i M = Maximum R = Average

$$PI_j = \sqrt{\frac{(Ci/Lij)^2_M + (Ci/Lij)^2_R}{2}}$$

The IP water quality value is determined from the maximum result value and the average value of the concentration ratio per parameter to the quality standard value. The IP index class is 4 as can be seen in **Table 2.**

TABLE 2: Pollution Index Classification.

PI_j Index	Classification
$0 \leq PI_j \leq 1{,}0$	Good
$1{,}0 < PI_j \leq 5{,}0$	Less Contaminated
$5{,}0 < PI_j \leq 10$	Medium Contamination
$PI_j \geq 10$	Heavy Contamination

2.4. Standard Stream Evaluation

To know the ability of the river to receive wastewater processing required calculation of pollution load to compare the concentration of pollution substances with existing quality standards. This evaluation is done to determine the characteristics of wastewater that needs to be treated. It will also be the basis for the determination of the treatment unit to be advised in the planning of wastewater treatment. The Quality Standard used in this evaluation is Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management. The quality standard used is in accordance with the allocation of second class rivers as a means of watering residents and recreation of water [7]. Here is an equation for calculating the concentration of the mixture when water is discharged directly without any advanced treatment.

$$C_c = \frac{(Qs.Cs + Qe.Ce)}{(Qs + Qe)}$$

Where:

Q_s:River Discharge (L/s)

Q_e: Effluent Discharge (L/s)

C_s: River Concentration (mg/L)

C_e: Effluent Concentration (mg/L)

C_c: Mixing Concentration (mg/L)

2.5. Laboratory-scale constructed wetland processing unit trials

Testing of processing units on a laboratory scale will be carried out to determine the performance of processing results from IPAL units. Determination of the method of waste treatment units using the method of artificial wetland units with variations of sub-surface flow. Different treatment variations are used, namely with 3 variations of reactors, among others: reactors with mixed aquatic plants (Iris Pseudacorus & Typha Angustifolia), single aquatic plants (Iris Pseudacorus) and single aquatic plants (Typha Angustifolia). The determination of IPAL design will be guided by constructed wetland design formula sourced from Metcalf and Eddy [8].

The determination of the design of the processing tub referring to Metcalf and Eddy [8] requires some preliminary data including: BOD levels in the waste to be treated, maximum discharge of waste, plant species, and planting media to be used. The results of some of these parameters will be obtained the value of the detention time, the area of the tub needed, and the hydraulic loading rate (HLR). The process of testing constructed wetland processing units is divided into several stages, namely: preparation, acclimatization, processing trials, and measurement of processing effectiveness.

3. Result and Discussion

3.1. Textile Industry Wastewater Characteristics

The results of the textile waste testing laboratory that can be seen in **Table 3** showed that of the 7 parameters tested, including BOD, COD, TSS, Ammonia, Phenol, Chrome, and Sulfide, there are 5 parameters that exceed the waste quality standard. Referring to Central Java Regional Regulation No. 5 of 2012 on Wastewater Quality Standards 5 parameters that exceed quality standards include BOD, COD, Phenol, Ammonia and TSS with concentrations of 114 mg / L, 270 mg / L, 0.8441 mg / L, 187.9 mg / L and 52 mg / L. There are some parameters that still do not meet the quality standard value that should show that WWTP performance is not optimal and still requires optimization or addition of types of operations. The parameters that are still below the standard quality are BOD, COD, TSS, and Total Chromium. High COD values reveal that the textile industry wastewater is contain large amount of chemically oxidizable substances. The BOD value that exceeds the standard quality indicates high organic pollution from the textile industry process. TSS also high because of the dyeing process generates more solid [9].

Table 3: Wastewater Characteristics at Textile Industry at Pringsurat.

No	Parameter	Unit	Results	Standards Quality
1	BOD	mg/L	**114**	60
2	COD	mg/L	**270**	150
3	TSS	mg/L	**0,8441**	0,5
4	Total Phenol	mg/L	<0,0095	1,0
5	Total Chromium	mg/L	**187,9072**	8,0
6	Ammonia (NH_3 as N)	mgL	<0,0043	0,3
7	Sulphide (as S)	mg/L	**52**	50

3.2. River Water Quality

The results of the textile waste testing laboratory that can be seen in **Table 4** show that of the 5 sampling points have some parameters that exceed the quality standards in the parameters of BOD, COD, Phenol, and Ammonia while on the river before contact with waste or point S1 only phenol parameters exceed quality standards. Referring to Government Regulation No. 22 of 2021 on the Implementation of Environmental Protection and Management, the quality of allotments is included in the category of class 2 because based on the results of the interview shows its use is used as a means of agriculture and recreation of the water of the surrounding residents. The test results showed indirectly the concentration of waste from factory waste that meets quality standards clearly affects the quality of river water as the receiving body. The quality of the river before the outlet point has 1 parameter that exceeds the quality standard, namely the phenol parameter, but after receipt of textile wastewater there is an increase in BOD, COD, phenol, and ammonia parameter on water quality.

