Batik is an Indonesian technique of wax-resist dyeing applied to whole cloth. The designation of the Indonesian batik as a UNESCO Intangible Cultural Heritage has increased demand for batik. Consequently, Indonesia faces severe environmental problems caused by waste/wastewater generated by batik enterprises. However, current circumstances in batik and textile wastewater treatment have not been fully reported. This paper reports the current situations in three wastewater treatment plants (WWTPs) for batik wastewater in Pekalongan City based on field survey and data analysis. Jenggot Village has used a horizontal subsurface flow constructed wetland. Kauman Village has used an activated sludge process. Banyuurip Village has used anaerobic biological treatment followed by constructed wetland. Those WWTPs have conformed to effluent quality standards for temperature, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids, total chrome, total ammonia, and pH, except for BOD and COD concentrations at Jenggot Village WWTP during maintenance period. Influent and effluent quality scores of those WWTPs were evaluated through the effluent quality index (EQI). The respective EQI scores of influent and effluent of the WWTPs were comparable to water resource class III and II scores in Indonesia. The EQI scores suggest that the Banyuurip Village WWTP was the most effective at batik wastewater treatment.

**Key Words**: activated sludge, anaerobic treatment, batik wastewater, constructed wetland, effluent quality index

### 1. INTRODUCTION

Artisans of batik, a hand-dyed fabric ornament in many areas across Southeast Asia, draw designs using dots and lines of hot wax as dye-repellent mask to cover parts of a design. This method allows the artisan to color cloth selectively by soaking the cloth in one color, removing the wax with boiling water, and then repeating the masking and dyeing if multiple color patterns are desired. In 2009, UNESCO designated Indonesian batik as part of the intangible cultural heritage of humanity. The demand for batik increased considerably and also raised the number of batik industry areas. Consequently, Indonesia is confronted by severe environmental problems caused by waste/wastewater generated from the batik industry, especially deterioration in river water quality. Batik wastewater contains high concentrations of hardly biodegradable organic compounds with high pH and temperature, and strong color. Some azo dyes in the batik industry are aromatic compounds that are toxic, mutagenic, and carcinogenic. In Malaysia, where batik is also famous, the biological treatment process alone or physicochemical treatment followed by a biological treatment process is commonly used in major textile industries.

In Laweyan Batik Village, Sukoharjo, Central Java Indonesia, wastewater is treated at a wastewater treatment plant (WWTP) using physical treatment by filtration and sedimentation, followed by anaerobic...
biological treatment, absorption, and constructed wetland\textsuperscript{7}). However, current circumstances in batik and textile wastewater treatment in other regions of Indonesia have not been fully reported.

In Pekalongan City, a major batik-producing area in Central Java, Indonesia, small and medium enterprises in the batik industry play an important economic role. Although details on WWTPs managed by private sectors in the city are not well known, Pekalongan City operates three batik WWTPs using biological treatment systems to meet wastewater-quality standards set by the Central Java Local Government. However, the scattered locations of batik enterprises lead to difficulties in providing wastewater treatment to all customers.

This paper reports the current situations of three WWTPs for batik wastewater in Pekalongan City: Jenggot Village, Kauman Village, and Banyuurip Village. The influent and effluent qualities of these WWTPs were evaluated using the effluent quality index (EQI). The EQI is a tool for the evaluation of overall effluent quality, translating several parameters to a single score\textsuperscript{8}). This index is helpful for water resource planners and decision makers to compare water quality from different samples and to evaluate standards and criteria\textsuperscript{9}).

### 2. SURVEY OF BATIK WWTPS

Hearing surveys for three batik WWTPs were done in Jenggot, Kauman, and Banyuurip Villages in Pekalongan City in February 2019. Basic data on the WWTPs are shown in Table 1 and Fig. 1. The city has decided that all three WWTPs use mainly biological treatment processes, which have lower operation and maintenance costs than those of physicochemical processes.

