JTL 13 (2) December 2024
Page: 166-173
Contents list available at Jurnal Teknologi Laboratorium

JURNAL TEKNOLOGI LABORATORIUM

Journal Homepage: www.teknolabjournal.com
ISSN 2580-0191(Online) I ISSN 2338 – 5634(Print)

Original Research

OPEN ACCESS

Environmental and health implications of liquid waste from the stone carving industry: Case study in Sedayu Village, Magelang, Central Java, Indonesia

**Sutaryono [1*], Rezyana Budi Syahputri [1], Tuti Susilowati [2], Teguh Setyadi [3], Purwanti [3], Sukamsi [3], Dhanik Ernawati [3], Mohamad Samsudin [4]
Taufiq Hidayat [4], Hastin Dyah Kusumawardani [4], Ina Kusrini [4]**

1 Administrasi Kesehatan Program, Fakultas Kesehatan dan Teknologi, Universitas Muhammadiyah Klaten, Indonesia
2 Permata Indonesia, Health Polytechnic, Yogyakarta, Indonesia
3 Bappeda dan Litbangda Kabupaten Magelang, Magelang Regency, Indonesia
4 Badan Riset dan Inovasi Nasional (BRIN), Indonesia

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 Environment; Health Environment

INTRODUCTION

Local heritage and serves as a source of income through exports and educational tourism in villages such as Sedayu. Despite its economic and cultural benefits, this activity also poses challenges to the environment and public health.[1]

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 particles, stone fragments, and chemicals like lubricants and abrasives. This untreated water is discharged directly into the environment, causing pollution.[2 3] The stone carving process begins with selecting raw materials from natural stones sourced from

Corresponding author.
E-mail address: sutaryono@umkla.ac.id (Sutaryono)
DOI: 10.29238/teknolabjournal.v13i2.562
Received 08 December 2024; Received in revised form 09 December 2024; Accepted 12 December 2024

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.[3 4 5 6]

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.[7 8] In addition, the application of constructed wetlands (CW) using aquatic plants and biological processes helps filter and absorb pollutants.[9] 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.[8]

Rusdjijati's (2021) research in the upper reaches of the Biru River and the confluence of the Kranjang and Biru Rivers found five pollutants that exceeded environmental quality standards: TSS, BOD5, nitrite, sulfide, and hexavalent chromium. The stone carving industry impacts human health, ecosystems and resources, especially causing respiratory problems. Other studies have found that poor water quality affects health problems and decreased quality of life. 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, as a result of the use of diesel and stone machinery, analyzed at the Environmental Agency Laboratory (DLH) of Magelang Regency. Parameters were analyzed using standard methods: TSS by gravimetric analysis, BOD using the Winkler method, and chromium, phenol by atomic absorption spectroscopy (AAS). 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.

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:[10]

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

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

RESULTS AND DISCUSSION

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.[3] 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. [11 5 6 12]

The results of environmental parameter measurements for the liquid waste generated from the stone carving artisans' outlets in Sedayu Village, Muntilan 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

Table 1. Frequency distribution of wastewater quality test

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

* Indonesian 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.[13]. 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.[14]. 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.[15]

Biochemical Oxygen Demand (BOD) concentration at 50 mg/L and Chemical Oxygen Demand (COD) at 100 mg/L indicates significant organic pollution. These values are far beyond the quality standards (BOD ≤ 3 mg/L, COD ≤ 25 mg/L), reflecting high biological activity due to organic material in the wastewater. This aligns with research that states that the higher the BOD level, the more oxygen microorganisms need to decompose organic materials. Rahina mentions that microorganisms require dissolved oxygen to decompose organic matter in aerobic conditions, a characteristic feature of BOD.[16] In other words, BOD is the amount of oxygen required by bacteria to break down (oxidize) nearly all dissolved organic substances and some suspended solids in water.[17]

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 (≤ 0.05 mg/L). The phenol concentration was 0.05 mg/L, exceeding the quality standard (≤ 0.005 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.

