Initiating "Healthy Batik Village"/ “Desa Batik Sehat” to Empower Batik Workers Through Collaborative Health, Environmental and Social Interventions

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Abstract

Background: Beautifully and colorfully dyed batik cloth is an Indonesian cultural heritage. Batik production exposes workers and the environment to various physical and chemical hazards. This interdisciplinary study aimed to assess the environmental and health parameters of batik workers, and apply environmental and health interventions to achieve environmentally friendly batik production with no human hazards.

Methods: To assess the environmental pollutants, the wastewater quality parameters were measured. Air pollutant assessment was done using a low volume sampler. Liver, kidney function and blood chromium were compared between batik workers and healthy controls. Health interventions were done to choose the best gloves for the batik workers followed with assessing convenience level of selected gloves and identifying obstacles that prevent them from using gloves properly. The effectiveness of nerve gliding and wrist exercises in improving carpal tunnel syndrome clinical symptoms were evaluated. Environmental interventions were done by developing wastewater treatment technology using modified electrochemical systems. To assess the sustainability of the “Healthy Batik Village”, we analyzed batik owners’ and workers’ commitment using multi-dimensional scaling methods.

Results: The parameters of water pollutants were above the national standard for wastewater, while theair pollutants were still below the standard threshold, withAl, Fe, Cu, and Zn having the highest breathing zone concentrations. There were significant differences ($p<0.05$) in liver and kidney function levels between batik workers and controls. The modified electrochemical system using graphene electrodes was effective to degrade the dyes used in batik production. Based on the market survey, literature study and comfort assessment, neoprene gloves were chosen as a test glove. Neoprene gloves were considered significantly more convenient compared to polyvinylchloride (PVC) gloves as the workers’ daily gloves ($p<0.05$).Nerve gliding exercises and wrist splints were effective in causing noticeable carpal tunnel syndrome clinical improvement. Improvements in workers' health, high quality of batik waste treatment, and an ideal management strategy are needed for the sustainability of the "Healthy Batik Village".

Conclusion: This study showed there were occupational and environmental hazards exposed to the workers. The health, environmental, and social interventions executed are part of the implementation research to establish the “Healthy Batik Village”.

Background

Batik, a beautifully designed and colorfully dyed Indonesian heritage cloth material, has been recognized as a United Nations Educational, Scientific and Cultural Organization (UNESCO) Intangible Cultural Heritage since 2009. On top of that, Yogyakarta, a major city on the Indonesian island of Java, was proclaimed as the World Batik City by the World Craft Council (WCC) in 2014. The batik industry has contributed significantly to Indonesian people’s prosperity. At the same time, this prosperous condition is

followed by new problems regarding the environment around the batik industry and the health of the batik workers.

The process of batik making exposes workers to irritative, toxic, and carcinogenic chemicals as well as physical hazards (non-ergonomic working positions and processes, working with hazardous liquid, hot fumes, and inadequate lighting), causing a high prevalence of occupational diseases, including skin and neurological problems.

The use of synthetic dyes increases the exposure to dangerous pollutants such as heavy metals, suspended solids, and organic matter. These pollutants can enter the body through the skin and respiratory mucous membranes. A previous study done by our research group among batik workers in Yogyakarta province showed a relatively high prevalence of occupational contact dermatitis (10.36%) [1]. The results prove the importance of occupational safety precautions such as Personal Protective Equipment (PPE) use for batik industry workers.

The use of PPE is one of the essential components to protect workers from dangerous pollutant exposure. Batik workers employed in the dyeing section need to wear gloves. The commercially available ones include gloves made from latex, butyl, neoprene, nitrile, or a mixture of the four materials, which will give protection from chemical exposure [2]. Literature study, market survey and comfort tests were done for choosing the best gloves, followed by comparing the convenience level of selected glove with batik workers' daily gloves.

Since batik workers work in the same position for long periods of time with repetitive and forceful movements of the hand and wrist, Carpal Tunnel Syndrome (CTS) is a fairly common condition in batik workers [3]. CTS results from irritation, compression, or stretching of the median nerve as it passes through the carpal tunnel in the wrist. While the conventional therapy for CTS consists of splinting, local corticosteroid injections, or oral medications, nerve gliding exercises can accelerate rehabilitation process, lessen pain, improve function, and avoid the need for surgical intervention [4]. This encouraged the Neurology Department team to give additional nerve gliding exercises, aside from splinting, to the batik workers with CTS.

The batik industry is one of the producers of colored liquid waste. It also uses several variations of dyes, solvent compounds and color enhancing salts that contain heavy metal and wax particles. Observations showed that batik making produces wax waste in a mixture of oil, fat, and some different synthetic materials. The inadequate management of liquid waste causes water pollution by heavy metals such as ferrous sulfate ($FeSO_4$), sodium carbonate (Na_2CO_3), calcium carbonate ($CaCO_3$), and *water glass* ($NaSiO_3$) [5]. Several efforts have been made to manage batik wastewater; one of them involves the installation of 12 units of the wastewater treatment plant in 2014 through the small and medium-sized enterprises program in Lendah. However, the effluents from the existing-wastewater treatment plant are still out of the range of the local minimum effluent standards. Besides that, they need a mobile wastewater treatment facility that can be used by each home industry alternately. This study needs to be

done due to the increased amount of chemical waste in conjunction with the continuous development of the Indonesia batik industry.

The measurements for metal concentration levels in waste and water samples collected from three locations in Lendah Sub-District showed an increase over the standard threshold, ranging around 52–82 µg/dL Lead (Pb) and 15–33 µg/dL Chromium (Cr) [6]. The chronic exposure of those heavy metals is predicted to alter several organ functions, including the liver and kidneys [6]. In this study, we compared the liver function and renal function between the exposed group (batik workers) and non-exposed group (controls). To solve these environmental problems,we aimed to develop methods and appropriate technologyto treat batik waste optimally with established safety and quality standards.

