

Preliminary Study of Tofu Industry Waste Management Using the ISWM Approach (*Integrated Sustainable Waste Management*)

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ABSTRACT

Waste from tofu and its by-products cause serious environmental problems because of its great volume, poor solubility, and mixing with other contaminants. In order to overcome the problem of tofu waste, it is important to have systematic and sustainable waste management system. This study aimed to review studies and scientific papers on the management of tofu industry waste and develop a sustainable waste management approach by applying the principles of an Integrated Sustainable Waste Management (ISWM) framework. The research method used in this study is a systematic literature review (SLR) method by analyzing the scientific articles in the last 10 years. The journals that were used are international journals that related to the management of tofu industry waste and ISWM framework. The results of literature analysis showed that most of the tofu industries applied partial waste management approaches that mainly focused on the technical approaches of liquid waste and solid waste management. The findings of some of studies revealed the potential of tofu waste utilization through biological treatment, biogas production, composting, and materials and energy recovery. The synthesis of the studies found that the integrated framework of ISWM is very relevant to support the development of a more sustainable waste management system in the small-scale industry of tofu. An integrated waste management approach also has a positive impact on the environmental performance of industry, and a contributor to sustainable agro-industrial

development. The results of this study hope to contribute to the implementation of waste management system that is more sustainable for small and medium-scale industry of tofu in Indonesia.

Keywords: *Tofu industry waste, sustainable waste management, ISWM, systematic literature review, agro-industry*

INTRODUCTION

Tofu industry in Indonesia especially in Sumedang Regency is rapidly developing to meet the demands of local communities and the external markets. The development of the industry also has created thousands of job opportunities and has increasingly raised the income of local communities. However, in line with the industry's development and growth, there also is generated a lot of waste, both in liquid form containing high organic content such as wastewater of soy milk extraction and in solid form such as tofu residue (okara).

The wastewater generated from tofu processing and production contains high concentrations of polluting compounds mainly includes Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), if discharged into the environment without adequate treatment could cause pollution to environment (Aye et al., 2019; Kim et al., 2019). Waste management practices in most small and medium-scale tofu industries are conventional due mainly to technology, financial and institutional constraints (Nguyen et al., 2020).

Integrated Sustainable Waste Management (ISWM) is a holistic approach that looks at waste management as an integrated system which considers technical, environmental, economic, social and institutional aspects Marshall & Farahbakhsh (2013); Scheinberg et al. (2010). The approach has been utilised as an analytical framework to assess waste management practices and investigate sustainability gaps in a range of contexts, including the agro-industrial sector Guerrero et al. (2013); Wilson et al. (2015).

Although there are some studies on waste management in small-scale tofu industries, few of them utilize an integrated approach of ISWM. This study is a preliminary study that is performed as a systematic literature review. The aim of this study is to synthesize scientific evidence from previous studies, which provide general idea or concept on waste management of tofu industry and similar type of agro-industrial waste. The synthesis outcome is expected to be able to provide a conceptual foundation for future research and development of more effective waste management practices for the tofu industry.

METHODOLOGY

This research starts from a preliminary approach. It is a literature review that conducted as a Systematic Literature Review (SLR). The purpose of this research is to know about how waste management practiced by tofu industry players and how Integrated Sustainable Waste Management (ISWM) is applied, based on the previous research result.

This paper presents results of search and screening of articles which were published within last 10 years. The search was conducted in several scientific databases such as Google Scholar, ScienceDirect and also in the biggest scientific database in the world, namely Scopus. Articles used in this study were those containing "tofu industry waste" or "tofu wastewater" or "agro-industrial waste management" or "Integrated Sustainable Waste Management" in their title, abstract, or keywords. Articles found in search process were then screened for their relevance of topics and how the articles related to the issue of tofu industry waste management or similar problems in other agro-industrial sectors that can be related to the ISWM framework.

Qualitative analysis and synthesis of selected relevant articles on ISWM for the tofu industry were conducted. The synthesized articles were analyzed using three main components of ISWM framework which are waste management system, stakeholders and sustainability. The results of the synthesized articles were further used to recognize research patterns, research gaps and also further suggestions for future research related to sustainable waste management in tofu industry..

