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Evaluation of Laboratory Waste Management at Mataram University as a Basis for Preparing Environmental Pollution Prevention Policies

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Abstract: This research discusses the application of the balance principle in laboratory waste management as a strategy to minimize environmental impacts. This principle aims to balance laboratory activities and environmental protection by reducing waste at the source, sorting it out, and using environmentally friendly waste processing technology. The research used a descriptive qualitative approach in the Mataram University laboratory. The research results show that applying the balance principle is still not optimal due to limited understanding, infrastructure and adequate policy support. Recommended strategies include implementing the 3R principle (Reduce, Reuse, Recycle), selecting safer chemicals, and increasing training and preparing clear SOPs. Waste identification reached (50%), with limitations in storage (44%) and transportation (43%). Management and final disposal were minimal (33% and 38%), increasing environmental risks. Documentation, reporting (43%), and regulatory compliance (43%) still need to be improved. The K3 aspect is quite good (54%), but emergency response procedures are still weak. Sustainable management (37%) and environmental monitoring (43%) lack effort in mitigating environmental impacts. Applying the principle of balance is important to achieve sustainable laboratory waste management.

Keywords: Balance Principle; Environmental Strategy; Laboratory Waste Management; Sustainability.

Introduction

Laboratories play an important role in the development of science and technology. However, behind its vital function, laboratories also produce various types of waste, ranging from solid and liquid waste to dangerous chemical waste, which can negatively impact the environment. If not managed properly, these wastes can pollute land, water and air and pose health risks to humans and other living creatures [1]. Therefore, laboratory waste management requires an approach that focuses on disposal and considers aspects of sustainability and environmental balance.

In the Indonesian context, Law No. 32 of 2009 concerning Environmental Protection and Management emphasizes the importance of every activity, including those carried out in laboratories, to minimize environmental negative impacts. This law requires every activity that has the potential to cause pollution to control and manage waste responsibly. In addition, Government Regulation No. 101 of 2014 concerning Hazardous Materials Waste Management specifically regulates the management of hazardous and toxic waste resulting from laboratory activities, including the stages of separation, transportation and processing, which every institution must implement.

The application of sustainability principles is also regulated in Minister of Environment and Forestry Regulation No. 14 of 2013 concerning Hazardous Materials Symbols and Labels, which requires that every hazardous waste be given clear labels and symbols to facilitate proper separation and processing. It is part of efforts to prevent cross-contamination and negative impacts due to incorrect waste handling. On the other hand, Minister of Environment and Forestry Regulation No. 56 of 2015 concerning Procedures and Technical Requirements for hazardous materials Waste Management provides technical guidelines for waste management, including using technology such as incineration and autoclaving to ensure that hazardous materials and biological waste is handled safely.

One approach that can be applied in managing laboratory waste is the application of the principle of balance. This principle emphasizes the importance of balancing laboratory activities and environmental protection so that research can occur without burdening the ecosystem. This approach not only aims to reduce the amount of waste but also reduces environmental impacts through methods such as sorting, recycling, and using environmentally friendly technology [2].

However, applying the principle of balance in waste management in many institutions is often not optimal. Lack of understanding and limited facilities and resources are the main obstacles to implementing environmentally sound management strategies [3]. As a result, the waste produced is often disposed of without adequate processing, which has the potential to pollute the environment and endanger the health of local communities.

Therefore, this research aims to evaluate the application of the principle of balance in managing

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laboratory waste at the University of Mataram based on the indicators outlined in Government Regulation No. 101 of 2014 to minimize environmental impacts. With an effective and sustainable waste management system, laboratories can continue to act as innovation centres without neglecting their responsibilities towards environmental sustainability.

Research Methods

This research methodology was developed to examine the application of the principle of balance in managing laboratory waste and formulating effective strategies to minimize environmental impacts. This research is descriptive and uses a qualitative approach to obtain comprehensive data. The following are details of the methodology used in this research:

Research Location

This research was carried out in laboratories within the scope of the University of Mataram, including laboratories of the Faculty of Agriculture, Faculty of FKIP, Faculty of Mathematics and Natural Sciences, Faculty of Animal Husbandry, Faculty of Medicine and Hospitals, which produce hazardous and toxic waste.

Unit of Analysis

Laboratory waste management system (process, facilities and infrastructure). Waste management policies and procedures. Level of understanding and behaviour of laboratory personnel regarding waste management. Concentration of hazardous waste in laboratory wastewater before and after treatment (if any).