Table 4: River Water Quality.

No	Parameter	Unit	Standards Quality	S1	S2	S3	S4	S5
1	BOD	mg/L	3	1,4	**6,8**	**2,6**	**3,4**	**4,1**
2	COD	mg/L	25	17,6	**61,7**	**17,3**	23,6	**32,8**
3	TSS	mg/L	50	7	25	14	22	18
4	Total Phenol	mg/L	0,005	**0,1236**	**0,2501**	**0,0939**	**0,0920**	**0,0843**
5	Total Chromium	mg/L	0,05	<0,0048	<0,0048	<0,0048	<0,0048	<0,0048
6	Ammonia (NH_3 as N)	mgL	0,2	0,0413	**31,7019**	**3,1583**	**3,1980**	**1,5096**
7	Sulphide (as S)	mg/L	0,3	<0,0043	<0,0043	<0,0043	<0,0043	<0,0043

3.3. Groundwater Quality

Laboratory results of water quality testing that can be seen in **Table 5** shows that from 4 sampling points have several parameters that exceed the quality standards in BOD, COD, and Phenol parameters. Referring to Government Regulation No. 22 of 2021 on the Implementation of Environmental Protection and Management, the quality of allotments falls into the category of class 1 because based on the results of interviews showed the use of groundwater used by the community as a source of raw water for the surrounding residents. Based on topographic patterns and the results of measurements of groundwater level, it shows the absence of a direct influence on the impact of wastewater directly discharged into the river on groundwater quality. The existence of several parameters that exceed the quality standards in citizen wells is suspected because of the influence of factory exhaust gases that are not in accordance with ambient air quality standards. This is known from citizen interviews and at the time of water sampling, it was found some white powder from the chimney of textile industry factories.

TABLE 5: Groundwater Quality.

No	Parameter	Unit	Standards Quality	A1	A2	A3	A4
1	BOD	mg/L	2	**5,3**	**2,4**	**5,3**	0,9
2	COD	mg/L	10	**52,1**	**11**	**49,5**	**13,6**
3	TSS	mg/L	25	7	6	13	4
4	Total Phenol	mg/L	0,002	**0,035**	**0,2146**	**0,0834**	**0,0034**
5	Total Chromium	mg/L	0,05	<0,0048	<0,0048	<0,0048	<0,0048
6	Sulphide (as S)	mg/L	0,3	<0,0043	<0,0043	<0,0043	<0,0043

3.4. Pollution Identification and Evaluation

4. River Pollution Index

The results of the pollution index calculation showed that five samples of river water taken into the category of moderately polluted. The highest pollution index values among the five samples taken were in river water samples in contact with sewage, while the lowest were in river water before outlets. There is an increase in the value of the pollution index in river water after contact with waste This is because the results of wastewater discharged directly to the water body have not been adjusted to the specified quality standards. The decrease in the value of the pollution index at the sample point S3, S4, S5 is estimated because of the river's ability to re-decompose polluting substances or commonly called self-purification this ability affects the value to the least point S5 before the continued branching.

Based on these results, it is necessary to be known by the surrounding community and the responsible authorities to be able to control and monitor the condition of the river. In addition, public knowledge is needed to limit the use of rivers such as their use as irrigation or recreation of water in which there are contact activities with water bodies to potentially cause disease. The water quality point of the river can be seen in Figure 2.

TABLE 6: River Pollution Index.