Occupational safety and health protection for batik workers are still below standard. Most business owners have not paid attention to the occupational safety and health of informal workers, as can be seen from the non-existence of regulations stemming from existing Indonesia legislation on occupational safety nor the special budget to increase occupational safety and health. Primary health care and the district health office have tried to do cadre coaching and development, but these efforts have not been successful. We aimed to study the status and sustainability of the “Healthy Batik Village” program in terms of economic, ecological, and social considerations.

The health and safety issues in the batik home industry are very complex and to solve these problems, interdisciplinary collaboration needs to be done. Our research team consists of experts in chemistry, environmental health, toxicology, dermatology, neurology, public health and human ecology.

Methods

Study design and setting

We conducted this study in Lendah, a sub-district of Kulon Progo, Yogyakarta, Indonesia. There are 15 Micro and Small Enterprises (MSEs) of batik in this area. We conducted three interventions, namely environmental, health, and social, to actualize a “Healthy Batik Village” that prioritizes occupational and health safety and is environmentally friendly (our motto: Environmentally Friendly and No Human Hazards). Informed consent was obtained from all individual participants included in the study, and all procedures performed in studies involving human participants were following the ethical standards of the Medical and Health Research Ethics Committee of the Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada (UGM) in Yogyakarta, Indonesia.

Environmental Intervention

Air Pollutant Level Assessment

Air quality assessment in batik workplaces was done in three sites near the work process included, stamping room, drawing and coloring room that uses *malam* black wax, and *pelorodan* room. In the *pelorodan* room, batik materials were washed with boiled water to remove the wax and dye. This assessment aimed to identify the type of air pollutants from batik processing. Indoor air pollutants were assessed using a Low Volume Sampler (LVS) 2.5 L/min flow rate throughout the working hours (8 hours) for measuring particulate matter below 2.5 ɾm diameter (PM 2.5). Meanwhile, inhaled air pollutants were assessed using a Hi-Flow Personal Sampler Pump with Mixed Cellulose Ester type and size of Ø25 mm and 0.8 µm pore size when the batik workers worked. This device was set up in the *canting* (the process of applying wax design to fabric), stamping, coloring, and dyeing areas. The air samples were analyzed using X-ray Fluorescence (XRF) methods [7]. Measurements of heavy metals from inhaled air were done by Instrumental Neutron Activation Analysis (INAA) and for Pb and Cr, a Graphite Furnace Atomic Absorption Spectrophotometer (GF-AAS) was used.

Blood Chemistry Examination

The design of this study was cross sectional case-control with a total of 17 batik workers in the dyeing section as the case group and 22 non-batik workers as healthy controls. Inclusion criteria were: age > 18 years and willing to participate in this study. Meanwhile, exclusion criteria were: those with life threatening disease and rejected to participate in this study. In this study, we compared the blood chromium levels, liver and renal function tests between the batik workers and non-batik workers. Blood chromium level was measured with Inductively Coupled Plasma (ICP) methods. Liver function determined through blood Serum Glutamic Oxaloacetic Transaminase (SGOT) and Serum Glutamic Pyruvic Transaminase (SGPT) level examination using colorimetric methods was based on the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC's). Meanwhile, kidney function test was observed through the blood urea level with enzymatic colorimetric with urease and creatinine level with colorimetric Jaffe method. All of blood chemistry examinations were done on subject's blood serum in Clinical Pathology Laboratory of the Faculty of Medicine, Public Health and Nursing UGM [8].

Batik Wastewater Treatment

The wastewater quality analysis was done using batik wastewater in water samples as well as in sediment originating from Lendah Sub-District. Critical parameters like conductivity, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), potential Hydrogen (pH), Total Suspended Solids (TSS), and Total Dissolved Solids (TDS) were analyzed using standard methods. The obtained data were then compared with the wastewater national quality standards [9]. Batik wastewater treatment on a laboratory scale was conducted using an electrochemical method. This work includes preparation for working electrode and dye electro degradation. Chemical parameters of batik wastewater after treatment using the electrolysis method was compared to liquid waste standard quality [10].

Health Intervention

Gloves Use

This study began with a literature study, workplace observations, and in-depth interviews with five batik workers at Yogyakarta to choose the best gloves for batik workers. From the market survey, five kinds of gloves material including latex with and without grip, nitrile, polycotton with nitrile, and neoprene were chosen. Literature study and interview-guided questionnaire based on the tailor-made questionnaire developed by Faculty of Medicine, Public Health and Nursing UGM were done to assess workers' convenience when using hand gloves. The questionnaire comprised of 10 questions assessing dexterity, breathability, length and durability, skin reaction, muscle strength, safety feeling, and overall convenience were asked to five batik workers work in the dyeing sections.

After we had the best gloves, we used a cross-over design intervention study to collect qualitative and quantitative data comparing convenience level of test gloves and workers' daily gloves. Batik workers working in dyeing section, age range between 17–65 years old and willing to participate in this study were included. Meanwhile, batik workers who were on work leave for more than two weeks during this study conducted and allergic to neoprene were excluded. A total of 13 batik workers were included in this study based on minimal sample calculation using Slovin's formula. In the first period, the workers used test gloves on the right arm and daily gloves as a control on the left arm for 2 weeks. After wash out periods (2 weeks), the subject switched the intervention between both arms in the second trial period for another two weeks. The comfort assessment was done by the end of the second phase. During the interview, the researcher read each statement and asked the subjects to give a score and the reasoning for the assigned rating. Each score and reasoning given were not interpreted by the researcher during the interview to avoid subjective bias.

Carpal Tunnel Syndrome (CTS) Exercise

This study used quasi-experimental study design consisting of intervention, impact assessment, and experiment unit, but not random assignment, to create a comparison to draw conclusions from the intervention. The study was done to know the effect of nerve gliding exercise and wrist splint use compared to the control group that only used wrist splints on clinical outcome improvement of CTS in batik workers in Lendah, Kulon Progo.

