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Analysis of Heavy Metals Concentration in Textile Wastewater in Batik Industry Center

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Abstract: The textile industry is the main source of environmental pollution in terms of quality and quantity. It consumes large amounts of water (200 m3/ tonne of products), and around 90% of the quantity is wastewater. Improper disposal of textile wastewater will cause serious environmental problems due to the presence of heavy metals in the waste which will adversely affect aquatic organisms. To analyze, the concentration of heavy metals in textile (batik) wastewater was collected from 15 small, medium, and large-scale textile industry waste disposal centers located at the Batik Industry Center of Kampoeng Batik Laweyan Surakarta, Indonesia August 2019. Standard methods of 22nd Edition 2012 APHA -AWWA-WEF with inductively coupled plasma optical emission spectroscopy (ICP-OES) was used to analyze the concentration of Iron (Fe), Copper (Cu), Chromium (Cr), Cadmium (Cd), Lead (Pb) and Nickel (Ni) in the sample. The results of the analysis showed that from 15 sample locations, several locations had levels of Cu, Pb, Ni, Cr, and Cd below the detection limit, i.e. 2 (<0.01 ppm), 13 (<0.02 ppm), 13 (<0.01 ppm), 15 (<0.01 ppm), and 15 (<0.02 ppm) locations for each metal respectively, while Fe levels were above the detection limit at all locations. The mean levels and number of locations for Fe, Cu, Pb, and Ni were 2.63 ± 5.01 (n = 15), 0.48 ± 0.99 (n = 13), 0.05 ± 0.03 (n = 2) and 0.02 ± 0.00 (n = 2) and the ranges of each metal level were 0.07-19.4 ppm, 0.01-3.73 ppm, 0.02-0.07 ppm, and 0.01-0.02 ppm respectively. Among these heavy metals, the highest concentration was Fe, and all samples had Cr and Pb levels below the detection limit. By comparing the results of this study with the safe limit for industrial wastewater according to Central Java Provincial Regulation No. 5 of 2012, only wastewater originating from two sampling locations can be used for irrigation and aquaculture, namely at locations B2 and B5.

Keywords: Heavy metal concentration; Textile industry; Wastewater

Introduction

The textile industry is a major source of environmental pollution in terms of quality and quantity (Sakamoto et al., 2019). The textile industry consumes a large amount of water (200 m^3/tonne of product), of which about 90% of the quantity ends up as wastewater. Improper disposal of textile wastewater will cause serious environmental problems due to the presence of heavy metals in the waste which will have a negative impact on aquatic organisms (Alif et al., 2020; Chowdhary et al., 2020; A. A. Khan et al., 2022; F. S. A. Khan et al., 2021; Mondal et al., 2017; Velusamy et al., 2021) with the emergence of human civilization, population growth, the industrial revolution and rapid urbanization, water assets are now often used as a dumping ground for industrial and domestic waste.

The Kampoeng Batik Laweyan industrial area is one of the largest batik industrial centers in Surakarta City. Although not all industries produce waste, if any of the waste that is produced containing certain chemical

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compounds with toxic and hazardous materials is released into the environment, this will result in pollution, both in rivers, soil and air. Several times it was found that the color of the water in the Jenes River, which passes through the Laweyan batik industrial area, turned dark red, dark green and even pitch black. The results of monitoring conducted by the Surakarta City Environmental Service regarding the quality of 6 river waters in Surakarta City show that the Jenes River is polluted.

There are approximately 10,000 chemical-based dyes found in nature with a global annual production of nearly 7 × 10^5 metric tones (Dhruv Patel & Bhatt, 2022; Khataee & Kasiri, 2010). The main aesthetic problem of textile waste is color, due to the use of many synthetic organic compounds as dyes. Chromophores, which have azo bonds (–N = N–), can be mono-azo, di-azo, and poly-azo; –C = O; –N = O, etc., are responsible for the coloring properties of dyes. The shipment of untreated textile wastes including liquid, gas and solid wastes causes severe environmental problems, affecting aquatic ecosystems by reducing the penetration of sunlight and thereby reducing the rate of photosynthesis as well as increasing the demand for biological oxygen (Lenka & Kant, 2012).

