Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 23 | No. 4 | pp. 2009-2023 | 2024
Original Research Paper
https://doi.org/10.46488/NEPT.2024.v23i04.009
Open Access Journal

The Waste Management System in the Parking and Traders Arrangement in the Borobudur Temple Area, Central Java, Indonesia

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 03-01-2024
Revised: 19-03-2024
Accepted: 05-04-2024

Key Words:
Waste management system
Reduce-reuse-recycle
Borobudur temple
Water quality
Plankton
Benthos
Diversity index

ABSTRACT

The Indonesian government continues to accelerate the resolution of all problems related to the planning, infrastructure development, and arrangement of tourist visits, including the arrangement of parking spaces and commercial areas in the Borobudur temple area. The purpose of this study is to develop a waste management system in the parking and commercial areas of Kujon as an alternative to structuring the Borobudur temple area. The research method is a descriptive-qualitative observational approach. Surface water and groundwater examinations are carried out in laboratories and compared with quality criteria determined by the Indonesian government. Toxic and hazardous waste is stored in temporary facilities until it is collected by a company licensed by the Indonesian environmental ministry. The Shannon-Wiener Plankton and Benthos Diversity Index measures the diversity of organisms in a community. The study's findings highlight the need to establish a waste processing facility based on the reduction, reuse, and recycling principles. Waste will be collected at a certain site and stored temporarily in line with the technical instructions for the Minister of Environment and Forestry's Regulation. The findings of surface water and groundwater studies demonstrate that all measured parameters continue to meet the Indonesian government's quality thresholds. Plankton Bioindicator Measurements: Plankton diversity index values range from 1.040 to 1.943, indicating moderate pollution, while benthos values range from 0.811 to 0.918, indicating weakly to moderately contaminated conditions. Sustainable environmental management is critical and should serve as a baseline for environmental quality in the activity area.

INTRODUCTION

Tourism is one of Indonesia's fastest-expanding economic sectors, both in terms of variety and growth. The positive consequence of tourism activities will be the construction of new hotels, restaurants, and retail complexes, which will result in the creation of more jobs and an increase in regional income. According to the United Nations World Tourism Organization (UNWTO), tourism has contributed to the gross domestic product (GDP) of numerous countries across the world (Khan et al. 2020). Tourism may also be detrimental to the environment, particularly in terms of garbage (waste) generation brought on by the large number of tourists and activities at tourist destinations. The conservation and preservation of historical sites, natural regions, and archeological artifacts are also hampered by this (Barakazı 2023). Borobudur Temple Tourist Park is a major tourist destination for both domestic and international visitors, as well as a cultural heritage site. Borobudur Temple Tourist Park has already been declared one of the world's seven wonders (Scolaro 2016). The Magelang Regency Central Statistics Agency projects that 1.44 million tourists will visit Borobudur Temple in 2022.

The Borobudur Temple Tourist Park presents a bright prospect for state revenue. Annual increases in tourism have both beneficial and detrimental effects on the environment. The amount of rubbish generated by the growing number of visitors to Borobudur Temple is one of the negative effects. (Ahmed et al. 2019). The waste processing process in the Borobudur Temple area includes physical, chemical, and biological processes, all of which must meet the criteria set by the government. (Bravi et al. 2020). The establishment of a waste management system requires a paradigm shift that prioritizes an environmentally friendly waste management process by reducing and utilizing waste before it is disposed of in the landfill or into the environment. Referring to Presidential Regulation Number 1 of 1992 concerning Waste Management and Control implemented by the State-Owned Enterprise (BUMN) PT Taman Wisata Candi Borobudur, Prambanan, and Ratu Boko (Persero) (Purwaningsih et al. 2021). The protection of the Borobudur World Cultural Heritage Area is carried out in accordance with Law Number 11 of 2010 concerning Cultural Heritage, while the surrounding cultural landscape is carried out in accordance with Law Number 26 of 2007 concerning Spatial Planning, with the Borobudur Temple Complex designated as a National Strategic Area. (Susilo & Suroso 2015). The waste management system plan consists of sorting and containerization, collection, and processing at the waste processing site using the Waste Management Site reduce-reuse-recycle method (TPS 3R), transfer, and transportation to the final processing site. The management results are validated based on physical and chemical parameters. and biology and parameters do not exceed quality standards that have been determined based on government regulations (Perdana 2023)

The waste management system is a systematic, comprehensive, and sustainable activity that includes reducing and handling waste (Heidari et al. 2019). The waste management system in Indonesia is governed by Law No. 18 of 2008. It aims to promote public and environmental health by converting waste into resources that can be sustainably handled. The waste management system includes both technical and non-technical components. Waste management technically refers to decreasing and handling waste, which involves storing and segregating waste, collecting, transferring, and transporting it. Non-technical handling comprises institutions, regulatory and legal subsystems, financing, and community participation. These two factors are mutually sustainable and must be carried out in tandem to build a good waste management system (Karjoko et al. 2022). Waste generated from the operations of the Borobudur Temple tourist area must be managed first so that it does not cause ecological disturbance. This waste must meet environmental quality standards with physical, chemical, and biological parameters. River water quality standards must meet the requirements set by the Indonesian government, especially regarding National Water Quality Standards based on Government Regulation Number 22 of 2021 (Susanto 2023), Minister of Health Regulation Number 32 of 2017 for Environmental Health Quality Standards, and Clean Water Health Requirements. The water quality standard for biological parameters is to know the plankton and benthos diversity index. Management of toxic and hazardous waste must be in accordance with Regulation Number 6 of 2021 concerning procedures and techniques for managing hazardous and toxic waste. (Astuti et al. 2020)

The concept of the Borobudur Destination Development Acceleration program guides the spatial planning of the temple area, including the arrangement of parking lots and merchant spaces, to preserve the temple as a top priority for the Indonesian government. To maintain and preserve the extraordinary special value that Borobudur Temple has, a sustainable waste management system must go hand in hand with the creation of this policy.

The research question is whether the waste management system for parking and trading locations in the Kujon area can provide an alternative solution for the Borobudur temple area, as well as whether groundwater and surface water quality standards can be managed following established quality standards. Likewise, with the management of solid waste, toxic, and hazardous materials related to research questions, this research aims to design an environmental management system that is suitable for structuring parking allocations and trade activity zones in the tourist area around Borobudur Temple, including standard management. Quality of surface water and groundwater, and management of toxic and hazardous waste as per the regulations set by the Indonesian government.

MATERIALS AND METHODS

On March 18-21, 2021, this study was conducted in the Borobudur temple tourism region of Magelang Regency. The sample conditions were sunny, wind speed 0.50-2.1 $m.s^{-1}$, the total wind direction was dominated by the east by 23%, the air temperature was 28.6°C, air pressure mmHg was 739.7 mmHg, and air humidity was 76.7%.

Management of Solid Waste

Waste management is the practice of managing waste from conception to disposal, which includes collection, transportation, processing, and disposal, as well as waste management rules. Clear environmental boundaries are needed to manage and comply with waste impact analysis and solid waste management so that assessments in environmental monitoring can be more thoroughly confirmed. The ecological boundary of waste management is the location where waste is collected, sorted, reused, recycled, processed, and finally processed (Quilley & Kish 2019).

