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Original Research



Environmental and Health Implications of Liquid Waste from the Stone Carving Industry in Sedayu Village, Magelang



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Abstract: Sedayu Village in Magelang Regency is a hub for stone carving craftsmanship, generating liquid waste that poses potential environmental contamination and health hazards. This study aims to analyze the quality of liquid waste produced and evaluate environmental health risks. Implementing the composite sampling method, liquid waste samples were taken from industrial outlets and released into the Keranjang River. The analyzed parameters include TSS, pH, BOD, COD, nitrate, chromium, and phenol. Laboratory results revealed concentrations of TSS at 200 mg/L, BOD at 50 mg/L, COD at 100 mg/L, nitrite at 1 mg/L, hexavalent chromium at 0.1 mg/L, and phenol at 0.05 mg/L, all exceeding environmental quality standards. The health risk assessment, conducted using the Environmental Health Risk Assessment (EHRA) method, the RQ values for nitrite (0.039), chromium (0.129), and phenol (0.006) are below 1, indicating low immediate risk, chronic exposure could lead to bioaccumulation and long-term health effects such as methemoglobinemia and carcinogenic risks. Thus, immediate intervention is essential. As a mitigation strategy, the study recommends waste management interventions. The proposed WWTP should include activated carbon filtration to remove heavy metals and advanced oxidation processes for organic pollutants like phenol.

Keywords: Stone carving, Waste liquid, Parameter, Health Environment

INTRODUCTION

Magelang Regency is renowned for its stone carving craftsmanship, hosting around 326 businesses across Muntilan, Salam, Sawangan, Dukun, and Mungkid subdistricts. Sedayu Village in Muntilan is a central hub, with 3,129 artisans (3,126 men and three women) specializing in stone carving and masonry. The region produces diverse crafts, including statues, garden ornaments, stone cladding, lanterns, and mortar-pestle sets, for domestic and international markets.^{1,2,3}

Despite efforts to relocate the industry to Sewan and Banaran hamlets in Sedayu Village, significant environmental pollution persists due to poor liquid waste management. Wastewater from stone cutting, smoothing, and finishing contains fine

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particles, stone fragments, and chemicals like lubricants and abrasives. This untreated water is discharged directly into the environment, causing pollution.^{4 5} The stone carving process begins with selecting raw materials from natural stones sourced from local quarries around Magelang. These stones are cut using electric cutting machines, generating stone fragments and dust as solid waste. The stones are then processed further using grinding or carving tools to achieve the desired designs. Water is used intensively at this stage to reduce frictional heat and prevent machine damage. The resulting liquid waste contains high levels of Total Suspended Solids (TSS) and hazardous chemicals, such as hexavalent chromium (Cr(VI)) and phenol.^{5 6 7 8}

Treating wastewater effluent from the stone-cutting industry requires an integrated approach to prevent environmental pollution from solid particles and heavy metals. Techniques such as coagulation-flocculation with polyaluminum chloride (PAC) or alum effectively reduce turbidity and suspended solids (TSS) in wastewater.⁹ ¹⁰ In addition, the application of constructed wetlands (CW) using aquatic plants and biological processes helps filter and absorb pollutants.¹¹ This approach can be integrated with the concept of circular economy, where treated carbonate sludge can be reused. The use of settling ponds and filters such as sand, gravel and activated carbon are also effective for filtering heavy metals and chemicals.¹⁰

In the field of Sedayu Village carving stone craftsmen, there is no wastewater treatment, and it is directly discharged into irrigation rivers, which impacts aquatic biota and public health risks. Therefore, this study aims to determine the impact of pollution on the environment by analyzing the quality of liquid waste from the stone carving industry both physically and chemically and identifying the risk of its impact on environmental health.

MATERIAL AND METHOD

This study employs a quantitative approach supported by laboratory analysis, which is a procedure used to test wastewater samples to identify, measure, and analyze their physical and chemical components. The research was conducted among stone carving artisans in Sedayu Village, Muntilan Subdistrict, Magelang Regency, with liquid waste samples collected from industrial outlets discharging into the Kranjang River using the composite sampling method is a combination of samples from several sampling location points. The study was carried out over six months, from February to July 2024, encompassing primary data collection and laboratory testing of liquid waste parameters. These parameters include physical indicators such as pH, TSS, BOD, COD, and heavy metals like nitrite, chromium, and phenol, analyzed at the Environmental Agency Laboratory (DLH) of Magelang Regency. Data analysis was conducted descriptively and supplemented with a risk analysis using the Environmental Health Risk Assessment (EHRA) method. The study has received ethical clearance approval from the Ethics Committee of the Poltekkes Kemenkes Yogyakarta, with clearance number No.DP.04.03/e-KEPK.1/744/2023, to ensure that the research process meets ethical principles and protects human respondents as research subjects.