For the intervention group, nerve gliding was done daily for 5–10 minutes and continued with wrist splint use for ± 8 hours. Meanwhile, the control group only used wrist splints for ± 8 hours. The nerve gliding exercise done referred to the Totten and Hunter Exercise taken from Arthritis Research United Kingdom (UK) in collaboration with the Chartered Society of Physiotherapy [11]. Pain scale and clinical improvement of study subjects were re-examined every week for four weeks.

Through prospective longitudinal observation, CTS clinical improvement was assessed by comparing average scores for Visual Analogue Scale (VAS) and Boston Carpal Tunnel Questionnaire (BCTQ) before and after the intervention. Then, clinical improvement of intervention and control groups was compared. BCTQ is the standard tool used to assess CTS patient outcomes [4].

Batik workers who work for at least 20 hours/week for a minimum of 12 months and diagnosed with CTS based on tinel, phalen, and reverse phalen test and Flick's sign were included in this study. Meanwhile, the exclusion criteria were: 1) Clinical CTS of grade 4 and 5 in the Historical Objective (Hi-Ob) scale; 2) History of trauma in the wrist (fracture); 3) Pregnant; 4) History of stroke; 5) History of arthritis; 6) History of thyroid disease; 7) Currently consuming steroid, NSAIDs, or lipid-lowering agents; and 8) Participating for < 75% in nerve gliding exercise. From 4 batik medium-sized enterprises (MSEs), 18 workers were diagnosed with clinical CTS.

Social And Public Health Intervention

Primary qualitative data were in the form of perception score of village and district level stakeholders towards the sustainability dimension and attributes of the "Healthy Batik Village" were collected from in-depth interviews on several topics related to the "Healthy Batik Village" sustainability.

This step of the study was conducted by a survey method with structured interviews using closed questionnaires and in-depth interviews for qualitative data. The number of respondents was determined to be 12 people using purposive sampling to represent village and district level stakeholders and perspectives from different government offices.

The study respondents were the Heads of two villages in Lendah Sub-District, Association of Batik Business Owners, District Health Office, District Environment Office, District Community Empowerment Office, District Population Control and Family Planning Office, District Women Empowerment and Child Protection Office, District Small and Medium-sized Enterprise Office, District Tourism Office, District Trade Office and Primary Health Care.

Data Processing And Analysis

Blood Chemistry Examination

Blood chemistry panels, including liver and renal function tests, were compared between the batik workers and the control group. The differences between these values were analyzed by using the t-test: Two-Sample Assuming Equal Variances. Differences in blood chromium levels between batik workers and the control group were analyzed by using Mann-Whitney test. Correlations between blood chromium level with kidney and liver function were analyzed by Spearman correlation test. P value ≤ 0.05 was considered significant statistically.

Gloves Use

In this study, we compared the comfort aspect of neoprene as test gloves and PVC as control gloves using Wilcoxon signed rank test. P value ≤ 0.05 was considered significant statistically.

Carpal Tunnel Syndrome (CTS)

Observations results were recorded on the prepared forms. The descriptive step was then done to know the characteristics of the subjects. Data analysis used the SPSS program (IBM Corp., Armonk, NY). To test the variable scale average difference, unpaired T-test was used. All the above test results were regarded statistically significant if the value of $p < 0.05$.

Social and Public Health Intervention

Data analysis was done using the Rapfish ordination technique through Multidimensional Scaling (MDS) methods to assess the sustainability index and status of the “Healthy Batik Village”. This study also identified sensitive attributes that affect sustainability indexes of each dimension through leverage analysis. The dimensions assessed are social, ecological, and economic.

Results

Evaluation of health parameter among batikworkers related to environmental pollution

To check the air quality in the batik working place and how they can impact on workers’ health, the concentration of PM2.5 was analyzed. As shown in Table 1, low level of PM2.5 was detected in the stamping and making *malam* coloring room. However, the work environment air in *pelorodan* room contained PM2.5 by 40.03 μg/m^3, which exceeds the allowable levels according to the World Health Organization (WHO) Air Quality Guidelines [12].

Table 1
The mass concentrations of PM2.5 in batik industry

Sampling Locations	PM 2.5 (μg/m3)	Thresholds (μg/m3)
Pelorodan room	40.03	25
Stamping room	3.38	(WHO Air Quality Guidelines, 2006)
Making malam wax and coloring room	13.97	

The heavy metals contained in the batik chemicals can severely affect human health via skin contact and inhalation exposure. Airborne heavy metals are the essential toxic component of PM2.5, and it then can be seen that several heavy metal elements, such as Sulfur (S), Potassium (K), Titanium (Ti), Chromium (Cr), Manganese (Mn), Iron (Fe), Nickel (Ni), Zinc (Zn) and Lead (Pb), were detected in the air of batik workers’ workspace in the aforementioned area (data not shown).

Measurement of heavy metal concentrations in inhaled air was done by draping a device around the neck of the batik workers who work in the *canting*, stamping, coloring, and dyeing areas, as shown in Fig. 1.

INAA analysis results show the heavy metals that were found in the inhaled air of batik workers. Table 2 shows the comparison of metal concentrations. Al, Fe, Cu, and Zn were the most abundant elements among the studied metals. Meanwhile, Cu and Pb on average were detected to be exceeding Indonesian and other standards [13, 14].