The waste produced can be evaluated by calculating the amount of waste at temporary and final disposal sites using the SNI 19-3964-1995 standard, with the standard unit for large cities being 2-2.5 $L.person.day^{-1}$ or 0.4-0.5 $kg.person^{-1}.day^{-1}$ and the standard unit for medium or small cities is 1.5-2 $L.person^{-1}.day^{-1}$ or 0.3-0.4 $kg.person.hour^{-1}$ with waste management criteria based on Minister of Health Regulation Number 17 of 2020 (Kastolani 2019). The quantity of waste generated in a tourist location is directly correlated with the number of tourists, including vendors, and the local population. SNI 19-3964-1995 states that estimates from landfills for traditionally generated garbage (waste) can be utilized to estimate the volume of waste in a tourism region (Butar-Butar et al. 2020).

The data collection method used is observation, namely observing the availability of waste collection places and locations, the availability of cleaning staff, daily waste handling, the amount of organic and inorganic waste produced, the type of waste management facilities, and secondary data from the Magelang Regency Cleaning Service using the method of descriptive-qualitative analysis.

Surface Water Quality

The ecological boundaries for surface water parameters (river water) are based on water bodies in the vicinity of the research site. The Elo River is a river to the south of the research site, with an ecological border of surface water about 100 meters downstream.

The discharge of wastewater from anthropogenic activities in the Borobudur Temple tourist area into water bodies can impair the quality of surface water. Because wastewater typically flows into rivers, river water quality can be used to assess the success of wastewater treatment as well as the overall quality of a water body (Arum et al. 2019). Surface water quality measurements in the Elo River were carried out using a surface water sampling methodology based on SNI 6989.57:2008. The analysis was carried out experimentally in the laboratory using a spectrophotometer and then compared to the National Water Quality Standards, which are based on Government Regulation No. 22 of 2021(Cahyadi et al. 2023). The coordinates of the surface water sampling location are at Location AP-1: LS: 07˚36'11.76" - BT: 110˚11'47.11" and LS: 07˚36'18.63" - BT: 110˚11'46.34".

Water samples are collected in phases using a 1-liter water sampler before being composited, divided, and conserved for laboratory analysis. Water samples are collected based on the analytical designation, including metals, BOD, COD, and other parameters. Temperature, TDS, electrical conductivity, pH, and dissolved oxygen parameters, which can change quickly and cannot be preserved, are tested at the site where the water samples were collected, and the results are recorded on a field sheet or special notebook. Research on ecological boundaries is required in this study to direct the selection of sites for the first environmental baseline data collection and impact dispersion analysis. Every aspect of the impacted biophysical and chemical environment must be taken into account when determining ecological limitations (Strayer 2003).

Residential Well Water Quality

The ecological boundaries for well water are based on the impact of lowering the quality of well water within a 100-meter radius of the research site (Van Geen et al. 2016)

This study's sample was excavated using well water gathered utilizing purposive sampling procedures. SNI 6989 58 2008 Concerning Methods for Sampling Groundwater is the foundation for groundwater sampling (Lusiana et al. 2020). The analytical method relies on laboratory analysis with a spectrophotometer and comparison to quality standards of Minister of Health Regulation No. 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Cleanliness, Sanitation, Swimming Pools, and Public Baths (Erlinawati et al. 2021). Sampling location determined by coordinates: AB-1: Residents of Kujon Hamlet to the west of the location (LS: 07˚36'09.6" - BT: 110˚11'46.6") and location AB-2: a residents' well close to the location's south (LS: 07˚36'21.85"; BT: 110˚11'51.22").

Residential well water sampling: Before utilizing a water sampler, agitate the bottom of a dug well for 2-3 minutes. The sample was then placed in a plastic container with a capacity of 2000 mL without preservative, a 1000 mL bottle with HNO_3, a 500 mL bottle with H_2SO_4, and a 100 mL glass bottle for microbiological parameters, all of which were wrapped in aluminum foil.

Waste Management of Toxic Hazardous Materials

Ecological boundaries for managing toxic and hazardous waste include storage, collection, utilization, transportation, and processing in temporary storage areas before being taken by a third party and having permission from the Ministry of Environment based on the requirements of the Minister of Environment and Forestry Regulation Number 6 of 2021 (Widyaningsih & Sembiring 2021).

The management plan takes the form of temporary storage, and it refers to the Minister of Environment and Forestry Regulation Number 6 of 2021, which governs the procedures and techniques for managing hazardous and toxic waste (Budihardjo et al. 2023)

Plankton and Benthos Species Diversity Index Value

The ecological limits for plankton and benthos characteristics are the same as for surface water. The plankton sampling approach is carried out at two sites along the Elo River by filtering river water samples using a plankton net, while the benthos (macro-invertebrate) sampling method is carried out by taking mud and substrate samples from the river surface with a Grab and stream-net sampler. The Shannon-Wiener equation is used to get the species diversity index value. (Putri et al. 2019) Coordinates of Plankton/ benthos sampling locations at Location AP-1: LS: 07˚36'11.76" - BT: 110˚11'47.11" and Location AP-2: B LS: 07˚36'18.63" - E:

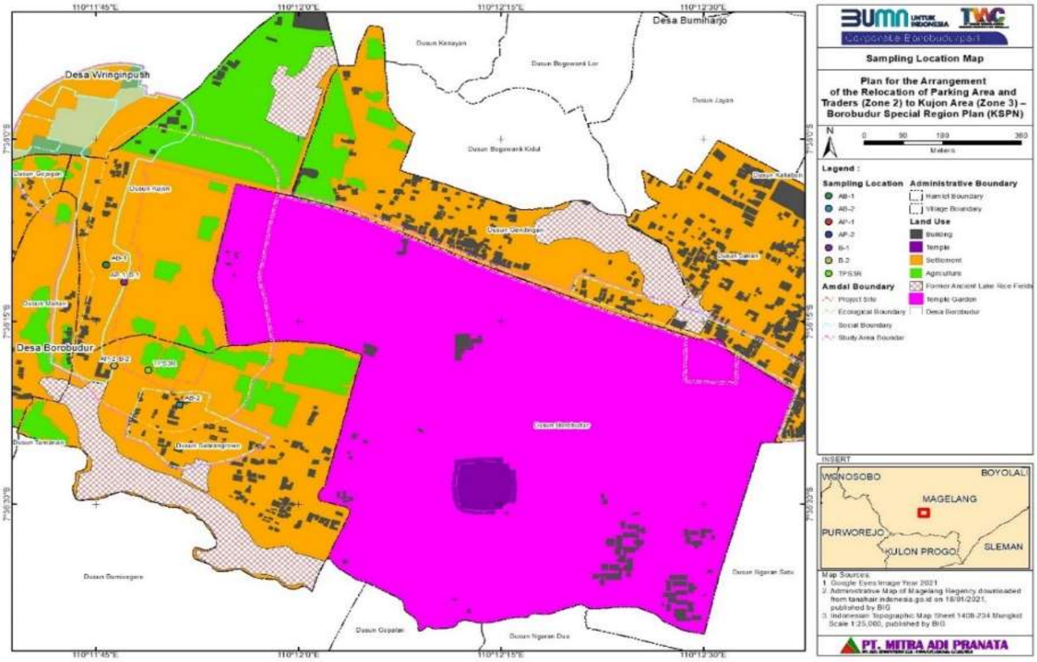


Fig 1: Research area boundaries.