Basic data on the influent and effluent qualities of the WWTPs were provided by the city government, as shown in Tables 2, 3, and 4. The wastewater-quality standard for textile and batik production are \(<38^\circ\text{C}, <60 \text{ mg/L biochemical oxygen demand (BOD)}\) for five days, \(<150 \text{ mg/L chemical oxygen demand (COD)}, <50 \text{ mg/L total suspended solids (TSS), <0.5 mg/L total phenol, <1.0 mg/L total chrome, <8.0 mg/L total ammonia (NH}_3\text{-N}, <0.3 \text{ mg/L sulfide (as S), <3.0 mg/L oil and fat, and 6.0–9.0 pH (Central Java Province Government Regulation No. 10 Year 2004 on Wastewater Quality Standards). The Environmental Government Office of the city has measured seven parameters for the WWTPs: temperature, BOD, COD, TSS, total chrome, total ammonia, and pH.}

#### Table 1 WWTPs for batik wastewater in Pekalongan City.

| Location        | Main processes                                  | Area (m\textsuperscript{2}) | Capacity (m\textsuperscript{3} day\textsuperscript{-1}) | Installed year | Const. cost (Rp) | Operation cost (Rp) | Enterprise served | Maintenance                          |
|-----------------|-------------------------------------------------|------------------------------|----------------------------------------------------------|----------------|-----------------|--------------------|-----------------|--------------------------------------|
| Jenggot Village | Constructed wetland                            | 3,000                        | 400                                                       | 2001           | 1.7 billion     | 50 million         | 80              | Extracting clogged grass and gravel  |
| Kauman Village  | Activated sludge                                | 200                          | 150                                                       | 2007           | 1 billion       | 90 million         | 23              | Adding nutrition                      |
| Banyuurip Village | Anaerobic pond and constructed wetland         | 500                          | 250                                                       | 2017           | 1.4 billion     | 30 million         | 40              | Adding nutrition                      |

Fig. 1 Schematic diagram of the Jenggot Village WWTPs in Pekalongan City. (A) Jenggot Village WWTP, (B) Kauman Village WWTP, and (C) Banyuurip village WWTP.
(1) Jengggot Village WWTP

Since 2001, Jengggot Village has used a horizontal subsurface flow constructed wetland system with capacity of 400 m³ day⁻¹ and operational cost of 50 million Rp year⁻¹. From the equalization pond, wastewater enters the five parallel constructed wetlands of 3,000 m² total area (Fig. 1 (A)). Waste sludge is withdrawn from the equalization tank once a year. The constructed wetland uses zeolite on impermeable sheets as a porous-filter medium. Heliconia sp. is planted in the wetland. Vegetation has generally better effects than plant-free systems for removal of pollutants because of increased supply of oxygen to the rhizosphere (10). The constructed wetland with subsurface flow is recommended for textile wastewater treatment to decrease color in anaerobic conditions in the deep zone (11). A shortcoming of constructed wetlands is substrate clogging caused by accumulation of solids, which reduces oxygen infiltration into the media. Because of their open-air construction, the high intensity of tropical rainfall can cause batik wastewater to overflow into rivers.

Table 2 presents water-quality data of the Jengggot Village WWTP. Reportedly, all seven effluent parameters of the WWTP satisfied the wastewater quality standard for textile and batik industry wastewater in 2018, except for BOD and COD during the maintenance period in February (12). This exception was also probably attributable to the large fluctuation in wastewater quality and quantity of batik enterprises, which are strongly influenced by market demand.

(2) Kauman Village WWTP

The Kauman Village WWTP has used an activated sludge process since 2007 for batik wastewater treatment with 200 m² area, 150 m³ day⁻¹ capacity, and operational cost of 90 million Rp year⁻¹ (Fig. 1 (B)). The activated sludge process is recognized as an effective method for degrading and mineralizing various organic pollutants on a large scale, although high energy expenditures are necessary for aeration. Another difficulty is its production of excess sludge as organic waste. Although this WWTP was designed to combine chemical coagulation and biological treatment, chemical treatment was omitted because of the high costs of inorganic sludge treatment. Table 3 presents the Kauman Village WWTP water-quality data. Effluent parameters at Kauman Village WWTP complied with the quality standard, except for COD in July 2018 (12).