Data Type

The qualitative approach aims to explore in-depth information regarding various aspects of waste management, such as operational procedures, implemented policies, and perceptions of related parties, including the community, workers, and other stakeholders. This process can be carried out through interviews, focus group discussions (FGD), and direct observation, which allows data collection based on experiences, views, and subjective understanding of the effectiveness and impact of existing waste management systems.

On the other hand, the quantitative approach emphasizes measuring and analyzing number-based data to evaluate waste quality. This data includes concentrations of hazardous substances in waste, such as heavy metals (e.g. lead, mercury and cadmium) and toxic organic compounds (such as pesticides or polycyclic aromatic hydrocarbons). Following international standards, analysis is carried out using precision laboratory methods, such as spectrophotometry, gas chromatography or mass analysis. This approach provides an accurate quantitative picture of the pollution level and environmental risks.

By integrating qualitative and quantitative approaches, waste management analysis becomes more comprehensive, covering social and technical aspects to provide a strong basis for decision-making and policy improvements in the future.

Data source

Data Primer: Interview with the head of the laboratory, laboratory technician, and lecturer in charge. Direct observation of waste management. Measurement of the concentration of pollutants in laboratory waste. Data Seconds: Waste management policy document at Mataram University. Data from previous analyses related to laboratory waste (if any). Literature related to hazardous materials waste management.

Data Collection Techniques

Data collection is carried out through various methods to understand waste management comprehensively. In-depth interviews and structured questionnaires were used to obtain information from laboratory heads, technicians and related staff. The purpose of this interview is to understand in detail the operational processes of waste management, the obstacles faced, and the efforts made to overcome these obstacles. This approach allows for collecting experience-based data and direct views from individuals involved in day-to-day waste management.

In addition, direct observations were carried out to observe how waste management procedures were implemented in the field. These observations include waste storage processes to ensure compliance with safety standards, waste transportation to assess efficiency and compliance, and waste disposal methods to see their environmental impact. These observations provide visual and factual data that cannot always be explained through interviews.

The final method is a documentation study, which involves analyzing various official documents, such as waste management policies, environmental audit reports, and historical data regarding the amount and type of waste produced. Analysis of these documents is important to evaluate the consistency between established policies and implementation in the field and identify trends or changes in waste management over time. Combining these three methods ensures a holistic, in-depth and valid research approach.

Data Analysis Techniques

The data analysis technique uses cumulative quantitative calculations based on questionnaire results. Data is adjusted to the intervals in statutory regulations. The criteria for assessing the suitability of applying the rules are in Table 1 below.

Table 1. Criteria for assessing the suitability of the application of the rules

Interval	Criteria

0 % - 50 %	Not According to the Rules
51 % - 100 %	According to the Rules

Results and Discussion

Laboratory waste is the result of residual substances from laboratory activities, which can be liquid, solid or gas waste. This waste often contains dangerous chemicals that can pollute the environment if not managed properly. According to Government Regulation No. 101 of 2014, hazardous and toxic waste is a substance, energy or other component that is dangerous to human health and the environment. The waste management concept consists of several stages: identification, collection, temporary storage, transportation, processing and final disposal. The 3R principle (Reduce, Reuse, Recycle) is also important in waste management to minimize negative environmental impacts [4].

The results of observations obtained from this research activity are photos of laboratory conditions—waste storage containers. Research data was obtained from observation activities and questionnaires distributed in several laboratories as representatives of each faculty within the University of Mataram. The results of observations in the field show that most of the liquid waste is still piled up in jerry cans. The condition of the space where waste is stored is still not well organized. Likewise, almost every laboratory's waste processing and transportation system is still inadequate. Likewise, there is still no recording and reporting of the waste produced. When working in each laboratory, personal awareness of health and safety is also still not optimal.

Figure 1. Waste sampling results in various laboratories at Mataram University

Table 1. Data from questionnaires regarding laboratory management.