110°11'46.34". Fig. 1 shows the sampling locations and ecological boundaries of the research.

RESULTS AND DISCUSSION

Management of Solid Waste, Waste Water, and Toxic Hazardous Materials

According to Waste Management Law Number 18 of 2008, waste is defined as the remains of anthropogenic activities or natural processes in solid or semi-solid form, in the form of biodegradable or non-biodegradable organic or inorganic substances that are no longer useful and are thrown into the environment. Tourist locations produce large amounts of waste due to tourist activities and supporting facilities; therefore, these places require a sustainable waste management system. The growth of tourist attractions in the Borobudur Temple area is a priority, especially plans for the development and arrangement of parking lots and merchant areas, so waste management is needed that meets technical requirements (Ernawaty 2018). Activities in parking areas, souvenir/culinary kiosks, open-air amphitheaters, bicycle & tourist car terminals, shuttle services, lobbies, courtyards, multi-purpose buildings, educational galleries, and parks are estimated to produce organic and inorganic waste. The amount of waste produced in tourist areas is determined by the number of visitors, traders, managers, and local communities based on SNI 19-3964-1995. If field observation standards for waste at the research location are not yet available, then to calculate waste heaps, the standard for the amount of waste heaps can be used. Residential areas, or using the standard waste collection unit for large cities, namely 2-2.5 $L.person.day^{-1}$ or 0.4-0.5 $kg.person.day^{-1}$, while the standard waste collection unit for medium/small cities is 1.5-2 $L.person.day^{-1}$ or 0.3-0.4 $kg.person^{-1}.day^{-1}$ (Widyarsana & Salmaa 2019).

The analysis of waste heaps in the Borobudur Temple tourist area is as follows: The producer or source of waste is mostly due to visitor activities, traders' areas, and parking areas in the Borobudur Temple tourist area, which is under the administration of Magelang Regency with the criteria of a metropolitan city with a population of 1,279,625 people. The assumption is that the amount of waste produced is 2-2.5 $L.person^{-1}.day^{-1}$ or 0.4-0.5 $kg.person^{-1}.day^{-1}$. The merchant and parking area in the Borobudur temple area is a non-residential market and public space. According to Aziz (2019), the usual unit for storing non-residential market-type garbage (waste) is 0.20-0.60 $L.m^{-2}.day^{-1}$ or 0.100-0.30 $kg.m^{-2}.day^{-1}$. The following is an explanation of waste heap analysis: Estimated waste heaps = 0.6 $L.m^{-2}.day^{-1}$, land area = 10.74 Ha, hence total waste generation = 0.6 $L.m^{-2}.day^{-1} \times 10.74$ Ha $\times$ 10,000 $m^2.ha^{-1}$ = 64,440 $L.day^{-1}$ (Aziz 2019). Based on the trash pile analysis, it is projected that waste heaps in Borobudur's merchant and parking areas, as well as visitor activities, will expand, necessitating the calculation of waste forecasts that refer to the increase in visitors. Table 1 shows the projected number of visitors in the Borobudur Temple area.

Table 1: Projection of the number of visitors.

Year of Visit	2021	2022	2023	2024	2025
Number of Visitors (people)	736222	846752	967838	1084891	1216285
Increase in Visitors (people)		110531	121086	117053	131393
Increase in Visitors [%]		15.00%	14.30%	12.10%	12.10%
Average Increase in Visitors [%]	13.40 % with linear prediction is y = 122565+722829				

Table 2: Projection of waste piles in the area in Borobudur temple area (L.day^{-1}).

Year of Foundation (2020)	73,074	82,867	93,971	106,563	120,842
64.44	65.3 % with linear prediction is y = 122565+722829				

The estimated garbage (waste) pile in the Kujon merchant and parking area of the Borobudur temple area is computed using a 13.4% increase in tourist numbers. Table 2 summarizes the trash generation projections for the Borobudur temple region.

A waste processing site with the Waste Management Site Reduce-Reuse-Recycle (TPS3R) concept will be built in the study area. The Waste Management Site Reduce-Reuse-Recycle (TPS3R) is a waste management pattern at the local or regional level that involves active government participation and community empowerment. This effort is expected to reduce the burden of waste processing at temporary waste storage areas (TPS) and integrated waste processing sites (TPST) in the study area (Fig 2).

a. The waste storage system is planned to use trash cans, while the waste transportation system to the A waste processing site with The Waste Management Site Reduce-Reuse-Recycle (TPS3R) is planned to use trash motorbikes, and waste transportation from The Waste Management Site Reduce-Reuse-Recycle (TPS3R) to the final processing site (TPA) or waste processing site integrated (TPST) is planned to use an arm roll truck. The waste management system is designed based on the following criteria:

b. Storage facilities: trash cans with a capacity of 40-50 liters (0.05 m^3)

   a) Means of Transportation: a) Garbage (waste) transport motorbike with capacity: 1.5 m^3.day^{-1}, recycling: 2 times per day. b) Arm roll Truck Ca-

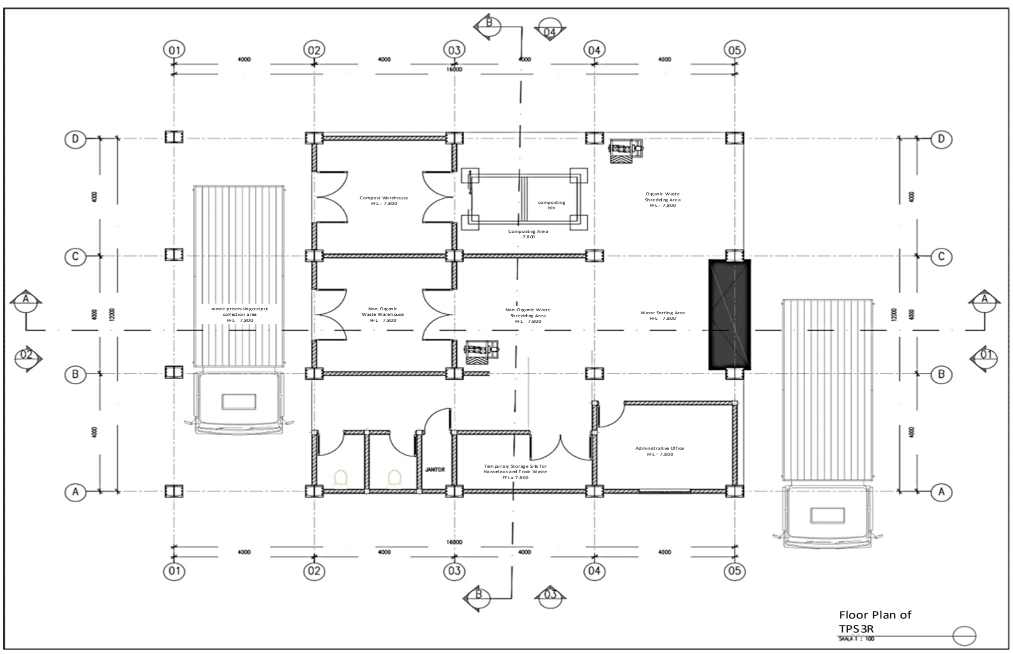


Fig. 2: Building plan the waste management site reduce-reuse-recycle (TPS3R).