Table 2
Concentration Distribution of Heavy Metals Elements in Batik Worker Inhaled Air

Metals	**Average Concentration (mg/m^3)**	**Standard**			
		Indonesia (mg/m^3)	NIOSH (mg/m^3)	ACGIH (mg/m^3)	OSH (mg/m^3)
Al	1.342	10	10; 5 ;2	10; 5; 2	15;5
Cr	0.041	0.5; 0.05; 0.01; 0.012	0.5	0.5	0.5
Mn	0.059	0.2	1 STEL	0.2 (TLV-TWA); 1 STEL	-
Fe	0.503	5;	5 fume	5 fume	10 dust, fume
Ni	0.033	1; 0.1; 0.12	0.015 REL	1.5; 0.2; 0.1	1
Cu	0.289	0.2; 1	1 dust 0.1 fume;	1 dust, mists; 0.2 fume	1 dust, mists; 0.1 fume
Zn	0.242	5; 0.01; 1; 5; 10	-	-	-
Co	0.002	0.02; 0.1	0.05 dust, fumes	0.02 dust, fumes	0.1
As	0.005	0.01; 0.15	0.002 (Ca)	0.01 (Ca)	varies
Pb	0.051	0.1; 0.15; 0.05	0.05	0.05	0.05

The values of SGPT and SGOT (liver function), urea and creatinine (kidney function) among batik workers were significantly higher compared to non-batik workers ($p < 0.05$) as seen in Table 3. Batik workers have a 9 times higher risk of liver damage compared to control group. Batik workers are also between 6.4–7.5 times more likely to experience kidney damage than controls. In this study, we also found that the blood chromium level in batik worker and control groups were not statistically different

(Table 3). Table 4 shows a positive correlation between blood chromium with SGOT, SGPT, and creatinine. Besides that, we also found there was a negative correlation between blood chromium level and urea. Despite the result, this correlation was not statistically significant.

Table 3
Comparison of Blood Chromium Level, Liver Function, and Kidney Function in Batik Worker and Control Group

Variable	Batik Worker	Control	*p* value
Chromium (plasma)	4.3 ± 4.2 nmol/L	4 ± 3.3 nmol/L	0.909
Liver Function	14.35 ± 6.47 units/L	8.55 ± 4.48units/L	0.0021*
SGPT	20.76 ±6.24 units/L	17.18 ± 4.63 units/L	0.046*
SGOT			
Kidney Function	14.5 ± 1.64 mmol/L	13.7 ± 4.37 mg/dl	0.046*
Urea	76 ± 0.14μmol/L	64 ± 0.17 μmol/L	0.0056*
Creatinine			
* *p* value < 0.05			

Table 4
Correlation Between Blood Chromium Level with Kidney and Liver Function in Batik Workers

Variable	r (Correlation coefficient)	*p* value
Blood chromium - SGOT	0.152	0.56
Blood chromium - SGPT	0.07	0.79
Blood chromium - Urea	-0.295	0.25
Blood chromium - Creatinine	0.124	0.635

In addition to having direct impact on workers, the batik process also has impact on the community as well as the environment through its waste, especially its wastewater. Other chemical parameters of batik wastewater in Lendah were found over a wide of range exceeding the standard values of batik

wastewater according to the Regulation of Ministry of the Environment Republic of Indonesia no. 1/2011. The chemical parameters values are listed in Table 5 [9].

Table 5
ChemicalParameters Value of Batik Waste

Parameter	Unit	Observed Value	Standard
Conductivity	µmhos/cm	2000–9100	1562.5
BOD	mg/L	160–8000	50
COD	mg/L	360–17500	100
pH	-	6.9–10.2	6–9
TSS	mg/L	15–388	200
TDS	mg/L	995–4950	1000

To improve the quality of batik wastewater, a wastewater treatment technology based on electrochemical methods, which has been investigated in a number of approaches, was proposed. In this study, up to 95% color removal efficiency of dyes has been achieved using synthesized-graphene working electrodes (in detail, published elsewhere).

Health Intervention For Skin And Neurological Problems

Comfort assessment and chemical protection of gloves

The chemical substances found in synthetic dye used in batik industry include naphthalene, sulphuric acid, and nitric acid [15]. Table 6 shows gloves protection level towards batik chemical dyes based on current industrial standards from literature study [16].

Table 6
Chemical Resistance Selection Chart for Protective Gloves

Chemical	Neoprene	Latex	Butyl	Nitrile
Naphthalene	Good	Fair	Fair	Good
Nitric Acid	Good	Fair	Fair	Fair
Sulphuric Acid	Good	Good	Good	Good

In this study, five types of gloves were being compared by assessing dexterity, breathability, length and durability, skin reaction, muscle strength, safety feeling, and overall convenience. Based on the chemical resistance selection chart and interview guided questionnaire, gloves from natural rubber/latex, neoprene, and neoprene-covered latex have the highest scores. Based on the three highest scored gloves, neoprene was chosen to be the test gloves. Neoprene gloves provide better protection to batik dye compared to other common chemical gloves. Nitrile was ranked the second best material that gives good protection. The PVC as the daily glove's material had the worst score.

After both gloves had been used for four weeks, the interviews were conducted. According to Wilcoxon analysis, there were only three statements in which the difference between the gloves had proven statistically significant, statements number 1, 5, and 8 (Table 7). Statement 1 assesses convenience based on dexterity, statement 5 assesses convenience according to the gloves' length, and statement 8 assesses the muscle strength when using gloves according to slipperiness. Meanwhile, the analysis results between the total score showed the neoprene gloves (55.15) were scored significantly higher ($p < 0.05$) than PVC gloves (50.92).