Heavy metal waste from the textile industry mainly comes from dyes (Panigrahi & Santhoskumar, 2020). Heavy metal waste produced includes: heavy metals arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), copper (Cu), zinc (Zn). The reason dyes contain heavy metals is because they are used as catalysts during the dye manufacturing process, besides that they are part of the dye molecules (Kurniasih, 2008). An increase in liquid waste that is not managed properly causes a decrease in the quality of surface water and ground water. The results of monitoring conducted by the Surakarta City Environmental Service regarding the quality of 6 river waters in Surakarta City show that the Jenes River is polluted. The purpose of this study was to analyze the concentration of heavy metals in textile (batik) waste water in small, medium and large-scale textile industry centers located in the Batik Industry Center Kampoeng Batik Laweyan Surakarta, Indonesia.

Method

This research is an analytic observational study using the standard method 22nd Edition 2012 APHA - AWWA-WEF with the Inductively Coupled Plasma Atomic-Optical Emission Spectrometry (ICP-OES) used to analyze the concentrations of Iron (Fe), Copper (Cu), Chromium (Cr), Cadmium (Cd), Lead (Pb), and Nickel (Ni) in the sample. The population in this study was all batik industry wastewater from small, medium and large-scale batik industry outlets in Kampoeng Batik Laweyan.

This research was conducted at the Kampoeng Batik Laweyan Industrial Center, Laweyan District, Surakarta City, Central Java. This location is the largest batik industrial area in Surakarta City. Samples were taken from 15 textile industry waste disposal centers representing small, medium and large-scale industries in the Kampoeng Batik Laweyan Industrial Center area.

The research subjects used were wastewater from small-scale (5 industries), medium-scale (5 industries), and large-scale (5 industries) batik industries in Kampoeng Batik Laweyan. Each industry takes 1 liter of waste water from the holding tanks. Furthermore, samples from small-scale industries were coded A (A1, A2, A3, A4, and A5), samples from medium-scale industries were coded B (B1, B2, B3, B4, and B5), and samples from large-scale industries were given code C (C1, C2, C3, C4, and C5).

Result and Discussion

Result

Sampling of wastewater was carried out at 15 batik industry outlets in Kampoeng Batik Laweyan. Sampling was incidental sampling because not all industries produce waste on the same day. The batik industry from which wastewater samples were taken includes 3 types, namely small industry, medium industry, and large industry. Parameters measured included: Iron (Fe), Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Copper (Cu).

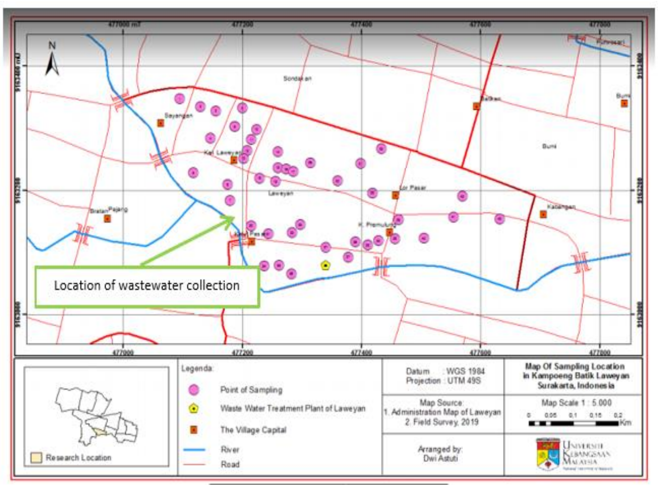

Figure 1. Map of the location where textile waste samples were taken at the Kampoeng Batik Laweyan Surakarta Center.

Table 1. Results of Examination of Heavy Metal Parameters in Wastewater from the Laweyan Surakarta Batik Industry

Parameter	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	Methods (APHA-AWWA-WEF, 2012)
Iron	0.24	0.71	0.29	1.41	0.07	1.76	0.18	0.91	5.45	0.09	1.52	6.25	0.45	0.76	19.4	3120 B, 3030 E
Copper	<0.01	<0.01	0.14	0.42	0.18	0.19	0.08	0.27	0.53	0.02	0.13	0.11	0.39	0.07	3.73	3120 B, 3030 E
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	3120 B, 3030 E
Cadmium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	3120 B, 3030 E
Lead	<0.02	<0.02	<0.02	<0.02	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	3120 B, 3030 E
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	3120 B, 3030 E