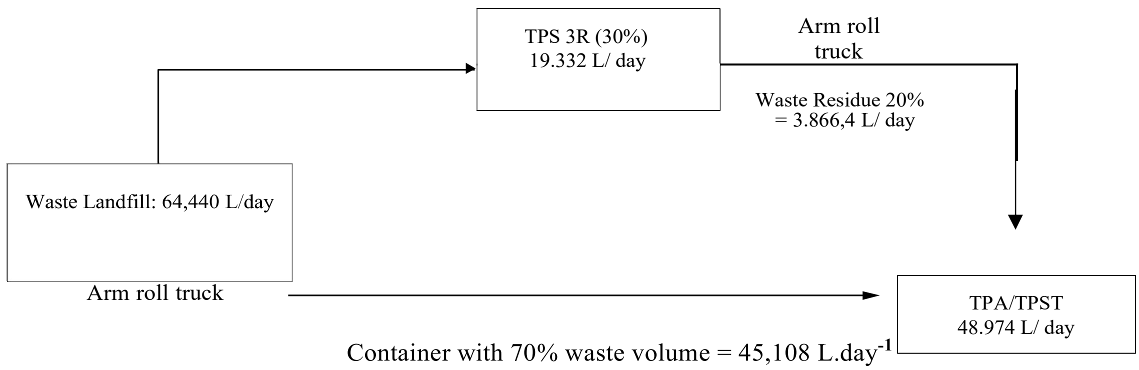
pacity: 6 m3; Ritation: 2 times per day. c) The Waste Management Site - Reduce-Reuse-Recycle (TPS3R) facilities capacity is 30 m^3

Waste management operational technicalities include sorting and containing, collection, transportation, processing, and final processing activities.

Waste Container System: The container design must meet the following requirements: a) Comply with the specifications for use as a temporary waste storage device, including the design. b) Tool uniformization can aid in the smooth execution of operations. c) The equipment includes a separate container for wet and dry garbage (waste) to aid in the process of minimizing waste at the source. Specifications for a container with a capacity of 40-50 liters manufactured of polyethylene plastic bin material and a service life of 3 years. The garbage (waste) container pattern is as follows: 1) Domestic garbage (waste), institutional waste (offices, hotels, stores, restaurants, and health facilities), and street waste are anticipated to be divided into organic and inorganic waste to aid in the reduction process. 2) Every morning at 05.00, traders collected the rubbish created so that the cleaning crew could collect and transport the waste around 06.00-07.00. 3) Make certain that the waste is not scattered; if there is surplus waste, place it in a plastic bag so that the cleaning crew can quickly collect it. 4) Waste containers will be provided at each trader's kiosk and in public locations. Meanwhile, the waste container from street sweeping is a zinc garbage (waste) can with a capacity of 40-50 liters, with a placement pattern on the road lane on the right and left of the road at a distance of 50 meters alternately. The waste management system plan diagram is shown in Fig. 3

The number of waste containers needed is described in Table 3.

Cleaning personnel then collect the gathered trash every morning between 6:00 and 7:00 a.m. and collect it using a waste motorbike for waste that will be processed at Waste Disposal - The Waste Management Site Reduce-Reuse-Recycle (TPS3R). Meanwhile, garbage (waste) is carried to



Note: Waste Management Site for The Waste Management Site Reduce-Reuse-Recycle (TPS3R)
Integrated Waste Processing Site (TPST)
Final Processing Place (TPA)

Fig. 3: Waste Management System Plan.

Table 3: Number of trash cans required.

Description	Number of trash cans	Information
Trader	1284	Waste containers are segregated and closed and provided by each trader
Courtyard with (Entrance hall)	4	Provided by the kujon merchant and parking area manager
Outdoor space-rock garden	8	Provided by the kujon merchant and parking area manager
Green-Landscape / Rare Forest Plants	15	Provided by the kujon merchant and parking area manager
Open Stage-creative space	10	Provided by the kujon merchant and parking area manager
Deck-Feeder Shuttle	20	Provided by the kujon merchant and parking area manager
Parking area	15	Provided by the kujon merchant and parking area manager
Bike & VW Safari Station	15	Provided by the kujon merchant and parking area manager
Number of containers/trash cans	1371	

Table 4: Power requirements for sweepers.

Areas	Number of Sweepers (People)	Information
Courtyard with (Entrance hall)	5	Every morning between 05.00 and 07.00, street sweeping takes place.
Outdoor space-rock garden	15	
Green-Landscape/Rare Forest Plants	20	
Open Stage-creative space	10	
Deck-Feeder Shuttle	25	
Parking area	20	
Bike & VW Safari Station	15	
Number of sweepers	110	

the Final Waste Processing Site (TPA) or Integrated Waste Processing Site (TPST) using an arm-roll truck. Sweeping is used to gather garbage (waste) in public areas and on roads. Sweeping power will be split into the locations as given in Table 4.

Each sweeping worker should be outfitted with the following items: 1 set of work clothes (striking color), 1 work safety hat, 1 broomstick, 1 bamboo cradle, 1 dust protection mask, 1 pair of work shoes, and 1 broomstick and bamboo cradle. Sweeping command. It is vital to inspect the sweepers regularly. It is vital to vary the work location regularly to create a new and pleasant working environment.

Transport System

The waste transportation system is carried out in the morning after sweeping, and traders have collected all the waste produced. Garbage (waste) transportation is carried out at 7:00 a.m. Transporting waste from waste containers to Waste Management Site - Reduce-Reuse-Recycle (TPS3R) uses a trash motorbike while transporting waste from waste containers and residue from Waste Management Site - Reduce-Reuse-Recycle (TPS3R) is carried out using an arm roll truck. garbage (waste) Motor Capacity: 1.5 $m^3.day^{-1}$; Processing: 2 times per day Arm roll truck capacity: 6 m^3; recitation: 2 times per day.

The waste transportation system requires that the waste transportation equipment be equipped with a waste cover, at least using a net so that the waste is scattered, that the maximum height of the transportation tank is 1.6 m, that it has a lever, that the capacity of the waste is determined by the class of road that will be traversed, and that the truck body is equipped with wastewater protection. The trash transportation system is planned in collaboration with Magelang Regency sanitation officials to transfer waste to the Final Processing Site / Integrated Waste Processing Sites (TPST), while the management provides waste transportation equipment to Waste Management Site - Reduce-Reuse-Recycle (TPS3R) in the form of a waste motorbike.

Analysis of the need for waste transport motorbikes is described as follows: Volume of waste transported to Waste Management Site - Reduce-Reuse-Recycle (TPS3R) = 19,332 $L.day^{-1}$, the capacity of motorbike transport = 1.5 $m^3.day^{-1}$ with rotation: 2 times a day = 7 motorbikes carrying waste, the number of waste motorbikes required is 7 units; therefore, 7 riders are needed.