	S1	S2	S3	S4	S5
Pollution Index	5,72	8,966	5,43	5,48	5,32
Classification	Medium Contamination	Medium Contamination	Medium Contamination	Medium Contamination	Medium Contamination

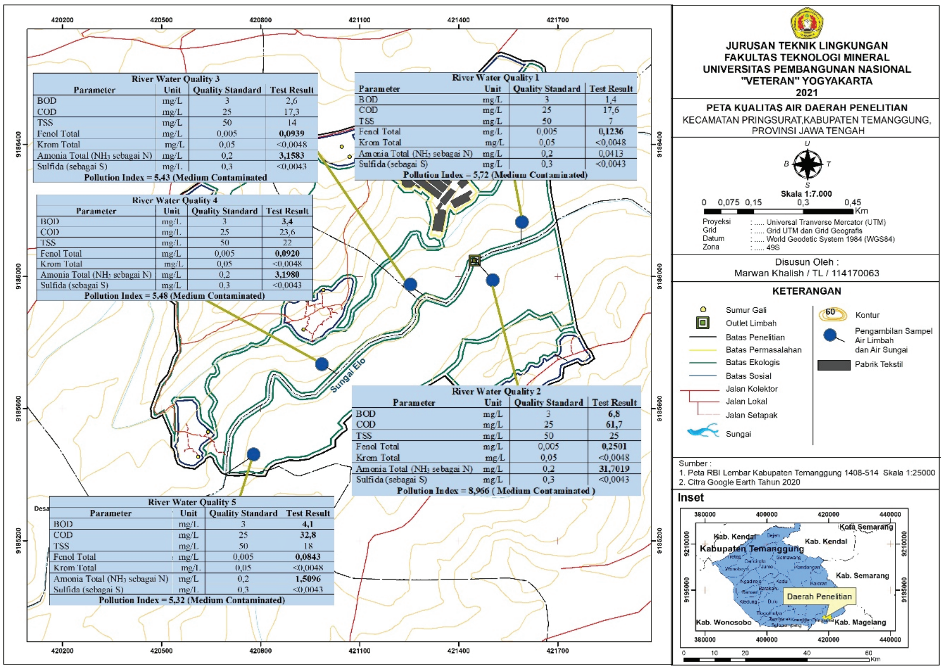

Figure 2: River Pollution Index.

4.1. Groundwater Pollution Index

The results of the pollution index calculation on **Table 6** showed that three groundwater samples taken into the category of moderately polluted and one category of mild. The highest pollution index value among the four samples taken was found in well water sample 2 in Kaligetas Gunung Village, while the lowest was on the side of the river at Grabag Village. Based on the measurement of groundwater level, the condition of the groundwater level is higher than the river water level (effluent). Therefore, the number of parameters that exceed the quality standard is considered as indirect influence from the waste of factory.

The quality of groundwater that has not been in accordance with the designation shows that the community must limit the use of well water as a source of drinking raw water and the relevant government must participate in monitoring and control of waste generated from the textile industry. The status point of well water quality can be seen in Figure 3.

Table 7: Groundwater Pollution Index.

	S1	S2	S3	S4
Pollution Index	**5,441**	**8,32**	**6,77**	**1,65**
Classification	Medium Contamination	Medium Contamination	Medium Contamination	Less Contaminated

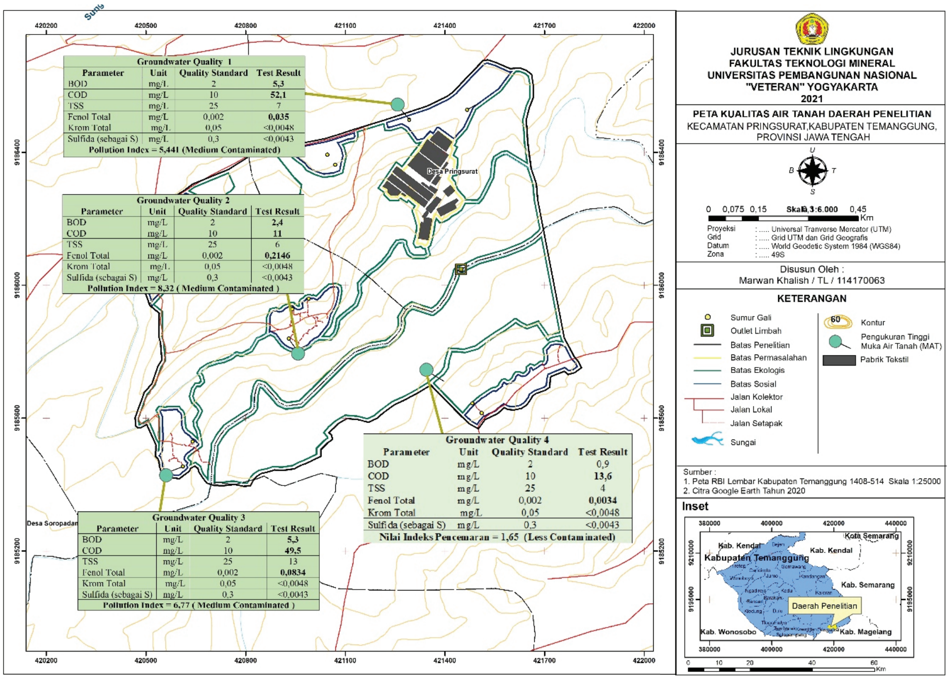

Figure 3: Groundwater Sampling Point.