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.[18 19 20]

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.[21 22]

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.[23–26]

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.

Data on the study of the impact of stone carving craftsmen's activities on the variable health problems of disease prevalence were obtained through interviews and secondary data searches. The stone craftsmen were all male, with an average age of 40.8 ± 12.2 years. Their age is mostly in the range of 40-49 years, which is 38.3 percent. The negative impacts are exposure to dust, noise and liquid waste. The results of the health examination of the stone craftsmen showed hypertension at 51.7%, sensorineural impairment at 33%, and the incidence ISPA was 43.3%.

CONCLUSION

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.

ACKNOWLEDGEMENT

All authors thank their respective institutions, Bappeda and Litbangda of Magelang District, for facilitating this research.

FUNDING INFORMATION

The Bappeda dan Litbangda Kabupaten Magelang, Magelang Regency, Indonesia, funds research activities based on decision letter Number 180.186/27/KEP/24/2023.

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.

REFERENCE

1. Navi D, Arum P, Setyaningsih P, et al. Kecelakaan Kerja Pada Pengrajin Batu Kecamatan Muntilan Kabupaten Magelang Dalam Perspektif Keselamatan Dan Kesehatan Kerja. *Jurnal Kesehatan Tambusai*. 2024;5(4).
2. Wahana S, Eviyati R, Amini Z. Analisis Produksi dan Air Limbah Industri Batu Alam dengan Perlakuan Eco-Enzym Analysis of Natural Stone Industrial Production and Wastewater with Eco-Enzyme Treatment. *BIOFARM Jurnal Ilmiah Pertanian*. 2023;19(2).
3. Oktriani A, Darmajanti L, Soesilo TEB. River pollution caused by natural stone industry. In: *AIP Conference Proceedings*. Vol 1823. American Institute of Physics Inc.; 2017. doi:10.1063/1.4978129
4. Beggio G, Peng W, Lü F, Cerasaro A, Bonato T, Pivato A. Chemically Enhanced Solid–Liquid Separation of Digestate: Suspended Solids Removal and Effects on Environmental Quality of Separated Fractions. *Waste Biomass Valorization*. 2022;13(2):1029-1041. doi:10.1007/s12649-021-01591-y
5. Esti RN, Windraswara R. Metode Kombinasi Menurunkan Kadar BOD 5 dan COD Limbah Cair Tepung Aren. *Higeia Journal Of Public Health Research And Development*. 2020;4((4)). doi:10.15294/higeia/v4i4/34881
6. Gbarakoro SL, Gbarakoro TN, Eebu WL. Impact of Industrial Effluent Discharge on the Physico-chemical Properties of Aleto Stream, Eleme, Rivers State, Nigeria. *Annu Res Rev Biol*. Published online April 6, 2020:79-89. doi:10.9734/arrb/2020/v35i130183
7. Ozun S. Enhanced Implications on Turbidity Removal from Natural Stone Wastewater by Binary Mixtures. *ACS Omega*. 2024;9(26):28218-28227. doi:10.1021/acsomega.4c01448
8. Tazzini A, Gambino F, Casale M, Dino GA. Managing Marble Quarry Waste: Opportunities and Challenges for Circular Economy Implementation. *Sustainability (Switzerland)* . 2024;16(7). doi:10.3390/su16073056
9. Hassan I, Chowdhury SR, Prihartato PK, Razzak SA. processes Wastewater Treatment Using Constructed Wetland: Current Trends and Future Potential. Published online 2021. doi:10.3390/pr
10. Abbas HH, Lestari A, Gafur A, Bur N. *Environmental Health Risk Assessment (EHRA) of Ammonia (NH3) Exposure to Scavengers at Tamangapa Landfill*.; 2019.
11. Dwi Sukmarani A, Ekonomi Pembangunan J, Ekonomi F, Negeri Semarang U. Analisis Produksi Industri Rumah Tangga Penghasil Pahat Batu Di Kecamatan Muntilan Kabupaten Magelang. *Economics Development Analysis Journal*. http://journal.unnes.ac.id/sju/index.php/edaj
12. Susanto B, Wiratno, Sugandi D, Surdiyanto Y, Sutrisna N, Argo Y. Technology alternative for managing paddy fields exposed to natural stone industry wastewater in Cirebon Regency. In: *IOP Conference Series: Earth and Environmental Science*. Vol 648. IOP Publishing Ltd; 2021. doi:10.1088/1755-1315/648/1/012156
13. Gholami M, O'Sullivan AD, Mackey HR. Nutrient treatment of greywater in green wall systems: A critical review of removal mechanisms, performance efficiencies and system design parameters. *J Environ Manage*. 2023;345. doi:10.1016/j.jenvman.2023.118917
14. Nasution RRIBAYE. Rancangan Teknik Reklamasi Penambangan Pasir dan Batu di Disusun Banaran, Keninger, Dukun, Magelang, Jawa Tengah. 2020;2((2)).