Wastewater Management

Wastewater management planning refers to the Regulation of the Minister of Public Works and Public Housing Number 04/PRT/M/2017 concerning the Implementation of Domestic Wastewater Management Systems. The planned dirty water treatment system or sewage treatment plant uses a biofilter septic tank. The Sewage Treatment Plant (STP) is utilized to handle all wastewater generated by building activities. (Vindriani et al. 2023). Biotank is a bioseptic tank that treats home wastewater and is an advancement of simple septic tank technology. Domestic wastewater treatment systems will be differentiated based on building clusters, namely buildings with culinary clusters and buildings without culinary clusters (Fig. 4 & 5). The domestic wastewater treatment system in buildings with culinary clusters will have a grease trap added before it enters the bio-filter septic tank. The grease trap that will be used is made of fiberglass with a volume of 35 L. In general, the grease trap functions to Filter and wash cooking and dining utensils after removing waste fat and oil from kitchen garbage (waste) and Separating fat or oil with water so that the oil does not clump and freeze in the drain pipe, clogging the line.

Domestic wastewater treatment systems in non-culinary buildings do not have grease traps before entering the bio-filter septic tank.

34 biofilter septic tanks will be used, each with a capacity of 8 m^3. The biofilter septic tank has 4 (four) segments/bulks, namely:

The initial settling tank: It serves as an initial filter media to separate solid and liquid waste; solid waste

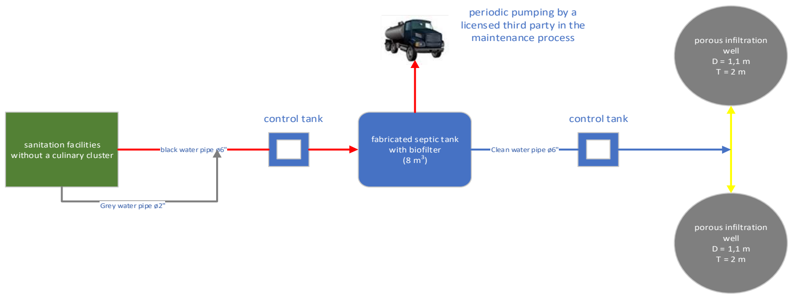


Fig. 4: Domestic wastewater treatment system scheme for facilities without culinary clusters.

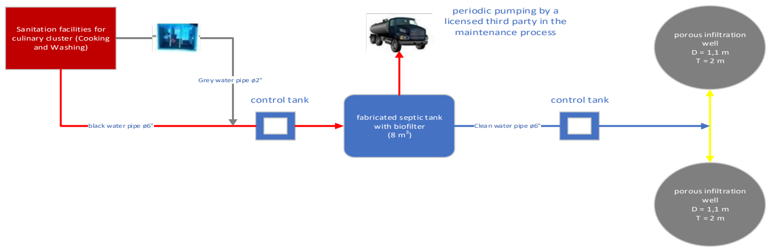


Fig. 5: Domestic wastewater treatment system scheme for facilities with culinary clusters.

is removed from unclean water and allowed to settle fully.

Anaerobic Zone 1: Sewage waste will be divided into solid waste and liquid waste using a filtration system, allowing for perfect separation of unclean water and solid waste.

Anaerobic Zone 2: It is the third filter, which produces better and clearer water that no longer harms the environment. In this filter, there are balls, also called bioballs, which influence the final results of wastewater treatment.

Anaerobic zone: It is a wastewater treatment filter equipped with decomposing bacteria whose job is to break down residual waste so that it is not harmful to the soil and water areas. Concentrated bacterial tablets will be inserted into this filter periodically so that the decomposition process can take place efficiently and effectively.

A chlorination tank (disinfectant medium): It is a wastewater treatment component that is beneficial for destroying germs in wastewater. Chlorine will be injected into this chlorination tank before it flows through the biofilter section tank's outlet or effluent (Fig. 6). The water treated by the biofilter septic tank will subsequently be directed to the water catchment (Da Silva et al. 2013).

Management of Hazardous and Toxic Waste

The trade and parking areas in the Borobudur temple area will produce hazardous and toxic waste (B3) during operational activities, namely Toxic and Hazardous Waste originating from non-specific sources (not otherwise specified) in the form of used batteries, used electronic equipment refrigerants, and electronic waste (PCB/Print Circuit)., TL lamp, and battery. The management plan in the form of temporary storage before being taken by a second party will be related to the Minister of Environment and Forestry Regulation Number 6 of 2021 concerning Procedures and Requirements for Management of Hazardous and Toxic Waste (Zulfikri 2023). An estimate of the amount of hazardous and toxic waste produced during operational activities (peak conditions) is shown in Table 5.

Toxic and hazardous waste will be collected at a certain location in a temporary storage area with an area of 8 m^2. The Waste Management Site - Reduce-Reuse-Recycle (TPS3R) building must be flood-free, closed, and protected from rain, have an air circulation ventilation system, and have a watertight and non-wavy floor.

The amount of toxic and hazardous waste produced is less than 50 $kg.day^{-1}$ (Category 1). The longest storage period

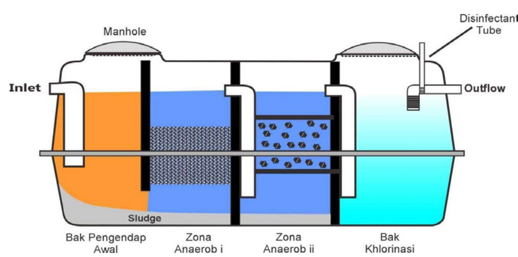


Fig. 6: Bio Filter Septic Tank Scheme.

Table 5: Name, characteristics, and amount of toxic and hazardous waste.

No	Name and Code	Source	Type	Characteristics	Amount
1.	Used battery Code: A102d	Electronic equipment includes: wall clock, remote, microphone	Congested	Toxic and corrosive	20 $kg.month^{-1}$
2.	Refrigerant used for electronic equipment, Code: A111d	Electronic equipment includes AC, refrigerator, dispenser, and freezer.	Liquid	Poisonous	250 $L.month^{-1}$
3.	Electronic waste (Printed Circuit Boards, TL lamps), Code: B107d	Electronic equipment includes lights	Congested	Poisonous	60 $pcs.month^{-1}$

is 180 days from the time the toxic and hazardous waste is produced. Supervision of Toxic Waste Storage activities in the form of supervision during the placement and/or removal of Toxic Waste from the toxic and hazardous Waste Storage room; inspection of toxic and hazardous waste packaging; documentation of storage activities. Toxic and hazardous waste will be collected at a certain location in a temporary storage area with a room area of 8 m^2. The Waste Management Site - Reduce-Reuse-Recycle (TPS3R) building must be flood-free, closed, and protected from rain, have an air circulation ventilation system, and have a watertight and non-wavy floor.

The amount of toxic and hazardous waste produced is less than 50 $kg.day^{-1}$ (Category 1). The longest storage period is 180 days from the time the toxic and hazardous waste is produced. Supervision of Toxic and Hazardous Waste Storage activities in the form of supervision during the placement and/or removal of Toxic and Hazardous Waste from the Toxic Waste Storage room; inspection of **To**xic and hazardous waste packaging; documentation of toxic and hazardous waste storage activities; and supervision of housekeeping procedures.

Every toxic and hazardous material waste that is included in the toxic and hazardous material waste is recorded and reported. Transport and handling of toxic and hazardous waste is delegated to other parties who have permits. The storage flow for toxic and hazardous waste; and supervision of housekeeping procedures are shown in Fig. 7.

Every toxic and hazardous material waste that is included in the toxic and hazardous material waste is recorded and reported. Transport and handling of toxic and hazardous waste is delegated to other parties who have permits. The storage flow for toxic and hazardous waste is shown in Fig. 7.

