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Review

Sustainable Waste Management in Japan: Challenges, Achievements, and Future Prospects: A Review

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Abstract: Japan is subject to global interest due to its waste management system, which aims for sustainability and is known for its efficiency. The purpose of this study is to examine Japan's steps towards sustainable waste management practices and highlight its formation, achievements, problems, and prospects for the future. Through a comprehensive review of official governmental data and the academic literature, the main achievements—including extensive government initiatives such as proposing programs, plans, and legislation for sustainable waste management and encouraging public involvement in establishing a Sound Material-Cycle Society (SMCS) and 3Rs—were defined. Thus, the state and the population alike take general measures to combat pollution. Looking at the future of waste management in Japan, the country continues to struggle despite all these efforts and impressive results. It is focusing on developing more sustainable and cost-effective solutions. This includes investing in new technologies, increasing efforts to reduce and recycle waste, and promoting environmental awareness.

Keywords: Japan; waste management; sustainable development; a Sound Material-Cycle Society (SMCS); 3Rs

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1. Introduction

The commonly accepted definition of "waste" refers to materials or processes that are discarded or planned to be discarded [1]. This all-encompassing definition includes the broad spectrum of substances classified as "waste", from home rubbish to industrial waste. Waste management includes all the duties and practices necessary to control waste from its creation to its final disposal. This process comprises the collection, transportation, processing, and final disposal of waste materials and oversight of the waste management processes [2]. Recycling is one option, whereas composting has unique challenges and potential [3].

1.1. Importance of Waste Management

Firstly, waste management is crucial to environmental conservation. Adverse effects on the planet result from ineffective waste management procedures. Poor waste management, particularly concerning toxic or non-biodegradable waste, may severely damage the land. Dangerous substances leach into the soil, harming plant life and entering the food chain. Affected fertile fields may become barren, impacting farming operations and biodiversity [4].

Water bodies also sustain damage. Pollution of rivers, lakes, and oceans results from improper waste disposal, particularly industrial effluents and plastic garbage. This affects communities that depend on these water sources for everyday needs as well as endangered marine species. Numerous health problems, from gastrointestinal infections to more severe illnesses, can be caused by contaminated water, putting millions of lives in danger. The

improper management of garbage also results in air pollution. Burning garbage, mainly plastic, causes poisonous gases to be released into the air, lowering its quality. Chronic exposure to such contaminants can result in cardiovascular disorders, respiratory problems, and other health problems. Therefore, ensuring garbage is correctly disposed of and treated helps to protect the environment and sustain the well-being of all organisms.

Secondly, in pursuit of resource efficiency, it is essential to view waste as a potential resource that has gone missing rather than merely as discarded items. Making garbage into useful things is becoming increasingly important when resources are running out, and sustainable practices are crucial [5]. Organic waste can be composted to create nutrient-rich manure, meaning the usage of artificial fertilizers can be avoided. Similarly, recycling programs can transform waste into raw materials for new products, reducing the need for virgin resources. The circular economy, a cyclical strategy, emphasizes the value of recycling and reuse to promote sustainability.

Lastly, effective waste management has numerous positive effects on the economy. Beyond their primary goal, effective waste management systems are powerful engines for job growth. Each stage of the waste management procedure, from waste collection through sorting, recycling, and disposal, offers job possibilities. Waste treatment technology and sustainable product design also have room for innovation and entrepreneurship, and waste can be turned into marketable goods [2]. These items, which include upcycled goods, biogas produced from organic waste, and recycled materials, can reduce waste and boost the economy.

1.2. Relationship with Sustainability, Sustainable Development, and the SDGs

Sustainable development has a strong connection with waste management in efforts to meet the present requirements without jeopardizing the future [6]. The efficient use of resources, the preservation of ecosystems, and a healthy environment for future generations are all ensured by proper waste management. Furthermore, Thacker et al. (2019) highlight that sustainable growth relies heavily on the infrastructure of efficient waste management [7].

The UN's Sustainable Development Goals (SDGs) [8] highly value ethical consumption and production. SDG 12's primary goal is to "Ensure sustainable consumption and production patterns", and efficient waste management is essential to achieving this goal [9]. Additionally, the principles of waste management indirectly impact other SDGs, such as life below water (SDG 14) and clean water and sanitation (SDG 6), highlighting the significance of reducing trash to save aquatic habitats [10].

1.3. Current Waste Issues

Consumption habits have seen an exponential rise in today's rapidly changing society, which has led to a sharp increase in waste production. A global movement toward urban lifestyles and an ongoing need for consumer goods are to blame for these shifting patterns. Population growth, together with urbanization, makes this issue worse. Cities, which are growing at an unprecedented rate, are leading to greater waste production, and managing this growing amount of waste has become an enormous burden [11].