15. Khofifah and Maisari Utami. Analysis of Total Dissolved Solid (TDS) and Total Suspended Solid (TSS) Levels in Liquid Waste from Sugar Cane Industry. *IJCR-Indonesian Journal of Chemical Research*. 2022;1(7).
16. Hamuna B, Tanjung RH, Maury HK, Alianto dan, Ilmu Kelautan dan Perikanan J. Kajian Kualitas Air Laut dan Indeks Pencemaran Berdasarkan Parameter Fisika-Kimia Di Perairan Distrik Depapre, Jayapura. 2018;16:35-43. doi:10.14710/jil.16.135-43
17. Kumaravel R, Shanmugam VK. Biomimetic and ecological perspective towards decolorization of industrial important Azo dyes using bacterial cultures – A review. *Sustainable Chemistry for the Environment*. 2024;7. doi:10.1016/j.scenv.2024.100130
18. Seyyedsalehi MS, Mohebbi E, Tourang F, Sasanfar B, Boffetta P, Zendehdel K. Association of Dietary Nitrate, Nitrite, and N-Nitroso Compounds Intake and Gastrointestinal Cancers: A Systematic Review and Meta-Analysis. *Toxics*. 2023;11(2). doi:10.3390/toxics11020190
19. Belzer A, Krasowski MD. Causes of acquired methemoglobinemia – A retrospective study at a large academic hospital. *Toxicol Rep*. 2024;12:331-337. doi:10.1016/j.toxrep.2024.03.004
20. Dey S, Naga Veerendra GT, Phani Manoj AV, Anjaneya Babu Padavala SS. Invasive lignocellulose-based plants bio-sorbents for the elimination of nitrites of emerging concern from water. *Environmental Functional Materials*. 2023;2(3):255-274. doi:10.1016/j.efmat.2024.05.002
21. Chege SM, Wang D. The influence of technology innovation on SME performance through environmental sustainability practices in Kenya. *Technol Soc*. 2020;60. doi:10.1016/j.techsoc.2019.101210
22. Ray A, Jankar JS. A Comparative Study of Chromium: Therapeutic Uses and Toxicological Effects on Human Health. *J Pharmacol Pharmacother*. 2022;13(3):239-245. doi:10.1177/0976500X221128646
23. Rifqi Aufa. Teknik Penyisihan Fenol Dari Air Limbah. *ReserachGate*. Published online 2017.
24. Aini Dahalan F, Abd Gami A, Yunus Shukor M, Abdul Khalil K, Khalid A, Aqlima Ahmad S. *Phenol and Its Toxicity*. Vol 2.; 2018. https://www.researchgate.net/publication/271508777
25. Mohd A. Presence of phenol in wastewater effluent and its removal: an overview. *Int J Environ Anal Chem*. 2022;102(6):1362-1384. doi:10.1080/03067319.2020.1738412
26. Mamman S, Abdullahi SS ad, Birniwa AH, et al. Influence of adsorption parameters on phenolic compounds removal from aqueous solutions: A mini review. *Desalination Water Treat*. 2024;320. doi:10.1016/j.dwt.2024.100631