The general procedure for storing hazardous waste is as follows: a) hazardous waste is produced from the Kujon merchant and parking area in the form of used batteries, used refrigerants, and electronic waste. b) Toxic and hazardous waste will be packaged according to its characteristics. Temporary storage of Toxic and hazardous waste will use packaging in accordance with the waste code, type, and characteristics of Toxic and hazardous waste. Used refrigerant (A111d) uses the original packaging or other watertight packaging if the original packaging is not available (in the form of a drum), while used batteries (A102d) and electronic waste (B107d) will use packaging/containers in the form of sacks or plastic. c) Packages containing Toxic and hazardous waste will be given labels and symbols in accordance with the Minister of Hazardous Environment Regulation Number 14 of 2013 concerning Symbols and Labels for Hazardous and Toxic Waste. d) Toxic and hazardous waste that has been packaged and given a symbol will be stored Special Temporary Storage Area e) Stored according to its characteristics and not exceeding the storage time limit. f) Managed further by a third party who has a Toxic and hazardous waste processing permit, namely in the form of transporting Toxic and hazardous waste.

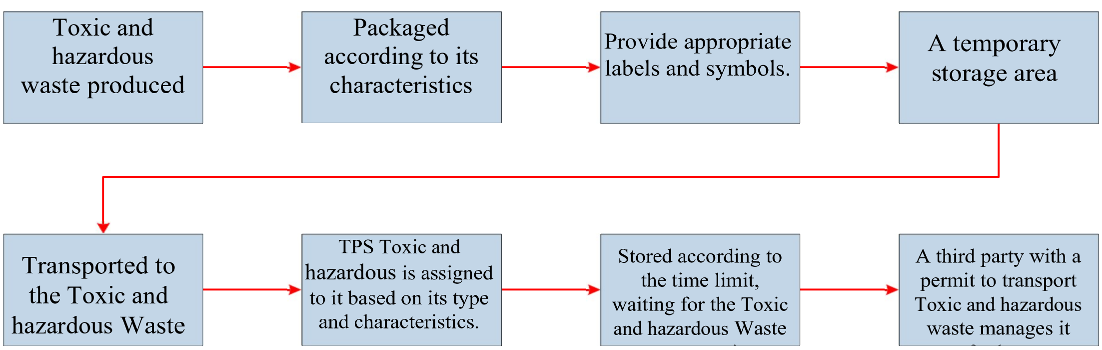


Fig. 7: Toxic and hazardous waste storage flow.

Environmental Quality Indicators

Surface Water Quality and Ground Water Quality

The quality of surface water at a location can be used as an indicator of environmental quality. This is because, generally, the impact of an activity, especially liquid waste, will end up in water bodies (Akhtar et al. 2021). Measurements of surface water quality in water bodies (class III category designated as urban drainage channels) are known to provide results, except for the BOD parameters at the measurement location to the south of the

Table 6: Measurement results for surface water quality.

No.	Parameter	Unit	Result		Environmental Quality standards			
			AP-1	AP-2	Class1	Class 2	Class 3	Class 4
	PHYSICS							
1.	Temperature	°C	27.4	27.6	Deviasi 3	Deviasi 3	Deviasi 3	Deviasi 5
2.	Total dissolved solids (TDS)	$mg.L^{-1}$	148	173	1000	1000	1000	2000
3.	Total suspended solids (TSS)	$mg.L^{-1}$	< 3	< 3	40	50	100	400
4.	Color	Pt-Counit	32.7	< 3	15	50	100	-
5.	Rubbish		Nil	Nil	Nil	Nil	Nil	Nil
	CHEMISTRY							
6.	Degree of acidity (pH)		6.50	6.83	6-9	6-9	6-9	5-9
7.	Biochemical oxygen demand (BOD)	$mg.L^{-1}$	< 2	3	2	3	6	12
8.	Chemical oxygen demand (COD)	$mg.L^{-1}$	4	12	10	25	40	80
9.	Dissolved oxygen (DO)	$mg.L^{-1}$	5.9	5.2	6	4	3	1
10.	Sulfate (SO_4)	$mg.L^{-1}$	11	8	300	300	300	400
11.	Chloride (Cl)	$mg.L^{-1}$	9	13	300	300	300	600
12.	Nitrate (as N)	$mg.L^{-1}$	3	4	10	10	20	20
13.	Nitrite (as N)	$mg.L^{-1}$	0.02	0.01	0.06	0.06	0.06	-
14.	Ammonia (as N)	$mg.L^{-1}$	0.07	0.05	0.1	0.2	0.5	-
15.	Total Nitrogen	$mg.L^{-1}$	3	4	15	15	25	-
16.	Total Phosphate as P	$mg.L^{-1}$	0.004	< 0.003	0.2	0.2	1	-
17.	Fluoride	$mg.L^{-1}$	0.4	0.3	1	1.5	1.5	-
18.	Sulfur as H_2S	$mg.L^{-1}$	0.001	0.002	0.002	0.002	0.002	-
19.	Cyanide (CN)	$mg.L^{-1}$	< 0.002	< 0.002	0.02	0.02	0.02	-
20.	Free chlorine	$mg.L^{-1}$	0.08	0.01	0.03	0.03	0.03	-
21.	Oil and fat	$mg.L^{-1}$	< 0.3	< 0.3	1	1	1	10
22.	Total detergent	$mg.L^{-1}$	< 0.008	< 0.008	0.2	0.2	0.2	-
23.	Phenol	$mg.L^{-1}$	< 0.0005	< 0.0005	0.002	0.005	0.01	0.02
24.	Barium (Ba) is dissolved	$mg.L^{-1}$	0.02	0.03	1	-	-	-
25.	Boron (B) is dissolved	$mg.L^{-1}$	0.5	0.3	1	1	1	1
26.	Dissolved mercury (Hg)	$mg.L^{-1}$	< 0.002	< 0.0002	0.001	0.002	0.002	0.005
27.	Dissolved Arsenic (As)	$mg.L^{-1}$	0.0005	0.0003	0.05	0.05	0.05	1
28.	Selenium (Se) is dissolved	$mg.L^{-1}$	0.0003	0.0009	0.01	0.05	0.05	0.05
29.	Dissolved cadmium (Cd)	$mg.L^{-1}$	< 0.002	< 0.0002	0.01	0.01	0.01	0.01
30.	Dissolved cobalt (Co)	$mg.L^{-1}$	0.0008	0.0004	0.2	0.2	0.2	0.2
31.	Manganese (Mn) is dissolved	$mg.L^{-1}$	0.2	0.11	0.1	-	-	-
32.	Dissolved nickel (Ni)	$mg.L^{-1}$	0.0006	0.0005	0.05	0.05	0.05	0.1
33.	Zinc (Zn) is dissolved	$mg.L^{-1}$	0.01	0.06	0.05	0.05	0.05	2
34.	Dissolved copper (Cu)	$mg.L^{-1}$	0.004	0.006	0.02	0.02	0.02	0.2
35.	Lead (Pb) is dissolved	$mg.L^{-1}$	0.0005	0.0007	0.03	0.03	0.03	0.5
36.	Hexavalent chromium (Cr^{6+})	$mg.L^{-1}$	< 0.002	< 0.002	0.05	0.05	0.05	1
37.	DDT	$mg.L^{-1}$	< 0.008	< 0.008	2	2	2	2
	MICROBIOLOGY							
38.	Fecal Coliforms	$MPN.100\ mL^{-1}$	622	790	100	1.000	2.000	2.000
39.	Total Coliforms	$MPN.100\ mL^{-1}$	1.013	1.300	1.000	5.000	10.000	10.000

Information: Environmental Quality Standards for River Water Quality Standards and the like are in accordance with Republic of Indonesia Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management (Soeprobowati 2023). The sign (-) indicates that the parameter is not required for quality standards, and the sign (<) indicates results below the detection limit. Sampling location: Location AP-1: Water body west of the planned activity location; LS: 07° 36' 11.76" - BT: 110° 11' 47.11" and Location AP-2: Water body south of the planned activity location; S: 07°36'18.63" - E: 110°11'46.34" planned activity location, all of which are still below standard quality in accordance with Republic of Indonesia Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management (Widodo & Hossain 2022). The analysis and measurement findings related to surface water quality are shown in Table 6.