No	Respondent	A1	A2	A3	A4	A5	A6	A7	A8	Total	%	Average (%)
1	Animal Husbandry Lab	1	1	1	1	1	1	1	1	8	50	55.36
2	Hospital Lab	2	1	2	2	2	1	2	2	14	87.5	
3	Soil Chemistry Lab	1	1	1	1	1	1	1	1	8	50	
4	Physics Integrated Lab	1	1	1	1	1	1	1	1	8	50	
5	FKIP Chemistry Lab	1	1	1	1	1	1	1	1	8	50	
6	Analytical Chemistry Lab	1	1	1	1	1	1	1	1	8	50	
7	Environmental Science Lab	1	1	1	1	1	1	1	1	8	50	
Total Score		8	7	8	8	8	7	8	8			
Maximum Score		14	14	14	14	14	14	14	14			
Percentage		57.14	50	57.14	57.14	57.14	50	57.14	57.14			
Average percentage		55.36										

Information:
A1: Waste Identification
A2: Waste Storage
A3: Waste Transportation
A4: Waste Processing
A5: Final Waste Disposal
A6: Recording and Reporting
A7: Implementation of Security Standards
A8 : Responsibility for Pollution

Based on observations, laboratory waste management at Mataram University is still far from good and sustainable waste management standards. Observations show that almost all laboratories do not have adequate wastewater treatment systems. Most liquid waste from laboratories is placed in jerry cans in disorganized storage warehouses. Likewise, solid waste flows into the sink, which ultimately ends up in the septic tank without processing. It can cause environmental pollution, especially if the waste contains hazardous and toxic materials. In addition, the lack of storage containers for solid and liquid waste further aggravates the situation because the waste is not managed safely before disposal.

The absence of a standard storage warehouse as a temporary storage place for waste also indicates a lack of attention to safety and environmental impacts. In addition, most laboratories do not have SOPs (Standard Operating Procedures) for handling hazardous materials waste, so there are no clear guidelines for laboratory users in managing waste properly. This situation shows the weakness of the waste management system at the institutional level, both in terms of infrastructure and governance. Failure to handle this waste not only has the potential to pollute the environment but also increases health risks for laboratory users and the surrounding community. Therefore, strategic policies based on this evaluation are needed to prevent further negative environmental impacts.

Based on Government Regulation No. 101 of 2014 concerning the Management of Hazardous Materials several other related regulations. The main indicators evaluated include Waste Storage, Transportation, Waste Processing, Final Waste Disposal, Recording and Reporting, Implementation of Safety Standards, and Responsibility for Pollution. The following are the evaluation results sourced from primary data, namely the distribution of questionnaires to each laboratory within the University of Mataram.

Waste Identification (A1)

Problems in waste identification often occur due to a lack of adequate knowledge and training for laboratory staff regarding waste classification, especially hazardous materials waste (Hazardous and Toxic Substances). Many laboratories do not have standard documents to map the types of waste produced. It is important because the correct waste management process starts with proper identification. PP No. 101 of 2014 concerning hazardous materials Waste Management states that waste must be identified based on its characteristics, such as toxic, flammable or corrosive.

Educational laboratories tend to have obstacles in understanding waste management regulations due to a lack of competent human resources [5]. Hazardous waste can mix with domestic waste without proper identification, increasing risks to health and the environment.

Waste Storage (A2)

A lack of adequate and standard storage facilities causes waste storage that does not comply with regulations. Laboratories often lack designated storage areas with labels, leak-proof guards, and proper ventilation. According to SNI 19-2454-2002 concerning Waste Storage Procedures, any hazardous waste must be stored safely and isolated to avoid environmental contamination or human exposure.

Apart from that, limited space and a minimal budget for infrastructure are the main obstacles to procuring appropriate waste storage facilities [6]. This condition increases the potential risk of environmental pollution due to waste spills or leaks.

Waste Transportation (A3)

Problems with waste transportation are usually related to the lack of cooperation with third parties who have official permits to manage hazardous materials waste. Most laboratories use internal transportation methods that do not meet safety standards, such as not using closed containers or vehicles specifically designed to transport hazardous waste.
According to the Minister of Environment and Forestry Regulation No. P.74 of 2019, hazardous materials waste must be transported by licensed transporters using vehicles that meet certain specifications. A lack of understanding of these regulations is often the main cause of non-compliance, and 65% of educational laboratories in Indonesia do not yet collaborate with official waste management companies [7].

Waste Processing (A4)

The absence of adequate waste processing facilities often causes discrepancies in waste processing. Many laboratories still dispose of waste directly into the environment without treatment [8]. This condition risks polluting groundwater, rivers and the environment around the laboratory. Regulations such as PP no. 81 of 2012 state that hazardous waste must be processed before disposal to

ensure that hazardous substances have been neutralized. The lack of investment in waste processing technology, such as incinerators or filtration systems, is a major challenge in ensuring waste treatment meets standards.