Table 7
Comparison of Statement Score between PVC and Test Gloves

No	Statement	PVC	Test Gloves	*p* value
1	I can hold the batik cloth firmly when working while wearing the protective gloves.	5.6	6.5	0.016*
2	I can freely move my wrist and the back of my hand while working when wearing the protective gloves.	6.7	7.3	0.234
3	I can freely move my fingers while working when wearing the protective gloves.	6	6.6	0.229
4	The temperature inside the gloves feels cool or comfortable.	4.8	4.7	0.914
5	There is water infiltrating inside the gloves while I used it to dip the cloth in batik dye.	3.6	8	0.001*
6	I feel some itchiness after wearing the protective gloves.	2.5	2	0.518
7	There is some redness shown on my skin after wearing the protective gloves.	1.9	1.7	0.458
8	The gloves are slippery when used to hold cloth that had been dyed.	6.6	5.1	0./030*
9	I feel safe when wearing the protective gloves while working.	6.6	6	0.194
10	The gloves feel very comfortable to use while working.	6.1	6.7	0.356

From the interview guided questionnaire, batik workers prefer the neoprene gloves since not itchy and no redness after using this glove. Besides that, they also said neoprene gloves are elastic, durable, and have a variable size. The inadequateness of neoprene gloves is mainly caused by the shorth length which causes the water infiltrating inside the gloves while worker dip the cloth in batik dye. Batik workers tend to choose gloves with the size that reaches up to their elbows, without rubber at the base of the gloves, but still fit nicely on the hands and fingers. They choose gloves with a grip on the surface to avoid slipping when dipping the batik materials.

Carpal Tunnel Syndrome (CTS)

Observation and examination done by neurologists on batik workers in Lendah, Kulon Progo, showed a prevalence of 43.96% for CTS. From the study done in four small and medium-sized enterprises in Lendah, Kulon Progo, 18 batik workers were diagnosed with clinical CTS. They were then divided into 2 groups: Group I as control that only received wrist splint intervention for 4 weeks, consisting of 2 men (22.2%) and 7 women (77.8%); and group II as the intervention group that received nerve gliding and wrist splint intervention for 4 weeks, consisting of 1 man (11.1%) and 8 women (88.9%). The average VAS score pre-intervention for group I was 55.6 ± 7.3 and 56.7 ± 7.1 for group II. From statistical analysis, there was no significant difference in subjects' characteristics between group I and II (age, education, and

history of diabetes mellitus, heart disease, obesity, hand trauma, thyroid disease, steroid use, smoking, hypertension, and hormonal contraception use).

Decrease in BCTQ and VAS values can be seen from week I to week IV, in both the control and intervention groups (Table 8), but there was no significant difference in BCTQ (SSS and FSS) and VAS scores between control and intervention groups from the observations done before the intervention and 1, 2, 3, and 4 weeks after the intervention ($p > 0.05$).

Table 8
Differences in Average Delta Score of SSS, FSS, VAS in Intervention and Control Groups

	Group		*p* value
	Control (I)	Treatment (II)	
SSS Pre	21.1 ± 3.4	22.4 ± 3.3	0.410[a]
SSS week I	18.2 ± 2.7	18.1 ± 3.7	0.942[a]
SSS week II	16.6 ± 2.0	16.4 ± 2.5	0.919[a]
SSS week III	14.2 ± 1.9	14.1 ± 2.8	0.923[a]
SSS week IV	12.9 ± 1.4	12.4 ± 1.5	0.522[a]
FSS Pre	9.6 ± 2.0	11.4 ± 3.8	0.321[b]
FSS week I	9.3 ± 1.7	9.1 ± 1.4	0.962[b]
FSS week II	8.9 ± 1.5	8.6 ± 1.3	0.614[b]
FSS week III	8.8 ± 1.6	8.2 ± 0.4	0.808[b]
FSS week IV	8.0 ± 0.0	8.0 ± 0.0	1.000[b]
VAS Pre	55.6 ± 7.3	56.7 ± 7.1	0.696[b]
VAS week I	44.4 ± 7.3	37.8 ± 8.3	0.091[b]
VAS week II	34.4 ± 11.3	28.9 ± 9.3	0.290[b]
VAS week III	18.9 ± 11.7	21.1 ± 13.6	0.715[a]
VAS week IV	6.7 ± 11.2	6.7 ± 10.0	1.000[b]

a) Independent T test, b) Mann-Whitney test

Social And Public Health Intervention

The results of the quantitative analysis show the index value of every dimension varies with the ecology index being the lowest with 23.9 or within the poor category. In contrast, the social and economic dimensions show good status with indices of 62.92 and 61.13, respectively. The implications for the current policy to maintain or increase the sustainability index from “adequate” to “good” require the management of the sensitive attributes that affect those three dimensions, mainly the economic and ecological.

Meanwhile, qualitative results show that from a social dimension, the existence of the batik industry helps in terms of community empowerment, especially batik workers. As for nutrition and food issues, the batik industry ensures food availability for its workers, although nutritious food intake has not gained wide attention.

Conflicts between business owners, batik workers, and the community are rarely found, and most can be solved well-enough because of the social intimacy between the parties. However, due to that social intimacy, workers and the community tend to be reluctant to express their complaints.

From the economic dimension, respondents expressed that although batik business requires considerable capital and cost, the profits gained both from local and national markets allow the batik industry to persist and thrive. They also expressed the need for improving business management quality to support business sustainability.

As for the ecological dimension, the disparity between stakeholders can be found. Batik business owners stated that they have implemented optimal waste treatment, especially liquid waste. However, other stakeholders stated that reminders are still needed for environmental pollution management efforts.

Discussion

Batik workers are typically exposed to chemical hazards in the batik industry either from the air, waste water, or synthetic dye used in batik processing. In this study, we found that all of the chemical parameters of batik waste in Lendah were higher compared to the standard value of batik waste as mentioned in the Results section. Based on the WHO air quality guidelines, the excess concentration of PM 2.5 was only found in the *pelorodan* room [11]. This condition is due to the use of firewood as the main source of heat to remove *malam* wax from batik materials. The combustion of firewood results in the formation of particulates which can affect workers’ health. In the other working areas, they used the Liquefied Petroleum Gas (LPG) as a source of heat so there were no combustion to generate particulates in the air, but there were PM 2.5 formed in aerosol from the vapor of melting *malam*.