However, not all waste is equal. The widespread use of plastics, especially microplastics, is an alarming aspect of this garbage onslaught. These little pieces of plastic pose serious environmental risks. They endure in ecosystems, wreak havoc on aquatic life, and eventually move up the food chain, endangering people's health [9]. The current handling of waste worsens this problem. Only a tiny portion of the garbage produced is properly recycled or composted. This inefficiency highlights the urgent need to develop and deploy effective waste management strategies to handle the current volume and foresee future issues.

In the 1990s, Japan faced a severe environmental problem due to high dioxin emissions from waste incineration plants, illegal waste dumping, improper waste treatment and

wastewater leaks from landfills, and intensive production and consumption of goods. This prompted the country to develop a recycling-oriented society.

In 2000, the passage of the Fundamental Act for the Establishment of a Sound Material-Cycle Society (SMCS Act) led to the enactment of various laws that regulate the disposal of different types of waste, including packaging, household appliances, automobiles, and others. Further, in 2007, the "Guidelines for Shaping a Nation's Environmental Strategy for the 21st Century" highlighted three critical aspects for creating a sustainable society. Thus, Japan is developing a Sound Material-Cycle Society (SMCS) to promote resource conservation and develop a low-carbon society to reduce greenhouse gas emissions and coexist harmoniously with nature [12].

Japan faced a significant increase in waste due to higher consumption and industrialization following its rapid post-WWII economic growth. In addition, Saitoh (2022) assumes that the increasing challenge of solid waste in Japan is driven by urbanization [13]. With limited space for waste disposal in this densely populated country, managing waste has become crucial to prevent environmental damage and health risks, underscoring the need for effective waste management systems. Waste management strategies are critical to Japan's sustainable development to ensure environmental preservation.

This study aims to analyze Japan's various environmental policies, providing an in-depth review of waste management practices, their effectiveness and the likelihood of further improvement for the country's benefit [14]. This study examines Japan's path to becoming environmentally sound by adopting favorable waste management strategies and a circular economy [15]. The importance of this study lies in the possibility of adapting Japanese practices to other countries that need practical strategies that have shown positive results [16].

This study's novelty lies in its holistic study of Japan's waste management system. While Japan has made significant strides in reducing waste generation and increasing recycling rates, this study provides an in-depth look at persistent challenges and the strategies being developed to address them. This includes enhanced efforts to reduce and recycle waste and initiatives to promote environmental awareness among the public.

Furthermore, this study offers a forward-looking perspective on Japan's waste management, acknowledging that despite impressive achievements, there is still a need for more sustainable and cost-effective solutions. By focusing on future strategies, this study highlights Japan's commitment to continuously improving its waste management practices.

2. Materials and Methods

This article aims to review the existing literature on waste management in Japan. Its objective is to study the formation of waste management strategies and their effectiveness and explore policy interventions. To comprehensively examine Japan's environmental sustainability and waste management strategies, this study provides an overview of the past and current approaches taken by the country [17]. To achieve that purpose, the authors conducted a literature search using the Scopus, Web of Science, and Research Gate databases. Official data, such as regulations, laws, plans, strategies, government environmental reports, white papers, and statistics, were collected through the official website of the Japanese Ministry of Environment (MoE). Additional statistics were obtained through the Statistics Bureau of the Ministry of Internal Affairs and Communications (MIC) to provide data on the nation's current state of waste management.

Sources and materials include a brief review of the development of waste management with chronological data, an in-depth study of Japan's SMCS Act and the 3Rs, and some steps toward a circular economy within the framework of sustainability. This study will look into critical achievements and prospects for further development.

3. Development of Waste Management in Japan

3.1. Waste Classification in Japan

Article 2 of the Waste Management and Public Cleansing Law (Waste Management Law) (Law No. 137 of 1970 (last amended by Law No. 66 of 2001)) defines "waste" as "garbage, bulky garbage, cinders, sludge, excrement, waste oil, waste acid, waste alkali, animal carcasses, and other filth or unnecessary materials, whether solid or liquid (excluding radioactive materials and items contaminated by them)" [18]. Additionally, not only is garbage considered waste by law; also considered waste are various unnecessary items that are no longer needed by owners but cannot be sold or given away for free [18,19]. Conversely, if something is bought and sold as a raw material, it is not considered waste. Radioactive waste is regulated under a separate law and is not subject to the Waste Management Law [19]. Dredging of ports, rivers, and similar areas generates earth and sand; fishing activities capture aquatic animals and plants in nets, and operators discharge these near the fishing sites. The use of earth, sand, and similar materials exclusively for land development also does not fall under the jurisdiction of the law [20].