4.2. Standard Stream Evaluation

Evaluation of wastewater quality is calculated using standard stream evaluation calculations. Evaluation of stream standards is calculated to determine the concentration of mixing domestic wastewater with the receiving water body before the wastewater is treated. The river discharge used in this calculation is 1410 L/s and the waste discharge is 0.28 L/s. Calculated discharge is the actual discharge measured directly in the field using the velocity area method using cork [10]. Based on the results of calculations that can be seen in **Table 7**, 6 of the parameters still meet the existing quality standards, thus, the ability of the river in receiving wastewater from the production of activities is still qualified but there is 1 parameter that is the phenol parameter still exceeds the specified quality standard.

Phenols are elements with high toxic compounds, have a sharp taste and smell and can cause irritation when in direct contact with the skin. Phenols in the water can affect tissues in fish and animals directly [11], [12]. The high concentration of phenols even before contact with waste due to the location of rivers between agricultural land, the high use of pesticides used in the agricultural industry can be a source of high concentrations of phenols in bodies of water. Waste disposal production caused an increase in the concentration of phenols from 0.1236 mg / L to 0.8441 mg / L which the quality standard is 0.005 mg / L.

Based on these results it is known that the company must be able to lower the parameters of phenols in their production efforts or optimize the available processing units so that the resulting concentration can be received by the environment properly, in addition, the role of responsible agencies is needed in monitoring excessive pesticide use in the agricultural industry.

Table 8: Stream Standard Evaluation.

No	Parameter	River Discharge (L/s)	Wastewater Discharge (L/s)	River Quality (mg/L)	Wastewater Quality (mg/L)	Mixing Concentration (mg/L)
1	BOD	1410	0,28	1,4	114	1,422
2	COD			17,6	270	17,65
3	TSS			7	52	7
4	Total Phenol			0,1236	0,8441	**0,1237**
5	Total Chromium			0,0048	0,0095	0,0048
6	Ammonia (NH_3 as N)			0,0413	187,9072	0,078
7	Sulphide (as S)			0,0043	0,0043	0,0043

4.3. Evaluation of Experiments with Laboratory-Scale Constructed Wetland Method

The results of the wastewater quality test after constructed wetland processing can be seen on Table 9

Table 9: Wastewater Quality Test Results with Constructed Wetland.

Parameter	Unit	Iris pseudacorus		Typha Agustifolia		Combination	
		Concentration	Efficiency (%)	Concentration	Efficiency (%)	Concentration	Efficiency (%)
BOD	mg/L	91,3	69,05	32,5	88,98	70,0	76,27
COD	mg/L	172,5	64,24	92,5	80,82	131,6	72,72
TSS	mg/L	16	88,8	15	89,51	14	90,2
Total Phenol	mg/L	<0,0215	89,81	<0,0215	89,81	0,0383	81,84
Total Chromium	mg/L	<0,0095	-	<0,0095	-	<0,0095	-
Ammonia (NH_3 as N)	mg/L	76,7519	60,81	39,2500	79,95	53,3927	72,73
Sulphide (as S)	mg/L	<0,0043	96,71	<0,0043	96,71	<0,0043	96,71

Laboratory-scale experiment results showed that all the most dominant processing efficiency parameters were found in *typha angustifolia* reactors with decreases of

88.98%, 80.82%, 89.51%, 89.81%, 79.95%, and 96.71% respectively. that were able to process 5 of the 6 total parameters tested to meet the specified quality standards, including BOD, COD, TSS, total Phenol, and Sulfide. Processing at *iris pseudacorus* reactor has a less effective processing result compared to the other two variations by only being able to process 2 of 6 parameters to match quality standards, this can occur due to plant adaptation factors that are less maximal compared to typha plant types so that the processing process is also not maximal, in addition, it can also be caused by the age of the plant has not reached the optimal age to be able to allowance the level of pollutants through the process of phytoremediation.