DISCUSSION

RESULTS OF SYSTEMATIC LITERATURE REVIEW AND RESEARCH MAPPING Twenty of selected articles were analyzed and presented as relevant to the subject matter of this research, namely dealing with tofu industry waste management and similar issues of agro-industrial waste management. Articles were mapped using the Integrated Sustainable Waste Management (ISWM) framework in terms of their focus, methodologies, and the sustainability aspects dealt with in the articles. A comparison of previous studies related to the issues are presented in Table 1.

Table 1. Comparison of Previous Research Related to Tofu Industry Waste Management and ISWM Based Agroindustry

No	Writer	Year	Research Focus	Research Methods	Key Findings	Aspect ISWM
1	Aye et al.	2019	Tofu industry liquid waste	Review	Tofu waste has high BOD and COD so it requires integrated processing.	Technical, Environmental
2	Kim et al.	2019	Anaerobic digestion of tofu waste	Eksperimental	Effective biogas production and significant COD reduction	Technical, Environmental
3	Zhang et al.	2018	Tofu Liquid Waste Processing	Eksperimental	Biological processes are effective in reducing pollutant loads.	Technical
4	Chen et al.	2019	Utilization of solid waste (okara)	Eksperimental	Okara has potential as animal feed and compost	Economy, Environment
5	Patel et al.	2018	Circular economy of agro-industrial waste	Review	Waste can be used as a value-added resource	Economy

6	Lim et al.	2017	Agro-industrial waste processing technology	Review	Cost and technology constraints on SMEs	Technical, Economic
7	Nguyen et al.	2020	Small scale tofu industry	Case study	Limited technology and capital hamper waste management	Technical, Institutional
8	Guerrero et al.	2013	Waste management in developing countries	Review	Institutional aspects play an important role in the sustainability of the system	Social, Institutional
9	Marshall & Farahbakhsh	2013	ISWM Framework	Conceptual review	ISWM is effective for integrating waste management systems	All aspects
10	Wilson et al.	2015	ISWM Implementation	Review	Stakeholder integration improves system performance	Institutional
11	Rahman et al.	2020	Industrial wastewater management policy	Review	Regulations determine the sustainability of waste management	Institutional
12	Singh et al.	2021	Stakeholder participation	Review	Collaboration increases the effectiveness of waste management	Social
13	Othman et al.	2021	Sustainability indicators of agro-industrial waste	Review	Sustainability evaluation requires comprehensive indicators	Environment
14	Kurniawan et al.	2022	Sustainable agro-industrial waste	Review	Circular economy increases	Environment, Economy

					resource efficiency	
15	Avtar et al.	2022	Waste management systems in Asia	Review	Integrated approaches are still weak in developing countries	All aspects
16	Hwang et al.	2020	Resource recovery of agro-industrial waste	Review	Resource recovery improves system efficiency	Economy, Environment
17	Lim et al.	2019	SME waste processing	Review	SMEs need simple and inexpensive technology	Technical
18	UNEP	2015	Global Waste Management	Report	The ISWM approach is important for developing countries	All aspects
19	Sukardi & Hidayat	2018	Solid waste tofu	Eksperimental	Waste utilization increases local economic benefits	Economic, Social
20	Scheinberg et al.	2010	Urban waste management system	Studi komparatif	Actor integration increases system sustainability	All aspects

Comparison of Research Findings

Most of the comparative studies have been based on treatment and disposal technologies of tofu industrial wastewater with biological processes as the main focus. Those studies indicated that the removal efficiencies of pollution loads from wastewater treated by various technologies were high enough to pose minimal or no environmental pollution. However, only few studies related to disposal based on economic and social perspectives have been conducted.

Studies that employ a systems approach to waste management, see Marshall and Farahbakhsh (2013), Wilson et al. (2015), highlight the importance of incorporating a range of stakeholders and adequate policy support in order to achieve sustainability. Strong institutional support for technical innovations is crucial to their long-term sustainability.