Waste can be broadly divided into three categories:

- general waste;
- industrial waste;
- specially controlled waste.

General waste refers to waste other than industrial waste. Although there is no legal classification, waste, such as human waste, is generated due to household and business activities [18,19]. Households mainly generate general waste, including food and bulky waste, while offices produce paper waste. Each municipality is responsible for collecting, transporting, and disposing of general waste. Additionally, the cleansing department has established a specialized bureau.

Industrial waste is discharged from industrial activities designed by law or government ordinance. However, not all waste generated from industrial activities is industrial waste [21].

Both industrial and general waste are separately classified as specially controlled waste. Specially controlled industrial waste includes materials that are explosive, toxic, infectious, or possess other harmful characteristics that can be detrimental to human health or the environment. This type of waste is defined and regulated under government ordinances. The law identifies certain items as hazardous in the general waste category and classifies them as specially controlled general waste. Table 1 presents a detailed list.

Table 1. Waste classification in Japan [18].

Waste Type	Classification	Description
General waste	Household waste General business waste Human waste	Items originating from the everyday activities of ordinary households. Items not classified as industrial waste but produced from commercial operations.
Industrial waste	Twenty legally stipulated varieties of items that emerge from commercial activities.	Items associated with all business activities (1–12): cinders, sludge, waste oil, waste acid, waste alkali, waste plastics, rubber scraps, metal scrap, glass/concrete/ceramic scraps, mine slag, debris, dust. Items for which the types of industries that emit emissions are limited (13–19): waste paper, wood shavings, fiber waste, animal-based solid waste, animal and plant residues, animal excrement, and animal corpses. (20) Concrete solidified sludge, etc. that has been treated for the purpose of disposing of industrial waste listed in (1) to (19), but does not fall under (1) to (19).

Table 1. *Cont.*

Waste Type	Classification	Description
Specially controlled waste	Specially controlled general waste	Among general waste, there are specially designated hazardous items: PCB-containing items such as air-conditioners, televisions and other. Ash collected from garbage incineration facilities and general infectious disease waste discharged from hospitals and other locations.
	Specially controlled industrial waste	Among industrial waste, specially controlled items: (1) Waste oil (flammable waste oil) (2) Waste acid (waste strong acid) (3) Waste alkali (waste strong alkali) (4) Infectious waste (5) Specified hazardous industrial waste • Waste polychlorinated biphenyls (PCBs), etc. • Polychlorinated biphenyl (PCB)-contaminated materials • Polychlorinated biphenyl (PCB)-treated products • Specified sewage sludge • Mining slag • Waste mercury, etc. • Waste asbestos, etc. (asbestos) • Waste oil (waste solvents) • others

3.2. Historical Background and Challenges

Hosomi (2015) claims that Japan's environmental planning views a sustainable society as one that combines a low-carbon economy, biodiversity, and a closed-loop material cycle rooted in the practices of the Edo period (1603–1868). During more than two centuries of self-isolation policy, Japan's economy and energy were primarily based on solar energy. This society efficiently used resources; foods were acquired from domestic plants, energy was sourced from wood and charcoal, and human waste was recycled as fertilizer, contributing to a material-cycle economy. This historical period provides valuable lessons for modern sustainability discussions in Japan [22]. However, the first waste management initiatives were during the Meiji Restoration and have continued in five stages of historical development up to now.

3.2.1. Late 19th to Early 20th Centuries: Meiji Restoration

An important turning point in Japanese history was the Meiji Restoration in 1868, which ushered in a time of rapid modernization and social change [23]. Following these changes, there was a noticeable transformation in the country's waste management practices, particularly concerning cleanliness and public health. Before the Meiji Restoration, Japan mainly used traditional waste disposal methods, including burying waste in public places. However, problems caused by population growth and increased waste generation became more apparent when Japan began industrialization and urbanization in the late 19th and early 20th centuries [23]. After more than two centuries of closure, Japan's sudden intense interaction with other countries led to the spread of infectious diseases such as cholera, exacerbating public health problems and highlighting the need for proper waste management. In 1900, Japan enacted the Waste Cleaning Act. Introducing municipal waste collection systems in megacities was one of the crucial events of that time. This legislation involved either self-disposal by manufacturers or collection and disposal by private organizations, emphasizing incineration as the preferred method [24].