RESULTS AND DISCUSSION

Magelang Regency, located in Central Java Province, comprises 21 subdistricts. Secondary data indicate that the stone carving industry is concentrated in six subdistricts: Salam, Dukun, Sawangan, Muntilan, Mungkid, and Secang. These industries are predominantly micro-scale or home-based, employing an average of 0–2 workers per business. In total, the stone carving industry in the region employs 456 individuals. The types of stone carving products produced are diverse, with each subdistrict exhibiting unique characteristics. For instance, in Sawangan, Dukun,

Sedayu and Muntlan, the majority of businesses focus on producing mortars, pestles, grinding stones, and pounding tools^{1 2 3}

The production process of stone carving generally consists of three main stages: a) Cutting or sawing stones; b) Shaping the stone pieces through carving, engraving, turning, or grinding; c) Finishing, which includes polishing and smoothing. The tools include saws and lathes powered by electricity or diesel fuel. Finished stone products are often smoothed using sandpaper, followed by an application of anti-moss coating (coating) using brushes for painting. This process generates liquid waste pollution that threatens river biodiversity and public health. The presence of chromium and phenol in the waste can lead to severe health problems such as cancer, kidney damage, or respiratory disorders. Additionally, high levels of Total Suspended Solids (TSS) and organic pollutants contribute to unpleasant odours, reduce the aesthetic value of the area, and exacerbate environmental degradation.^{5 12 7 8 13}

The results of environmental parameter measurements for the liquid waste generated from the stone carving artisans' outlets in Sedayu Village, Muntlan Subdistrict, Magelang, which discharge into the Kranjang River, are compared with the water quality criteria for Class II as stipulated in Government Regulation No. 22 of 2021 on the Implementation of Environmental Management and Protection. The comparison is shown in Table 1 below:

Table 1. Frequency Distribution of Wastewater Quality Test Results

No	Parameter	Unit	Result	Quality Standard*
1	Total Suspended Solid (TSS)	mg/L	200	50
2	Derajad Keasaman (pH)		7.0	8.46
3	Biochemical Oxygen Demand (BOD)	mg/L	50	3
4	Chemical Oxygen Demand (COD)	mg/L	100	25
5	Nitrite	mg/L	1	0.06
6	Hexavalent Chromium (Cr VI)	mg/L	0.1	0.05
7	Phenol	mg/L	0.5	0.005

* Government Regulation No. 22 of 2021

Table 1. Shows the measurement results of TSS (200 mg/L), BOD (50 mg/L), COD (100 mg/L), Nitrite (1 mg/L), Chromium 0.1 mg/L Moreover, all parameters of phenol (0.5 mg/L) exceeded the threshold value, while the pH parameter (7.0) was normal.

The high Total Suspended Solids (TSS) levels can lead to water turbidity, hinder light penetration, and affect the photosynthesis of aquatic organisms. TSS refers to suspended solids from sediment residues or stone particles that cause water turbidity because they do not settle and are not soluble in water.¹⁴. High TSS concentrations will impact the aquatic biota, as it can inhibit the photosynthesis process by phytoplankton and aquatic plants due to the obstruction and reduction of light penetration into the water body. This condition also leads to a decrease in the dissolved oxygen supply in the water.¹⁵. The high TSS content will also reduce the depth of the photic or euphotic zone, consequently decreasing the depth of productive waters. Another direct impact is the disruption of aquatic life, such as fish, as the dissolved solids are filtered by their gills.¹⁶

Biochemical Oxygen Demand (BOD) concentration at 50 mg/L and Chemical Oxygen Demand (COD) at 100 mg/L indicates significant organic pollution. These

Laboratory measurements showed a nitrite concentration of 1 mg/L, exceeding the threshold limit (0.006 mg/L), while hexavalent chromium was found at 0.1 mg/L, surpassing the set standard ($\leq 0.05 \text{ mg/L}$). The phenol concentration was 0.05 mg/L, exceeding the quality standard ($\leq 0.005 \text{ mg/L}$). These concentrations of toxic heavy metals can potentially cause internal organ damage if ingested through contaminated water, affecting human health and harming the river ecosystem.

This study also estimates the magnitude of the impact by calculating the health risks arising from the source of heavy metal hazards using the Environmental Health Risk Assessment (EHRA) method, which is calculated using the following formula:¹⁹

$$RQ = \frac{I}{RfC}$$

Where:

RQ = Risk quotient for health impact (non-carcinogenic)

I = Intake of the risk agent (inhaled or ingested)

RfC = Reference dose for risk agent exposure

The intake of a risk agent can be calculated using the following formula:

$$I = \frac{C \times R \times t_E \times f_E \times D_t}{W_b \times t_{avg}}$$

Where:

I = The intake of the risk agent (mg/kg × day)

C = The concentration of the risk agent

R = The absorption rate per hour (m³/hour) (default value: 0.83 m³/hour)

t_E = The duration or number of hours of exposure per day (hours/day)

f_E = The number of days of exposure per year

D_t = The number of years of exposure

W_b = The body weight of the population group

t_{ag} = The average period for health effects

The following table calculates health risks as a downstream effect of the decline in water quality based on heavy metal parameters in wastewater.