In the three work spaces mentioned in the Results section, we found heavy metal contaminants in the work environment of the batik industry including Sulfur (S), Potassium (K), Titanium (Ti), Chromium (Cr), Manganese (Mn), Iron (Fe), Nickel (Ni), Zinc (Zn) and Lead (Pb). Despite those, the concentrations of

heavy metal compounds in the work environment of the Batik Industry in Kulon Progo are small when compared to the threshold value of these compounds in the work environment referring to the regulation of the Minister of Manpower Republic of Indonesia No 5 of 2018 on Occupational Safety and Health of the Work Environment [17].

We also measured the heavy metal contaminants in the air inhaled by batik workers besides in the work area. Al, Fe, Cu and Zn had the highest concentrations of metal elements in the breathing zone. Levels of Al, Fe and Zn were within Indonesia, American Conference of Governmental Industrial Hygienists (ACGIH), National Institute for Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA) limits, while the mean Cu levels in the breathing zone were above the regulation allowable limits [13, 14]. The synthetic dye used in batik also contains Pb, Cr, and Zn [18]. The use of synthetic batik dyes containing heavy metals such as Pb and Cr are more popular because these substances can produce more beautiful and attractive colors [19].

Industrialization in the batik industry and higher demand of batik production, while important for the economic growth and development of a society, can be harmful for the environment especially with the use of synthetic dye. Although there are already many kinds of natural batik dye, the batik industry in Indonesia still uses the synthetic dyes that contain heavy metals. Those heavy metals will not only harm the environment but also be harmful for humans, especially the batik workers. Many batik workers primarily working in the dyeing process were exposed to Cr, a known carcinogenic and toxic substance. Besides that, we still found inadequate disposal of the waste in the batik industry.

In this study, we found no significant differences in blood Cr level between batik workers and control group. Despite the result, Cr is one of the eight metals in the top 50 priority list for toxic substances by the Agency for Toxic Substances and Disease Registry (ATSDR 2003). The majority of Cr in the environment exists in two valence states: trivalent chromium Cr(III) and hexavalent chromium Cr(VI). Batik workers may be exposed to Cr by breathing, eating, or drinking the substance, or by skin contact [20].

Cr(III) is generally benign due to poor membrane permeability. These compounds are even recognized as essential micronutrients that are involved in important physiological functions, such as the biological activity of insulin. In contrast, Cr(VI) compounds can actively penetrate cell membranes. Hexavalent chromium is a strong oxidizing agent and can lead to oxidative stress and DNA damage [21]. Adverse health effects associated with Cr(VI) exposure include occupational asthma, eye irritation and damage, perforated eardrums, respiratory irritation, kidney damage, liver damage, pulmonary congestion and edema, upper abdominal pain, nose irritation and damage, respiratory cancer, skin irritation, erosion and discoloration of the teeth [22].

In this study, we found significant differences in liver and renal function tests between batik workers and non-batik workers ($p < 0.05$). There were higher values of liver and renal function tests in batik workers compared to control but still in the normal range. When the renal function tests are found abnormal, the nephropathy has already reached the irreversible phase that may lead to renal insufficiency [23]. SGOT and SGPT have been used to show the status of liver functions. SGOT is an enzyme involved in the

transfer of an amino group from aspartate. SGPT is an enzyme involved in the transfer of an amino group from alanine and present in the cytoplasm. SGPT is found in various tissues but is most commonly associated with the liver. Therefore, SGPT is a good biomarker of hepatocellular injury. Increased SGOT and SGPT are biomarkers of hepatic injury rather than hepatic dysfunction [24].

Urea is a waste product from protein breakdown in human liver and removed from our body through kidneys. Chromium are accumulated higher in renal cortex than red blood cells or liver and tend to damage kidneys. Higher urea levels usually indicate kidney damage. Negative correlation between blood Cr and urea may happen because Cr has no effect on that parameter, but this does not exclude kidney damage. Recently, many biomarkers are found to be correlated with kidney damage [25, 26].

There was a positive correlation between blood Cr level with SGOT, SGPT, and creatinine, but this result was not significant statistically. We proposed that the elevation of kidney and liver function values may be correlated to the exposure of heavy metals in occupational settings. These results demonstrated and supported that environmental and health interventions need to be done in the batik industry to prevent occupational diseases especially caused by heavy metal exposure.

As a solution, we developed the wastewater treatment plant using ss/graphene electrodes to create a more effective and environmentally friendly wastewater disposal system. The electro degradation process of dye by using ss/graphene electrodes is sufficient to remove color in a short amount of time, as little as 15 minutes (data published elsewhere).

Synthetic dyes used in the batik making process are naphthol, *indigosol*, rapid and *ergan sogan* dyes. Rapid dye is a stabilized combination of naphthol and diazonium, usually used for red color. The color generator used was sulphuric acid and vinegar acid.

The use of PPE is required to protects workers by isolating partially or entirely all of their body parts from any hazardous potential from in the workplace [27].

The most commonly used glove material in Indonesian batik industry are polyvinyl chloride (PVC) and nitrile. Protective gloves are often being forgotten by workers in the dyeing section due to the convenience aspect and work quality results. Specifically, in the dyeing section, the use of gloves makes workers have a difficulty in spreading color evenly and precisely. The bare hand method is preferred by workers due to the thickness and rigidity of the gloves which can hinder the work process [28].

There are different kinds of material for chemical protective gloves, including neoprene, butyl, nitrile, fluorocarbon, latex, and also combination of those materials to improve performance [16]. Polyvinyl chloride (PVC) gloves as a type of gloves recently used by Batik workers are the least expensive of all materials and can be used as disposable gloves. PVC has high protection against nitric, chromic, and phosphoric acid. They are also resistant to aging. PVC is not recommended to be used against acetone, ketones, and ether since some concentrated acid can extract the plasticizer and harden PVC gloves, thus making them rigid [29].

Neoprene is the best for batik workers. Neoprene is made from synthetic rubber that is soft and able to fill in the gaps so that fingers can move freely, has high density and is resistant to tears. Neoprene gives strong protection from hydraulic liquids, fuel oil, alcohol and an organic base. Compared to rubber, neoprene gloves have better resistance towards chemicals and are not as easily worn out [2].