In response to the growing problems associated with urban waste, local governments have begun to provide essential waste removal services. The need to control different types of waste was recognized to stop the spread of disease and environmental pollution, so efforts were made to segregate waste streams. As a result, the Meiji period also saw the development of modern sanitation infrastructure. The result of the creation of treatment

plants and improvements to sewer systems was a decisive factor in raising public health standards. The move to more organized waste management practices reflects people's growing understanding of the link between proper waste disposal and public health. Educational activities have been launched to raise public awareness of the importance of safe waste disposal. Public health initiatives emphasizing cleanliness and hygiene encouraged appropriate waste management at the individual and community levels.

By 1933, 93% of cities had incinerators, and incineration accounted for half of waste disposal. However, the outbreak of the Pacific War in 1941 led to a revision of these regulations, de-emphasizing incineration due to the need to conserve resources, which increased interest in the recycling and reuse of materials [24].

3.2.2. 1945 to 1950s: Post-War

Japan went through a challenging yet revolutionary period following World War II. With the enormous work of restoration and rehabilitation ahead of it, the nation was in ruins. The Japanese post-war economic revival, marked by fast industrialization and economic expansion, occurred in this period [23,25]. However, this extraordinary progress also presented new difficulties, such as the need for extensive waste management rules due to increased waste generation. Japan's economy suffered significant damage during the war, and the country's rehabilitation efforts sparked a rise in industrialization and urbanization. Consequently, there was an increase in the generation of garbage from industry and households. The Japanese government developed and implemented creative waste management solutions in response to the urgent need to handle this growing waste crisis.

Systems for managing municipal garbage were upgraded and extended to handle the increasing waste situation. As the government realized the advantages of sustainable waste management for the environment and the economy, the emphasis on trash reduction, reuse, and recycling increased. The implementation of trash separation programs was one noteworthy initiative. Waste sorting into categories, including hazardous trash, non-hazardous garbage, and recyclables, was promoted for the general public. This significant change from past procedures set the stage for Japan's future resource recovery and recycling achievements. A significant development in Japanese environmental law occurred in 1954 with the creation of the Public Cleansing Act [23,26]. This statute established the foundation for tackling several pollution-related concerns, waste management included. With the development of waste incineration plants to handle non-recyclable garbage more effectively, technical improvements also contributed to waste treatment. As Japan's economy grew, waste management was incorporated into the national agenda.

The municipal waste management service faced significant challenges at each stage. During waste collection and transport, manual collection with handcarts limited the range and volume of waste that could be managed. This led to an inability to cope with increasing waste volumes and public health issues like waste scattering in living environments. Intermediate treatment suffered during the war, with incineration operations halted and facilities damaged. In the final disposal stage, waste was transported to landfill sites without incineration, leading to poor landfill management. This resulted in issues like spontaneous combustion, odors, and pest breeding due to the fermentation of organic waste [24].

3.2.3. 1960s to 1970s: Rapid Economic Growth

Japan had an unheard-of economic boom throughout the 1960s and 1970s, which propelled the country into an age of industrial significance. Japan's economy proliferated, and with it came an increase in industrial output and urbanization that presented severe environmental problems, especially concerning waste management [27].

This period was characterized by significant changes in consumer behavior and a noticeable increase in the volume of waste, including an increase in income, active use of household appliances, and the emergence of supermarkets and household stores. Mass production and consumption have led to a dramatic increase in the amount and variety of waste. Industrial activities contributed to several problems, and factories began producing

waste such as sludge, synthetic resins and waste oil without proper disposal methods. In addition, urban development has generated enormous amounts of construction waste, which is often dumped illegally.

Additionally, rapid industrialization led to the release of hazardous wastes from factories, including organic mercury and cadmium, which seriously affected public health. Plastic products, which are difficult to degrade, have further aggravated the situation. After plastics remain in soil, they release toxic substances during burning, contributing to air and water pollution.

To solve these problems, the Japanese government took several measures. In 1963, they adopted the Act on Emergency Measures Concerning the Development of Living Environment Facilities, and in 1967, the government signed the Fundamental Law for Environmental Pollution Control. This included setting standards for controlling emissions of air and water pollutants. As a result, the Environmental Protection Agency was created in 1971 to promote and implement pollution-related laws systematically [23].

The country's reconstruction after war damage and the preparation for the first Olympic Games (1964) in Asia became significant events. The government took measures to create a sustainable and safe environment for the Games, and the following waste management measures were taken:

1. Modernization of waste disposal: this includes proper collection, transportation and disposal;
2. Encourage reducing, recycling, and reusing possible waste materials;
3. Raising awareness of and encouraging cooperation among citizens on correct waste segregation and disposal methods;
4. Intensifying cleaning activities on roads and public facilities to maintain the overall aesthetic appearance of the city [28].