Table 2. Health Risk Calculation

Parameter (PM ₂₀)	C (mg/L)	R (m ³ /day)	t _E (hour/day)	f _E (day/year)	D _t (year)	W _b (kg)	T _{ag} (day)	Intake	RfC	RQ
Nitrite	1	0.83	8	350	1	55	10950	0.00386	0.1	0.039
Chromium	0.1	0.83	8	350	1	55	10950	0.00039	0.003	0.129
Phenol	0.5	0.83	8	350	1	55	10950	0.00193	0.3	0.006

Table 2 shows that the RQ of Nitrite (0.039), Chromium (0.129) and Phenol (0.006) indicates that all heavy metal parameters $RQ < 1$, meaning that the Sedayu area has a low risk to public health, but in the long term the nature of heavy metal accumulation is likely to have an impact on health and aquatic biota.

The nitrite content in the wastewater sample (1 mg/L) exceeds the standard of 0.06 mg/L. Nitrite in the industrial wastewater of stone carving industries can come from using certain chemicals in the production process, such as solvents, lubricants, or nitrogen coolants. The health impact of nitrite exposure from contaminated drinking water can lead to increased methemoglobin in the blood. This reduces haemoglobin's ability to carry oxygen, which is especially dangerous for infants and pregnant women. Nitrite can also react with amines in the body to form nitrosamines, carcinogenic compounds that increase the risk of stomach and esophageal cancer.^{20 21 22}

17 The chromium levels (0.1 mg/L) exceed the standard by 0,05 mg/L, posing risks of bioaccumulation in aquatic organisms and potential carcinogenic effects in humans through contaminated water. Chromium contamination originates from the use of abrasive and metal-based lubricants in the stone-cutting and polishing processes. As a heavy metal, chromium is highly toxic and can bind to sediment particles in rivers, creating long-term contamination in aquatic ecosystems. This metal can also enter the food chain through bioaccumulation, threatening aquatic organisms like fish. In terms of health effects, consumption of water containing chromium can cause allergies, dermatitis, neurotic disorders, and even cancer, kidney damage, and skin irritation in humans.^{23 24}

Phenol heavy metal concentration (0.5 mg/L) has exceeded the standard limit of 0.05 mg/L; this will harm the environment and human health because it is toxic and carcinogenic. Phenol comes from chemical compounds used to coat and clean the tools of stone tool production., which originates from chemical compounds used to coat and clean the stone carving production tools. As a toxic organic compound, phenol can kill microorganisms essential for natural waste treatment and the base organisms in river ecosystems. Health-wise, prolonged exposure to phenol can cause systemic poisoning in humans, leading to liver damage and central nervous system disorders.²⁵⁻²⁸

The long-term environmental implications of wastewater pollution from stone carving industries result in ecosystem degradation, which can alter the structure of river ecosystems, leading to the loss of sensitive species and reduced ecosystem resilience. Pollution also decreases the availability of clean water for household, agricultural, and livestock activities, which are essential for the residents of Desa Sedayu. The local population uses contaminated water for bathing, washing, and even irrigation, which poses a risk of further health impacts for the community.

Therefore, it is essential to implement wastewater management strategies, such as establishing communal wastewater treatment plants (WWTP) to capture and treat wastewater before it is discharged into rivers. Additionally, environmentally friendly production technologies should be developed for stone carving, such as carbon-based filtration technology to absorb phenol and heavy metals and bioremediation technologies using microorganisms to reduce BOD and COD levels in the wastewater.

The stone carving industry in Magelang Regency produces wastewater that exceeds environmental quality standards; measurement results of TSS (200 mg/L), BOD (50 mg/L), COD (100 mg/L), Nitrite (1 mg/L), Chromium 0.1 mg/L. Moreover, in phenol (0.5 mg/L), all parameters exceeded the threshold value, while the pH parameter (7.0) was standard. RQ of Nitrite (0.039), Chromium (0.129) and Phenol (0.006) indicates that all heavy metal parameters $RQ < 1$, meaning that the Sedayu area has a low risk to public health, but in the long term, the nature of heavy metal accumulation is likely to have an impact on health and aquatic biota. Further research and appropriate waste management interventions are recommended. The proposed WWTP should include activated carbon filtration for heavy metal removal and advanced oxidation.

AUTHORS' CONTRIBUTIONS

Sutaryono, as the team leader, ensured the smooth execution of the research by overseeing coordination and monitoring the entire process from start to finish. Rezyana Budi Syahputri contributed to the drafting of the final report and the writing of the scientific article. Tuti Susilowati developed the research methodology and assisted in preparing both the report and the article. Teguh Setyadi, Purwanti, Sukamsi, and Dhanik Ernawati managed the research budget and conducted data collection in the field. Meanwhile, Mohamad Samsudin, Taufiq Hidayat, Hastin Dyah Kusumawardani, and Ina Kusrini collected and analyzed laboratory data. These structured contributions ensured the research was conducted effectively and produced comprehensive data.

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DATA AVAILABILITY STATEMENT

The data used in this investigation were collected with the informed consent of all respondents. This research has undergone ethical clearance and received approval from the relevant ethics committee.

DISCLOSURE STATEMENT

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors. The data is the result of the author's research and has never been published in other journals.

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