(3) Banyuurip Village WWTP

The Banyuurip Village WWTP has used anaerobic biological treatment and a constructed wetland process since 2017, with 500 m² area, 250 m³ day⁻¹ capacity, and an operational cost of only 30 million Rp year⁻¹ (Fig. 1 (C)). The city government designed this latest WWTP for low operation and maintenance costs.

Batik wastewater first flows to equalization tanks and subsequently to anaerobic biological tanks. Synergistic microbial consortiums anaerobiically sequentially convert organic matter finally into methane and carbon dioxide with low sludge production and low

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**Table 2** Water quality of influent and effluent at the Jengggot Village WWTP (12).

| Parameter       | Unit | February 2018 | Effluent | July 2018 | Effluent | October 2018 | Effluent |
|-----------------|------|---------------|----------|-----------|----------|--------------|----------|
| Temperature     | °C   | 29            | 29       | 29        | 29       | 29           | 29       |
| BOD₅            | mg/L | 193           | 188      | 83        | 38       | 272          | 43       |
| COD             | mg/L | 513           | 302      | 324       | 67       | 647          | 45       |
| TSS             | mg/L | 47            | 11       | 53        | 7        | 69           | 4        |
| Total chrome    | mg/L | 0.046         | <0.01    | ND        | ND       | 0.01         | 0.02     |
| Total ammonia   | mg/L | 1.2           | 1.2      | 7.3       | 2.8      | 10.7         | 1.2      |
| pH              | -    | 8.2           | 7.5      | 7.5       | 7.2      | 8.0          | 7.7      |

ND, no data.

**Table 3** Water quality of influent and effluent at the Kauman Village WWTP (12).

| Parameter       | Unit | February 2018 | Effluent | July 2018 | Effluent |
|-----------------|------|---------------|----------|-----------|----------|
| Temperature     | °C   | 25            | 30       | 28        | 28       |
| BOD₅            | mg/L | 1516          | 11       | 51        | 9        |
| COD             | mg/L | 2636          | 77       | 1046      | 164      |
| TSS             | mg/L | 2             | 17       | 195       | 20       |
| Total chrome    | mg/L | 0.023         | <0.1     | ND        | ND       |
| Total ammonia   | mg/L | 1.2           | 1.2      | 0.4       | 0.2      |
| pH              | -    | 9.8           | 8.0      | 8.8       | 8.0      |

ND, no data.
energy requirement\textsuperscript{2}). The final process is a constructed wetland (15×7 m with 1 m depth) packed with 4–10 cm diameter rocks and planted with three plants: Heliconia sp., Typha sp., and Papyrus sp. Soluble pollutants including nitrogen, phosphorus, and other minerals are generally absorbed by the wetland plants via the epidermis and root vascular bonds and transported further up to the stem and leaves\textsuperscript{10}. Some organic pollutants are degraded by microorganisms in the rhizosphere. To improve effluent quality, wastewater is recirculated from anaerobic biological treatment to the equalization pond and from the outlet of the constructed wetland to the inlet. The salient shortcomings of anaerobic treatment include the difficulty of degrading some specific aromatic compounds. Moreover, rainfall can cause batik wastewater to overflow into rivers because this WWTP system, except for the anaerobic tanks, is open to air.

Table 4 shows the water-quality data of the Banyuurip Village WWTP. All seven effluent parameters of the WWTP constituted the quality standard for textile and batik industry wastewater in 2018.

### 3. EFFLUENT QUALITY INDEX

The influent and effluent quality scores of those WWTPs were evaluated using EQI with water resource class criteria used in Indonesia.

\[
\text{EQI} = \sum W_i / I_i
\]

where \( W_i \) is the weight of the parameter and \( I_i \) is the subindex score of the parameter.