Based on analysis of surface water, it is known that the BOD results have almost reached the quality standard limit, especially at the AP-2 sampling point, where the BOD results for class 2 (which includes water used for planting irrigation, fresh water for fish cultivation, livestock, and recreational purposes) are with value is 3. Biochemical Oxygen Demand, or BOD, is a property that indicates how much-dissolved oxygen a microorganism needs to break down organic matter under aerobic conditions. BOD conditions are a measurement of the amount of oxygen consumed by microbial populations living in water as a reaction to the entry of decomposed organic matter (Sonawane et al. 2020). Based on the analysis findings, organic materials are a source of pollution, so oxygen intervention is needed to support the healthy growth of aerobic microorganisms. An aerator needs to be introduced to organic waste processing facilities in order to lower the BOD.

The Quality of Clean Water (Well Water)

The average depth of groundwater in the research location

Table 7: Results of Well Water Quality Measurements.

No.	Parameter	Unit	Location AB-1	Location AB-2	SBM *
	MANDATORY PARAMETERS				
I	PHYSICS				
1	Turbidity	NTU	0.3	0.2	25
2	Color	Pt. Co	<3	<3	50
3	Total Dissolved Solids, TDS	$mg.L^{-1}$	217	195	1000
4	Temperature	°C	28.6	28.9	Suhu Udara ± 3
5	Smell	-	Tidak Berbau	Tidak Berbau	Tidak Berbau
6	Flavor	-	Tidak Berasa	Tidak Berasa	Tidak Berasa
II	BIOLOGY				
1	Total Coliforms	$CFU.100\ mL^{-1}$	8	49	50
2	E. Coli	$CFU.100\ mL^{-1}$	0	0	0
III	CHEMISTRY				
1	pH	-	6.89	6.85	6.5-8.5
2	Fluoride, F	$mg.L^{-1}$	0.26	0.14	1.5
3	Iron, Fe	$mg.L^{-1}$	0.06	0.02	1
4	Total Hardness, $CaCO_3$	$mg.L^{-1}$	85	162	500
5	Mangan, Mn	$mg.L^{-1}$	<0.00003	<0.00003	0.5
6	Nitrate, NO_3-N	$mg.L^{-1}$	3	1	10
7	Nitrite, NO_2-N	$mg.L^{-1}$	<0.003	0.007	1
8	Cyanide, CN^-	$mg.L^{-1}$	<0.002	<0.002	0.1
9	Surfactant (Detergent), MBAS	$mg.L^{-1}$	<0.008	<0.008	0.05
0	Total Pesticide	$mg.L^{-1}$	<0.000006	<0.000006	
	ADDITIONAL PARAMETERS				
IV	CHEMISTRY				
1	Mercury, Hg	$mg.L^{-1}$	<0.0002	<0.0002	0.001
2	Arsen, As	$mg.L^{-1}$	0.0001	0.0007	0.05
3	Cadmium, Cd	$mg.L^{-1}$	<0.0002	<0.0002	0.005
4	Hexavalent Chromium, Cr^{6+}	$mg.L^{-1}$	<0.002	<0.002	0.05
5	Selenium, Se	$mg.L^{-1}$	0.0003	0.0006	0.01
6	Zinc, Zn	$mg.L^{-1}$	0.03	0.2	15
7	Timbal, Pb	$mg.L^{-1}$	0.001	0.0005	0.05

Information: * SBM is a Quality Standard for Sanitation Hygiene Needs, in accordance with Minister of Health Regulation No. 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Sanitation Hygiene, Swimming Pools, Solus Per Aqua, and Public Baths (Table 1, 2 & 3) (Astuti et al. 2020). The sign (<) indicates results below the detection limit. Sampling location: Location AB-1: Kujon Hamlet Resident's Well to the west of the location (LS: 07°36'09.6" - BT: 110°11'46.6") and Location AB-2: Resident's Well to the south of the location (LS: 07°36'21.85" - E: 110°11'51.22") area and its surroundings ranges from 8 to 15 meters (Widodo 2019). The geological conditions below the groundwater surface affect its depth. Field observations and interviews with residents around the proposed location of the Kujon Hamlet trading and parking area show that a number of residents' wells in Kujon Hamlet, Borobudur Village, have an average water surface depth of around 13 meters.

Measurement of the quality of clean groundwater was carried out at residents' wells near the research location area (trader arrangement area and Kujon Hamlet parking) at 2 (two) points, as shown in Table 7.

Based on the results of measurements of groundwater quality in 2 (two) resident's wells around the area where traders and parking are arranged in Kujon Hamlet, it is known that all measured parameters still meet the threshold values according to Minister of Health Regulation No. 32 of 2017 concerning Environmental Health Quality Standards and Health Requirements for Water for Sanitation Hygiene, Swimming Pools, Solus Per Aqua, and Public Baths, for sanitary hygiene purposes (Erlinawati et al. 2021). The parameter that almost reaches the threshold value is the total coliform measured at location AB-2 (south of the location), which is 49 CFU.100 mL^{-1}, where the threshold value is 50 CFU.100 mL^{-1}. This is possibly due to poor sanitation in the surrounding area, so the well is contaminated with coli bacteria, and it is also possible that the well is close to a source of household waste disposal.

Table 8: Phytoplankton types and amounts discovered.

No.	Types of Organisms (Genera)	Phytoplankton			
		Location B-1		Location B-2	
		sel.L^{-1}	%	sel.L^{-1}	%
	Bacillariophyceae				
1	*Asterionella* sp.	170	10.33	70	22.58
2	*Bacillaria* sp.	10	0.61	25	8.06
3	*Fragilaria* sp.	20	1.22	25	8.06
4	*Navicula* sp.	5	0.30	5	1.61
5	*Synedra* sp.	-		10	3.23
	Chlorophyceae				
6	*Pediastrum* sp.	215	13.07	-	
7	*Tetraedron* sp.	10	0.61	-	
	Coscinodiscophyceae				
8	*Coscinodiscus* sp.	-		5	1,61
9	*Melosira* sp.	195	11.85	35	11.29
	Cyanophyceae				
10	*Aphanizomenon* sp.	875	53.19	50	16.13
11	*Aphanocapsa* sp.	120	7.29	80	25.81
	Euglenophyceae				
12	*Trachelomonas* sp.	5	0.30	-	
	Trebouxiophyceae				
13	*Chlorella* sp.	5	0.30	5	1.61
	Zygnematophyceae				
14	*Staurastrum* sp.	15	0.91	-	
Abundance (cells/L)		1645	100	310	100
Taxa (S)		12	1.943	10	
Diversity (H')		1.491	0.844		
Equalization (E)		0.600	0.171		
Domination (D)		0.330			

Description: Sampling location: AP-1 Location: LS: 07°36'11.76" - BT: 110°11'47.11" and LS: 07°36'18.63" - BT: 110°11'46.34"

Table 9: Zooplankton types and amounts discovered.