Measurements that have been carried out from 15 outlets of batik industrial waste in Kampoeng Batik Laweyan show that 10 of them exceed the maximum allowable iron content. In the Decree of the Minister of Health No. 492 /Menkes /Per /IV / 2010 concerning Water Quality Requirements, the maximum allowable iron content is 0.3 mg/l. Samples whose iron content exceeds the maximum threshold include A1, A4, B3, B4, C1, C2, C3, C4, C5. In the copper parameter, there is only one industry whose measurement results exceed the maximum allowable content limit, namely a sample of C5 with a concentration of 3.73 mg/l.

Table 2. Data of Coordinate Points for Industrial Wastewater Sampling Batik Laweyan Surakarta

Sample Code	Coordinate point
A1	-7.570170,110.792542
A2	-7.570393,110.797496
A3	-7.569670,110.793132
A4	-7.568814,110.799254
A5	-7.569028,110.798263
B1	-7.568851,110.792632
B2	-7.570765,110.798494
B3	-7.569185,110.793365
B4	-7.571795,110.793718
B5	-7.569978,110.800291
C1	-7.571989,110.293823
C2	-7.570026,110.793685
C3	-7.571937,110.793209
C4	-7.570854.110.794754
C5	-7.570689,110.795753

The parameter content of nickel in Kampoeng Batik Laweyan waste does not exceed the maximum threshold set at 0.07 mg/l. The lead content in all waste samples exceeded a predetermined maximum limit of 0.01 mg/l. The chromium content in all samples did not exceed the maximum allowed limit, which was 0.05 mg/l. The next parameter is Cadmium with all levels exceeding the allowable threshold.

Table 2 shows the coordinates of the sampling locations for small-scale industries coded A (A1, A2, A3, A4 and A5), samples from medium-scale industries coded B (B1, B2, B3, B4 and B5), and samples from large-scale industries are coded C (C1, C2, C3, C4, and C5).

Discussion

Today the batik industry has a special attraction for new entrepreneurs because batik is one of the leading commodities and has become one of the characteristics of Indonesia to attract tourists. The city of Surakarta, which is located in Central Java, has one sub-district which is one of the famous Batik Industry centers in Indonesia. Laweyan District with the nickname Kampoeng Batik Laweyan is the center of the largest batik industry in Surakarta City.

The process of making batik requires dyes that come from synthetic dyes that contain heavy metals. Heavy metals, one of the most dangerous pollutants that can pose a serious threat to humans and the environment. Most of the waste is directly discharged into the environment without going through the processing process first. This is due to the not yet optimal management of the WWTP and the lack of public awareness in the process of environmental preservation. This condition has a negative impact on the surrounding community, especially in terms of environmental health.

Industrial development has an important role for human life (Yaqoob et al., 2020). In addition, these developments also have a negative impact. One of the impacts that arise is the production of waste from existing processes in the industry. One type of hazardous waste is waste containing heavy metals. This is because waste containing heavy metals is toxic and non-biodegradable (Ahmed et al., 2021; Naimah & Aidha, 2017). One type of heavy metal that has high toxicity is copper (Cu). Cu metal is an essential metal because it is needed in certain amounts by organisms. These metals can cause toxic effects at certain levels (Maier, 2008). At a concentration of 0.01 ppm it can kill phytoplankton and at a concentration of 2.5–3 ppm waste containing Cu can kill fish (Fitriyah, 2013).

Liquid waste originating from industrial activities can contain several chemical contaminants in the form of compounds or heavy metals (APTKLI, 2019). Measurement of several parameters of heavy metals is very important in the process of monitoring the content of wastewater before it is discharged into river bodies. Parameters that have been tested include: Iron (Fe), Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Copper (Cu). The results of measurements of 15 (fifteen) outlets of batik industry waste that have been carried out in Kampoeng Batik Laweyan show that Nickel and Chromium levels do not exceed the maximum limits that are allowed to be in wastewater.