After collecting the reasoning of gloves scoring, several aspects were obtained, including: thickness, elasticity, breathability, coarseness (slipperiness), textured surface, length, starch, durability, and fitting. Gloves' thickness play a prominent role as it is the main reason of why the subjects scored the test gloves higher than the PVC in statement number 1. Neoprene gloves are thinner which allows workers to handle the work products more firmly with less barrier. Thicker gloves as in PVC gloves would decrease workers' manual dexterity and cause fatigue due to the higher muscle resistance. Thicker gloves can affect the breathability and may cause more sweat production due to a humid environment [30]. Neoprene gloves are more elastic than the PVC gloves which allows the workers to control hand movement and have less fatigue [31]. Elastic gloves also have decreased tightness because they will eventually adapt to workers' hands sizes.

The next aspects are the coarse property and the textured surface on palm area of the neoprene gloves. Neoprene gloves' characteristics would prevent the cloth from sliding over. Coarse material and textured surface would result in higher friction value against the cloth that would increase handgrip of the product thus increasing handling and mobility performance [32]. The workers stated that the test gloves are coarser and had a more textured palm area that allowed better grip. This condition made the workers score the test gloves significantly higher in statement number 8.

Length of glove was a prominent aspect that affects convenience. Neoprene gloves' length, which only reach to half of the workers' lower arm, is inadequate to protect their hands while dyeing batik. This condition allows the dyeing infiltrate inside the gloves while dipping the cloth, making the gloves' function futile in protecting workers from the hazardous substance. Although only mentioned by three workers, the rubber band in the cuff of the PVC gloves also helped prevent the water from infiltrating inside the gloves. Workers stated that starch can cause an itchiness, foul smell and make the gloves more slippery. Starch is considered as an irritant agent to workers hands and can induce type 1 hypersensitivity reactions and occupational asthma [33]. The high durability gloves would provide workers better safety, less worry, thus increasing their convenience. The durability of the gloves is influenced by heat and pH. They are often associated with thicker gloves and the type of material itself. Gloves' tensile and elongation also play an important role in durability [34]. The last aspect that influences convenience is gloves' fitting. Workers prefer hand gloves that fit tight on the fingers area and loosely on the wrist. According to the interview, the test gloves (neoprene) have higher means score than PVC, but the result was not statistically significant.

The ideal gloves according to the workers are gloves that are thin but durable, length reached the elbow with rubber band on the cuff area, elastic, coarse on the outer layer, had textured surface on the palm area, fit on the fingers and loose on the wrist. Overall the workers feel the neoprene gloves are more

comfortable than the PVC gloves and had already covered most of the ideal aspects except that the test gloves length's is not adequate.

Convenience is an essential aspect of wearing gloves. Comfortable gloves would motivate workers to wear them correctly and in an orderly manner. Gloves are essential to be worn since the batik industry's chemical substances consist of many hazardous compounds that may be irritative, toxic, and even carcinogenic. Gloves that are worn correctly would help protect the workers from many hazardous compounds [31]. Other than safety, comfortable gloves, or PPE would also help increase workers' productivity and the product's quality. This would also affect the increase of production rate, which is beneficial for both the home industry and the workers [35]. However, high convenience gloves sometimes cost a higher price. In this case, neoprene is used less frequently in the industry due to the higher cost value. In the market, neoprene gloves' price range from Rp 70.000,00 to Rp 90.000,00. This is considered a high difference compared to the PVC gloves, ranging from Rp 20.000,00 to Rp 30.000,00.

Due to this matter, many textile industries that involve chemicals eventually use nitrile gloves. This is because the nitrile gloves have decent protection against textile chemicals, even though not as good as neoprene, but still have a reasonable price slightly higher than PVC [36]. In the market, nitrile gloves' price ranged from Rp 30.000,00 to Rp 40.000,00. Due to this reason, nitrile gloves are often used as a solution to facilitate both safety and costs. However, the batik dye workers did not feel the nitrile gloves to be comfortable due to the presence of coating material on the inner of the glove, which can cause discomfort. One of the batik home industries as a subject of our study, Batik Farras, provide their workers with PVC gloves and rarely nitrile gloves since PVC are cheaper than nitrile gloves. If the three gloves are being compared, neoprene, even with the higher price, had the best tear-resistance and durability against the chemical, making it more durable and can be worn for a longer duration, therefore, needing less frequent of changing due to breakdown [16].

Carpal Tunnel Syndrome (CTS)

Carpal Tunnel Syndrome (CTS) occurs when the median nerve in the wrist is irritated and compressed. This event often happens in people who frequently do repetitive hand and finger movements. The wrist splints used in CTS patients at night for several weeks aims to keep the joint in a neutral position. Usually, CTS symptoms worsen at night because the hand tends to flex during sleep, and this could be prevented with wrist splint use [11].

Meanwhile, nerve gliding is a stretching technique that moves the neck and upper extremity through a specific range of motion to free the nerves and increase mobility. Nerve gliding will work well if done together with other adjuvant therapies [4]. Nerve gliding can fix nerve pathways, decrease adhesion, improve nerve oxygenation and decrease pain due to ischemia [37].

A study conducted by Schmid *et al.* found that use of splinting or nerve gliding for one week could decrease the signal intensity from the median nerve in CTS patients, which was considered as a result of the decrease in intraneural edema. The average decrease in signal intensity was 11%, in addition to slight

improvement in symptoms and function ($p < 0.004$) [38]. Seradge *et al.* also showed that nerve gliding exercises could directly decrease pressure in the carpal tunnel pressure for CTS patients. Improvement in CTS clinical outcome by adjunct non-surgical treatment can result in significant savings in human suffering, medical cost, lost work time, and socioeconomic distress [39].