Test results with one type of typha angustifolia plant proved better than its combination with iris pseudacorus. This can be caused by the condition of iris plants that have not been optimal in processing waste, or a combination that is not suitable between the two types of plants so as not to cause competition between plants in absorbing polluting content in wastewater.

5. Conclusion

The problem of textile industry wastewater that has been running for quite a long time in Pringsurat Subdistrict is its ability to treat wastewater that has not been optimal based on the test results found 5 parameters of BOD, COD, Phenol, Ammonia, and TSS that have not met the quality standards with consecutive values of 114 mg / L, 270 mg / L, 0.844 mg / L, 187.9 mg / L, and 52 mg / L. This causes the occurrence of pollution determined using the water quality status of the pollution index shows that in the river water body there are 5 points with pollution index values of 5.72., 8.96., 5.43., 5.48, and 5.32 which all indicate the occurrence of moderate pollution at the point before the outlet, contact and after the outlet. Based on the results of further stream calculations, it is also shown that the mixing concentration produced still has parameters that exceed the quality standard, namely phenol parameters. The design of the constructed wetland experiment with the highest sub-surface flow horizontal sub-surface flow model of a total of 3 variations and a stay of 49.9 hours averaged the efficiency of the highest levels of BOD, COD, TSS, Total Phenol, Ammonia, and Sulfide in the same variation of Typa angustifolia with decreases of 88.98%, 80.82%, 89.51%, 89.81%, 79.95%, and 96.71%. Lowest efficiency in the Iris pseudacorus variation. The combination reactor has a level of efficiency between the other two reactors. This shows that the combination of 2 types of plants does not trigger an increase in the effectiveness of the allowance due to the emergence of competition between 2 types of plants.

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References

[1] P. P. Sarjana, U. Hasanuddin, and N. I. Said, "Pengolahan Air Limbah Industri Kecil Tekstil Dengan Proses Biofilter Anaerob-Aerob Tercelup," *J. Teknol. Lingkung.*, vol. 2, no. 2, pp. 1–145, 2002.

[2] B. Tejokusumo, "Limbah Cair Industri Serta Dampaknya Terhadap Kualitas Air tanah Dangkal Di Desa Gumpang Kecamatan Kartasura," Universitas Sebelas Maret, 2007.

[3] U. Suriawiria, *Air dalam Kehidupan dan Lingkungan yang Sehat*. Bandung: Alumni, 1996.

[4] A. Utami, N. E. Nugroho, S. V. Febriyanti, and T. Nuur, "Evaluasi Air Buangan Domestik Sebagai Dasar Perancangan," *J. Presipitasi*, vol. 16, no. 3, pp. 172–179, 2019.

[5] A. Nurmitha, "Penurunan BOD, COD, dan Fosfat Pada Limbah Laundry Menggunakan Fitoremediasi Dengan Sistem SSF-Wetland Aliran Kontinyu," Universitas Gadjah Mada, 2017.

[6] Kementrian Lingkungan Hidup, "KepMENLH no. 115 Tahun 2003 Tentang Pedoman Status Mutu Air," 2003.

[7] R. Indonesia, "Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Pedoman Perlindungan dan Pengelolaan Lingkungan Hidup," *Sekretariat Negara Republik Indonesia*, vol. 1, no. 078487A. pp. 1–483, 2021, [Online]. Available: http://www.jdih.setjen.kemendagri.go.id/.

[8] Metcalf and Eddy, *Wastewater Engineering Treatment and Reuse*, Fourth. New York: McGraw-Hill, 2004.

[9] D. Mazumder, "Process evaluation and treatability study of wastewater in a textile dyeing industry," *International Journal Energy Endvironmentvironment*, vol. 2, no. 6, pp. 1053–1066, 2011, [Online]. Available: http://ijee.ieefoundation.org/vol2/public_html/ijeeindex/vol2/issue4/IJEE_03_v2n4.pdf.

[10] R. Herschy, "The velocity-area method," *Flow Measurement and Instrumentation*, vol. 4, no. 1, pp. 7–10, 1993, doi: https://doi.org/10.1016/0955-5986(93)90004-3.

[11] Sugiharto, *Dasar-dasar pengelolaan air limbah*. Universitas Indonesia (UI-Press), Jakarta, 2014.

[12] Isyuniarto, W. Usada, A. Purwadi, and Suryadi, “Degradasi fenol dalam limbah pengolahan minyak bumi dengan ozon,” *Prosiding PPI-PDIPT 2005*, vol. 1, pp. 76–81, 2005.