No complete data exist for the total chrome concentration in the Jenggot Village WWTP and the Kauman Village WWTP. Therefore, six of the seven parameters were used for EQI calculations. A report on EQI\textsuperscript{10} assigned weights from Min. 1 to Max. 5 to 13 water-quality parameters, namely, temperature, BOD, COD, TSS, NH\textsubscript{4}-N, pH, total dissolved solids, alkalinity, fecal coliform, total phosphorus, phosphate, total Kjeldahl nitrogen, and nitrate. Those were 2.63, 2.54, 2.53, 3.02, 3.28, and 2.97, respectively, for temperature, BOD, COD, TSS, NH\textsubscript{4}-N, and pH. Based on these weight ratios, the parameter weight (\( W_i \)) in this study was normalized as temperature 0.155, BOD 0.150, COD 0.149, TSS 0.178, NH\textsubscript{4}-N 0.193, and pH 0.175 (\( \sum W_i = 1.000 \)). The value of each selected parameter was scored to the subindex (\( I_i \)) with a range of 0–100, from acceptable to unacceptable. Mathematical functions for evaluating the subindex score have been described elsewhere\textsuperscript{8}.

The water resource quality in Indonesia was also scored using EQI. As shown in Table 5, the water resource quality in Indonesia is classified into four levels based on Government Regulation of Indonesia No. 82 Year 2001. Actually, the total ammonia concentration is not defined for classes II, III, and IV. For convenience, the EQI score for those classes were calculated using the total ammonia subindex score of 100 (total ammonia >53mg/L) as the worst case.

Fig. 2 shows the EQI scores of influent and effluent of the WWTPs. The EQI scores of all batik wastewater at three WWTPs in Pekalongan City were higher than 56.2, which was that of water resource class III. Effluent samples of the WWTPs yielded EQI values that were mostly lower than 45.5, which were those of water resource class II. The Jenggot Village WWTP, which used a constructed wetland system, had a considerably high EQI score, especially in terms of the TSS and NH\textsubscript{4}-N subscores. The Kauman Village WWTP, which used an activated sludge system, lowered the EQI score by reducing the BOD and pH subscores. The Banyuurip Village WWTP using a combination of anaerobic biological treatment and constructed wetland reduced its TSS, NH\textsubscript{4}-N, and pH subscores. Although the COD concentration was well reduced in all WWTPs, the COD subscore was still very high in effluent. According to the equations\textsuperscript{8}, the subindex score for COD >165 mg/L was 100, and that for COD = 50mg/L was 92, respectively. The EQI scores of the effluent samples were ranked as Jenggot Village WWTP > Kauman Village WWTP > Banyuurip Village WWTP. It is noteworthy that small-scale WWTPs usually have large fluctuation in water quality. Also, only 6 of the 46 physical, chemical, and microbiological parameters for water classification in Indonesia were considered in the EQI measurement used for this study. Other water-quality parameters such as total chrome, total phenols, sulfide, and oil and fat should also be considered.

### 4. CONCLUSIONS

Three WWTPs for batik wastewater in Pekalongan City conformed to the effluent quality standards of
Central Java Local Government regulations for temperature, BOD, COD, TSS, total chrome, total ammonia, and pH, except for BOD and COD concentrations at Jenggot Village WWTP during a maintenance period in February 2018 and the COD concentration at Kauman Village WWTP in July 2018. The EQI indicates that the WWTP treatment systems improved water quality. The EQI scores of influent and effluent of the three WWTPs were comparable to the scores of water resource classes III and II in Indonesia. However, not all wastewater produced by batik enterprises is treated because of the limited capacity and the limited availability of land for WWTPs: batik enterprises are mostly located in densely populated areas. In addition to the effective operation of the existing WWTPs, construction and operation of new WWTPs are necessary for sustainable development of the batik industry.

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