Iron (Fe) is an essential metal that is needed by living things in certain quantities so that it does not cause certain effects (Kamarati et al, 2018). The content of Fe in the body is needed in the formation of hemoglobin, but if the levels exceed the limit, it can cause poisoning and can even cause diseases such as cancer, liver and liver disease (Apriyanti, 2018). Lead (Pb) can easily cause nerve poisoning. Pb can also cause damage to the brain's nerve tissue, anemia and even cause paralysis. All of these can occur if the Pb level in drinking water is greater than 0.1 mg/l (APTKLI, 2019). Usually, people with lead poisoning are characterized by headaches, muscle aches, weakness and irritation (Ariana et al., 2020).

Cadmium can easily kill aquatic biota with a solubility rate of 1 ppm (Tarigan & Rozak, 2003). Cadmium has toxic properties and is very harmful to all living organisms, including humans. Chromium content is usually obtained from the washing process after dyeing batik cloth. The nature of Cr metal itself is carcinogenic or can cause cancer and can be toxic when it is in the waters (Sari, 2008). According to APTKLI, (2019) if the Cr level in water is more than 0.005 mg/dl, it can cause cancer of the skin and respiratory organs.

Nickel (Ni) is a type of metal that is very resistant to corrosion and oxidation at high temperatures, so it can be used to produce stainless steel. Ni is dispersed and is in the earth's crust naturally in combination with arsenic, antimony, oxygen, sulfur, oxides, silicates, sulfides and arsenides (Widowati et al., 2008). Usually Ni in water comes from sewage sludge, liquid waste, or from groundwater near landfill sites. Ni is found in DNA and RNA which functions to stabilize the structure of nucleic acids and proteins and is a cofactor for several enzymes. Nickel deficiency can cause damage to the liver and other organs (Ridhowati, 2013). Nickel exposure can occur through oral or direct skin contact. Copper (Cu) if the level in water is greater than 1.5 mg/l, can cause damage to the liver. In small amounts, copper does not interfere with health because it is needed in the process of metabolism and is also needed for the formation of red blood cells.

The emergence of the batik industry widely, forcing industrial owners to be serious in managing their waste. There is no denying the fact that nature has an amazing fascination for dealing with small amounts of wastewater and water pollution, but it would be very brave if large quantities of untreated wastewater were discharged into natural water bodies. Receiving and discharging water bodies carry hazardous industrial impacts that affect water quality and aquatic ecosystems and human life.

World recognition through UNESCO (United Nations Educational, Scientific, and Cultural Organization) seems to have had a significant influence on the growth of the batik industry in Indonesia because it was recognized as a genuine Indonesian cultural heritage on October 2, 2010. For example, the Pekalongan batik business grew by 40% and in the regions Initially there were only a few batik industries in East Java, but now the number is evenly distributed in 38 districts throughout Indonesia. Apart from that, batik in other areas such as Jambi and Bengkulu also increased, with regional characteristic motifs. This growth can also be seen from the increase in batik exports which reached US$ 11.5 million in 2010 (Kusumawati et al., 2012).

The positive impact of UNESCO recognition is also felt by the people of Surakarta, especially Laweyan batik craftsmen. The number of batik business units experienced a significant increase. However, of the positive effects arising from the development of the batik industry, there are a number of problems related to wastewater treatment because the batik industry is one of the largest industries in terms of using water in every step of production so that the waste water produced is very large.

Although heavy metal concentrations do not exceed the limits set by National and International regulatory agencies, values from Pearson correlation analysis conducted by Syuhadah et al. (2015) show that heavy metal concentrations in soil and plants are strongly influenced by heavy metal concentrations in waste (Zhou et al., 2023). batik, this may be because there is exposure to batik waste that has been used up without prior treatment. If this activity continues, sooner or later it will increase the concentration of heavy metals in plants and soil around the batik factory.

Conclusion

The batik industry for which wastewater samples were taken includes 3 types, namely small industry, medium industry, and large industry. The number of samples measured were 15 samples from different industries. Parameters measured included: Iron (Fe), Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Copper (Cu). The results of measurements of Fe levels, 10 industries showed levels exceeding the maximum allowable levels. Copper content is only found in one industry that exceeds the maximum threshold. Nickel and chromium parameters do not exceed the maximum allowed. The content of lead and cadmium in all samples exceeded the maximum allowable threshold. By comparing the results of this study with the safe limits for industrial wastewater according to Central Java Provincial Regulation No. 5 of 2012, only wastewater from two sampling locations can be used for irrigation and aquaculture, namely locations B2 and B5.

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