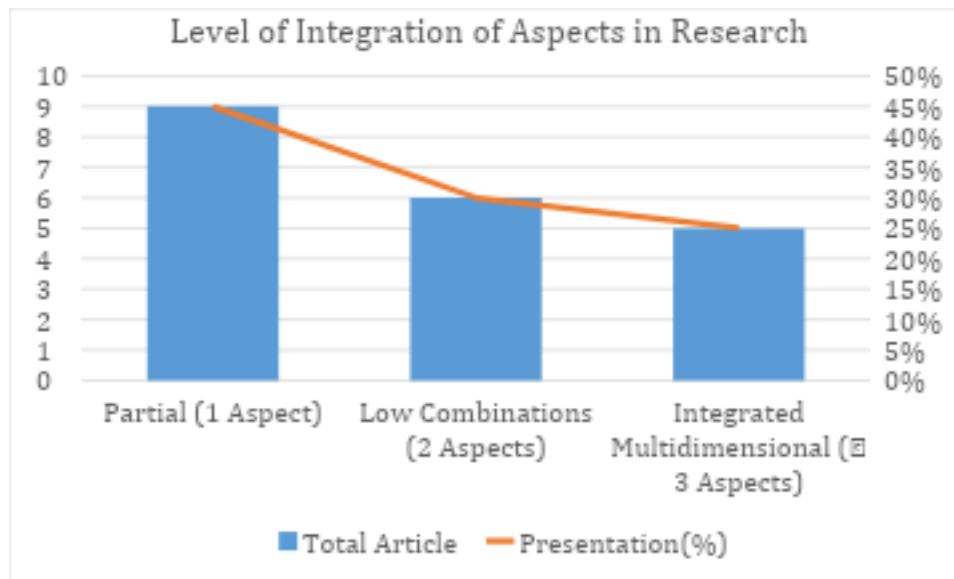


Figure 1. Level of Integration of Aspects in Research

Source: Author's calculation based on research, 2026.

Research Gaps and Relevance of ISWM

Although a literature synthesis was conducted on the social and institution aspects that influence the waste management practices carried out by the small-scale tofu industries, there still exists research gaps on the subject. Most of the studies place the industry as the main actor in facing the problems of waste management without paying attention to the roles of local governments and the surrounding community and other supporting institutions. The ISWM framework can be one of the conceptual approaches to look at the sustainability issue from different dimensions and can be a basis and inspiration for development of future research.

CONCLUSION AND RECOMMENDATION

Based on the findings of the Systematic Literature Review on waste management in the tofu industry and related agro-industrial sectors over the past decade, it can be observed that current practices are still largely partial in nature. Most approaches tend to emphasize technical solutions, particularly in wastewater treatment and the utilization of solid waste. While these efforts have proven effective in reducing pollution levels, their long-term sustainability is often limited by constraints such as inadequate technology, financial challenges, and limited operational capacity, especially within small and medium-sized enterprises.

Furthermore, the literature reveals that the integration of environmental, economic, social, and institutional aspects remains insufficient. This indicates a notable gap in developing comprehensive and sustainable waste management systems. In this context, the Integrated Sustainable Waste Management (ISWM) framework offers a relevant approach, as it promotes the integration of multiple dimensions of sustainability into a unified system. However, since this study relies solely on literature-based analysis, further research is needed to validate these findings through empirical investigation. Future studies are encouraged to apply the ISWM framework in real-world settings to assess its practical effectiveness, particularly in small and medium-scale tofu production centers such as those found in Sumedang Regency.

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Muhammad Rizzki Ar Rozak is an active and accomplished student throughout his college years. He has demonstrated a high level of dedication both academically and organizationally. One of his achievements was winning 3rd place in the inter-department basketball tournament on campus, showcasing his sportsmanship and strong teamwork. In academics, he also earned a hardware certification, proving his ability to understand and apply relevant technology. Additionally, Rizzki was actively involved in student organizations, particularly in the Industrial Engineering Student Association. He was entrusted with the position of Head of the Entrepreneurship Division, where he played a key role in developing programs and activities that fostered an entrepreneurial spirit among students. The combination of sports achievements, technical skills, and leadership experience makes him a well-rounded student, fully equipped to face challenges in the professional world.

Juan Ikhran Harvandhy is an active and accomplished undergraduate student in Industrial Engineering at Komputer University. Throughout his academic journey, he has demonstrated strong commitment in both academic and organizational activities. He achieved 3rd place in an inter-department basketball tournament at the university level, reflecting his teamwork and sportsmanship. In addition, he obtained a hardware certification, indicating his competence in understanding and applying relevant technological skills. He has also been actively involved in student organizations, particularly in the Industrial Engineering Student Association (HMTI), where he served as the Head of the Entrepreneurship Division, contributing to the development of programs that foster students' entrepreneurial mindset. His combination of academic capability, leadership experience, and extracurricular achievements highlights his readiness to face professional challenges in the future.