No	Types of Organisms (Genera)	Zooplankton			
		Location B-1		Location B-2	
		sel.L^{-1}	%	sel.L^{-1}	%
	IMBRICATEA				
1	Trinema sp.	10	40	-	
	TUBULINEA				
2	Arcella sp.	10	40	10	50
3	Centropyxis sp.	-		5	25
4	Difflugia sp.	5	20	5	25
	Abundance (cells/L)	25	100	20	100
	Taksa (S)	3		3	
	Diversity (H’)	1.055		1.040	
	Equalization (E)	0.960		0.946	
	Domination (D)	0.360		0.375	

Sampling location: Location AP-1: Water body west of the planned activity location; LS: 07°36’11.76” - BT: 110°11’47.11” and Location AP-2: Water body south of the planned activity location; S: 07°36’18.63” - E: 110°11’46.34”

Plankton

Plankton is a heterogeneous group of microorganisms consisting of plants and animals, very small in size and microscopic in nature, living floating in water, moving passively, and whose movements are strongly influenced by water movements or waves. Water quality can be determined by looking at the presence of plankton. The more plankton species that live in a body of water shows that the quality of the water is still good. To determine the condition of the composition, abundance, and diversity of plankton types found in the water bodies around the research location (planned activities for structuring the trading and parking areas of Kujon Hamlet, Borobudur Village). Plankton samples were taken at 2 (two) points at the same location as surface water quality measurements, namely water bodies to the west and south of the planned activity location. Sample collection and analysis were carried out by the Environmental Quality Testing Laboratory. The types and amounts of plankton and zooplankton found are presented in Tables 8 and 9 respectively.

Otene et al. (2023), plankton species diversity index value, criteria for the quality of the aquatic environment can be categorized as shown in Table 10 (Otene et al. 2023).

Based on the data above, it can be seen that the plankton diversity index value ranges between 1.040 to 1.943, so it is included in the medium category. The condition of the water body at the research location according to environmental quality criteria based on the plankton diversity index is included in the moderately polluted category.

Benthos

Benthos are organisms, whether sessile, crawling, or burrowing, that reside at the bottom of the sea (substrate). Benthos can be found in dead or broken coral, dirt, rocks, or sand. Many organic compounds have a major impact on their occurrence in water. Similar to the presence of plankton, benthos can likewise be utilized as an aquatic bioindicator. When estimating imbalances in the biological, chemical, and physical environments of waterways, benthos is frequently utilized. Polluted waters will affect the survival of aquatic organisms, including macrozoobenthos, because macrozoobenthos are aquatic organisms that have been affected by pollutants, both chemical and physical (Rahayu & Fanni 2022), to determine the condition of the composition, abundance, and diversity of benthos types found in the bottom substrate of water bodies around the location of planned activities for structuring the trading and parking areas of Kujon Hamlet, Borobudur Village. Benthos samples were taken at two points at the same location as surface water quality measurements, namely water bodies to the west and south of the planned activity location. Sample collection and analysis were carried out by the Environmental Quality

Table 10: The plankton diversity index is the basis for the environmental quality criteria (Hossain et al. 2017).

Diversity Index Value Plankton	Category	Water Conditions
$H \geq 3$	High	Not polluted
$1 < H < 3$	Medium	Moderately polluted
$H \leq 1$	Low	Heavily polluted

Table 11: Types and numbers benthos.

No	Types of Organisms (Genera)	Macrozoobenthos			
		Location B-1		Location B-1	
		Ind.m^{-2}	%	Ind.m^{-2}	%
	INSECTA				
	Chironomus sp.	57	25	114	66.67
	Tanytarsus sp.	171	75	57	33.33
	Kelimpahan [ind.m^{-2}]	228	100	171	100
	Taksa (S)	2		2	
	Diversity (H')	0.811		0.918	
	Evenness (E)	0.811		0.918	
	Dominance (D)	0.625		0.556	

Information:

Sampling location: Location AP-1: Water body west of the planned activity location; LS: 07°36'11.76" - BT: 110°11'47.11" and Location AP-2: Water body south of the planned activity location; S: 07°36'18.63" - E: 110°11'46.34"

Table 12: Environmental quality criteria based on the Benthos Diversity Index (Ni et al. 2019).

Benthos Diversity Index Value	Category	Water Conditions
H ≥ 2,0	Very high	Not polluted
1.6 < H < 2.0	High	Lightly polluted
1< H < 1.6	Medium	Moderately polluted
H ≤ 1	Low	Heavily Polluted

Testing Laboratory. The types and amounts of benthos found in the study area are presented in Table 11.

Aquatic environmental quality criteria can be grouped based on plankton and benthos species diversity index values according to Ni et al. (2019), as presented in Table 12.

The benthos diversity index values of 0.811 and 0.918 indicate that only two benthos species were discovered, placing them in the low group according to the previously mentioned statistics. Based on benthos diversity index-based environmental quality criteria, the research location's water body is classified as extremely polluted.

CONCLUSION

The waste processing site that will be implemented at the research location follows the waste management site - reduce-reuse-recycle (TPS3R) concept. This effort is expected to reduce the burden of waste processing at temporary waste storage areas (TPS) and integrated waste processing sites (TPST) in the study area. The waste processing installation system is planned to use a biofilter septic tank. Management of wastes in compliance with the technical guidelines for toxic and hazardous waste management specified in Minister of Environment and Forestry Regulation No. 3/2021, toxic and hazardous trash will be gathered at certain sites in the temporary storage facility with a room space of 8 m^2.

Surface Water Quality: The BOD findings at the AP-2 sample point, with BOD results = 3 in the class 2 category, were determined to be in close proximity to the quality standard limit, according to the study of surface water. **Ground Water Quality:** All measured parameters continue to fall below the threshold levels specified by Minister of Health Regulation No. 32 of 2017, based on data from the assessment of the groundwater quality in two (two) residents' wells. The whole coliform measured at the AB-2 sampling point, 49 CFU.100 mL^{-1} (Quality Standard = 50 CFU. 100 mL^{-1}), is the metric that nearly reaches the threshold value.

Plankton: The data above shows that the plankton diversity index value is in the medium range, namely between 1.040 and 1.943. The waters at the research location are included in the moderately polluted category based on environmental quality standards. **Benthos:** The condition of benthos at the research location for Benthos diversity was 0.811 and 0.918 (< 1 lightly polluted)

ACKNOWLEDGMENTS

The author is very grateful to the management of PT Taman Wisata Candi Borobudur Prambanan Ratu Boko (Persero) and Environmental Consultant PT. Mitra Adi Pranata so that this research can run well.

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