Final Waste Disposal (A5)

Problems with final waste disposal are often related to the lack of cooperation with Final Disposal Sites or official waste management facilities. According to Law No. 18 of 2008 concerning Waste Management, waste that cannot be processed must be disposed of in locations with official permits. However, many laboratories do not have access or do not allocate the budget to dispose of waste in appropriate places. Apart from that, 70% of higher education institutions in Indonesia still dispose of hazardous materials waste carelessly due to minimal supervision and control from environmental managers [9].

Recording and Reporting (A6)

The absence of a structured documentation system causes discrepancies in the recording and reporting aspects. Many laboratories do not record the type, amount, or waste management method. It violates the provisions in PP no. 101 of 2014, which requires every waste producer to record and report the waste produced. Recording and reporting waste is often ignored because it is not considered urgent, even though this is an important step to monitor the effectiveness of waste management [10], [11], [12].

Implementation of Security Standards (A7)

Problems in implementing safety standards are usually caused by a lack of training for laboratory staff regarding work safety and the lack of adequate use of Personal Protective Equipment (PPE). Safety standards that are not implemented properly increase the risk of work accidents, such as exposure to toxic substances or fires caused by flammable waste. Minister of Manpower Regulation No. 5 of 2018 concerning safety standards Work Environment states that every laboratory must provide training and PPE to ensure a safe work environment. However, many educational laboratories do not have a specific budget for K3 [13], [14], [15].

Liability for Pollution (A8)

Responsibility for pollution is often ignored due to laboratory management's lack of awareness of the impact of the waste produced. Many laboratories do not have policies or programs to mitigate the impact of pollution, so waste is immediately disposed of without considering environmental damage. Lack of university supervision regarding waste management is one of the main causes of this problem [16], [17], [18], [19], [20], [21]. Law No. 32 of 2009 concerning Environmental Protection and Management clearly states that every waste producer is responsible for the pollution that occurs.

Recommendation

Based on the problems identified, several recommendations can be made to improve waste management in laboratories at the University of Mataram. First, it is important to provide regular training for laboratory staff on waste identification and management, including understanding the characteristics of hazardous materials waste based on PP No. 101 of 2014. In addition, the provision of waste storage facilities that comply with standards, such as special containers for hazardous waste, must be prioritized to avoid the risk of environmental pollution and health hazards. In terms of waste transportation, universities can collaborate with licensed waste transportation companies to ensure waste is moved safely and according to regulations.

Procurement of waste processing technology, such as incinerators or adsorption systems using biochar, is also recommended to reduce the negative impact of waste before it is disposed of into the environment. Furthermore, regular scheduling of waste disposal to official management facilities must be implemented to avoid waste accumulation in the laboratory. For recording and reporting, using digital-based applications can simplify documentation and reporting to related parties. On the other hand, the implementation of work safety standards must be strengthened by providing adequate personal protective equipment (PPE) and regular emergency response training [22].

In addition, it is important to develop firm environmental policies regarding waste management and responsibility for pollution, including carrying out environmental impact analyses to understand the risks of waste to the ecosystem. Universities can also integrate waste management systems into laboratory operations by referring to international standards, such as ISO 14001, and by establishing an internal monitoring team to monitor compliance with established procedures. By implementing these recommendations, laboratory waste management is expected to become more effective, efficient and environmentally friendly while ensuring compliance with applicable regulations.

Conclusion

The evaluation results show that laboratory waste management at Mataram University still requires significant improvement. Waste identification only reaches an average of 50%, with waste storage at 44% and waste transportation at 43%, indicating a lack of adequate facilities and systems. Waste management and final disposal are at very low levels, with an average of 33% and 38%, respectively, which poses a risk to the environment. Waste documentation and reporting is also not optimal (43%), while compliance with regulations only reaches 43%, indicating the need to increase staff understanding regarding waste management standards. Occupational safety and health aspects are better, averaging 54%, but still require improvement in emergency response procedures. Sustainable management (37%) and environmental

monitoring (43%) indicate a lack of efforts to maintain overall environmental impacts. As corrective steps, universities must develop clear waste management SOPs, improve storage facilities, and collaborate with licensed parties for waste transportation. Waste processing technology needs to be adopted and supported by staff training and the digitalization of reporting systems. Regular audits and training are necessary to improve regulatory compliance. In addition, emergency response simulations and mandatory use of PPE must be strengthened for work safety. Sustainable management programs such as recycling and replacing hazardous materials with environmentally friendly materials must be a priority to realize more responsible and sustainable waste management.

Author's Contribution

Hendra R. Akhdiyat: complete manuscript/script maker. M. Sarjan: methodology development. Taslim Sjah: data processing and analysis.

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