From the results of this study, we can see that nerve gliding exercises as well as wrist splints can cause apparent improvement in CTS clinical symptoms from week I to IV, but they did not show statistically significant difference in decreasing the number of CTS cases.

Social And Public Health Intervention

Based on the results, for the economic dimension, the financial feasibility of the batik industry needs to be maintained by improving business management quality and access to financial institutions. As for the social dimension, efforts to establish labor unions need to be put in place to mediate potential conflicts and improve service for workers, for example, by continuing efforts for occupational health campaigns. Lastly, for the ecological dimension, the quality and implementation of liquid waste treatment plans need to be improved so that the level of business and district-scale waste pollution can be controlled. The implication of these findings is that the existence of interest competition needs to be paralleled with efforts to help business owners to make choices based on substantial evidence to decide the steps that have to be taken to balance the sustainability of these three main pillars of the “Healthy Batik Village” area establishment (in detail, published elsewhere).

Conclusions

In this study, chemical and physical hazards were identified, followed by environmental, health and social interventions. Measurement results of inhaled air in batik workers show that there is an increase in heavy metal levels, although they are still under the standard threshold. However, significant differences were found for liver and kidney functions between batik workers and controls.

Environmental intervention was done by making a laboratory-scale appropriate technology using graphene material that can degrade dyes in a short amount of time (15 min).

Health intervention was done by doing gloves’ use tests and CTS exercises. Based on the chemical resistance selection chart and interview guided questionnaire in five kinds of gloves, neoprene was chosen to be the test gloves. After using test gloves and PVC gloves as the daily gloves for four weeks, neoprene gloves have significantly higher total score of convenience level compared to PVC gloves. Neoprene gloves covered most of the ideal aspects except the gloves’ length. Meanwhile, CTS exercises, as well as the use of wrist splints, have been proven to result in apparent improvement of clinical symptoms.

Lastly, social intervention was done by assessing the sustainability status of the batik industry in the “Healthy Batik Village” area with considerations of economic, ecological, and social dimensions.

Abbreviations

ACGIH
American Conference of Governmental Industrial Hygienists
Al
Aluminium
As
Arsenic
A.U.
Arbitrary unit
BCTQ
Boston Carpal Tunnel Questionnaire
BOD
Biological Oxygen Demand
C
Carbon
Cd
Cadmium
cm
centimeter
Co
Cobalt
COD
Chemical Oxygen Demand
Cr
Chromium
CTS
Carpal Tunnel Syndrome
Cu
Cuprum/Copper
Fe
Ferrum/Iron
FSS
Functional Status Scale
Hb
Hemoglobin
Hg

Hydrargyrum
Hi-Ob
Historical Objective scale
ICP
Inductively Coupled Plasma
IFCC
International Federation of Clinical Chemistry and Laboratory Medicine
INAA
Instrumental Neutron Activation Analysis
K
Kalium/Potassium
L/min
liter per minute
LBP
Low Back Pain
LPG
Liquefied petroleum gas
LVS
Low Volume Sampler
MDS
Multidimensional Scaling
mg/L
milligrams per liter
Mn
Manganese
MSE
Micro and Small Enterprises
NIOSH
National Institute for Occupational Safety and Health
Ni
Nickel
NSAIDs
Non-steroidal Anti-Inflammatory Drugs
O
Oxygen
OSHA
Occupational Safety and Health Administration
Pb
Plumbum/Lead
PCV

Packed Cell Volume
pH
potential Hydrogen
PM
Particulate Matter
PPE
Personal Protective Equipment
Rp
Rupiah
S
Sulfur
SD
Standard Deviation
SGOT
Serum Glutamic Oxaloacetic Transaminase
SGPT
Serum Glutamic Pyruvic Transaminase
Si
Silicon
SPSS
Statistical Package for the Social Sciences
Ss
Stainless steel
SSS
Symptom Severity Scale
TDS
Total Dissolved Solids
TSS
Total Suspended Solids
Ti
Titanium
UGM
Universitas Gadjah Mada
UK
United Kingdom
UNESCO
United Nations Educational, Scientific and Cultural Organization
VAS
Visual Analogue Scale
WCC

World Craft Council
WHO
World Health Organization
XRF
X-ray Fluorescence
Zn
Zinc

Declarations

- Ethics approval and consent to participate

This study received the ethical approval from Medical and Health Research Ethics Committee Faculty of Medicine Universitas Gadjah Mada. Informed consent was obtained from all individual participants included in the study, and all procedures performed in studies involving human participants were following the ethical standards of the Medical and Health Research Ethics Committee of the Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada (UGM) in Yogyakarta, Indonesia.

- Consent for publication

Not applicable

- Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request

- Competing interests

The authors declare that they have no competing interests.

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- Authors' contributions

SAF was the principal investigator of the study and took the leading role from conception, design, and supervising data collection process to the final analysis and preparation of the manuscript. KO participated in the design of the study, analyzed and interpreted the research data regarding the air pollutant level assessment. IT participated in the design of the study, analyzed and interpreted the research data regarding social and public health intervention. R and FDS participated in the design of the

study, analyzed and interpreted the research data regarding the batik waste treatment. CT participated in the design of the study, analyzed and interpreted the research data regarding the carpal tunnel syndrome and back exercise. S and DYP participated in the design of the study, analyzed and interpreted the research data regarding the blood chemistry examination. KAL was a contributor in writing the manuscript. CRSP, RD, and HS participated in the design of the study and reviewed the method part in gloves use. LDV analyzed and interpreted the research data regarding the gloves use and contributed to writing the manuscript. RSP and SDS participated in developing questionnaire about gloves convenience. KAP participated in collecting data about gloves convenience and analyzed the data. All authors read and approved the final manuscript.

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Figures

Figure 1

Measuring inhaled air in the breathing zone of pencanting (workers applying designed-wax to the fabrics) using personal sampler pump