The Tokyo Metropolitan Government's efforts to host the Olympic Games led to the creation of the current waste management system.

One of Japan's primary pieces of legislation was the Waste Management and Public Cleaning Law (Waste Management Law), passed in 1970. This law defined responsibilities and standards for managing all types of waste, distinguishing between industrial and municipal waste. Previously, municipalities were responsible for both solid waste and industrial waste. However, enterprises became responsible for properly disposing of waste from their business activities after this law (Paragraph 1 of Article 3, Paragraph 11 of Article 11) [18,29].

To combat the growing volume of waste and promote proper management of hazardous waste, the government has supported the construction of waste treatment facilities throughout Japan. This involved the community in promoting segregated waste collection and efficient treatment and disposal methods, thereby improving the waste management system.

At this time, faced with environmental degradation around landfills due to the rapid increase in waste volume and public opposition to incinerators, the governor of Tokyo declared a "War against Waste" in 1971. The Oil Shock of 1973 intensified and expanded events already occurring during the War against Waste, changing attitudes towards waste and the waste management industry [30]. The government promoted the development of environmentally friendly waste management facilities and increased public awareness of waste problems. These measures ultimately led to an improvement in the situation [24].

3.2.4. 1980s to Early 1990s: Rapid Economic Growth to the Bubble Economy

From the 1980s to the early 1990s, Japan shifted from fast economic expansion to the peak of the so-called "bubble economy" [31]. This era saw extraordinary affluence, industrial development, and urban development. This economic growth, nevertheless, was associated with a significant rise in garbage creation, prompting the establishment of a waste management policy to address the issues posed by increased consumption and urbanization. During Japan's extraordinary economic prosperity during the bubble economy, there was a

boom in consumption, resulting in exponential growth in the manufacture of disposable items and packaging. The ensuing increase in waste creation necessitated a rethinking of waste management systems to ensure the long-term management of the increased volume and diversity of garbage [24].

Japan was experiencing a severe shortage of landfills due to the rapid increase in waste. This crisis was exacerbated by public resistance to the construction of new landfills. This was due to concerns about environmental pollution.

The shortage of landfills has resulted in problems such as large-scale illegal dumping and increasing conflicts over waste management. Additionally, this period saw increased awareness and concern about the health hazards posed by dioxins emitted by incinerators. Reports of dioxin contamination in various regions and its detection in breast milk and incinerator fly ash have heightened public fear, leading to strong opposition to new incineration projects [32].

The Japanese government implemented several measures to reduce the environmental effect of increased trash creation. The Waste Management Law, amended in 1991 and 1997, was noteworthy during this time. This legislation attempted to control trash disposal practices, improve waste treatment technologies, and build a waste reduction framework. The Packaging Recycling Law, established in 1995, was a notable milestone [24].

3.2.5. 1990s to 2000s: A Sound Material-Cycle and Low-Carbon Society

Japan's waste management practices continued to develop throughout the 1990s and 2000s, focusing more on resource efficiency, ecological responsibility, and developing a SMCS [33]. Japan purposefully modified its waste management strategy to achieve a low-carbon society [34]. The Japanese government introduced several initiatives and regulations during this time to further the goals of a SMCS. Among the main strategies was the promotion of the 3Rs: Reduce, Reuse, and Recycle [35]. To assure resource efficiency, this policy aimed to enhance recycling efforts, encourage product reuse, and minimize waste formation at the source. Post-2000 policies have focused on integrating and developing SMCS and low-carbon approaches. Hara K. (2012) highlights the critical aspects of achieving a sustainable society: active recycling, especially for materials such as PET bottles, and a holistic approach to resource management that improves energy consumption, material recovery, and productivity [36].

3.2.6. 2010s up to Current Years: Domestic and Global Challenges Period

On 11 March 2011, a powerful earthquake of magnitude of Mw 9.0 occurred on the Pacific coast of Japan; it is also known as the Great East Japan Earthquake Tohoku earthquake. The main affected areas were three prefectures: Miagi, Fukushima, and Iwate. The Daiichi Nuclear Power Plant in Fukushima suffered severe damage due to the tsunami, which released radiation into the region [37]. Shortly after the earthquake and tsunami, young scientists from the Japan Society of Material Cycles and Waste Management (JSMCWM) established the Waste Management and Disaster Recovery Group, which actively worked to develop guidelines for post-disaster waste management under "Strategies for Separation and Treatment of Disaster Waste" [38]. Then, in 2014, the Ministry of Environment released the Disaster Waste Management Guidelines, corrected in 2018 [39].

The coronavirus outbreak in 2019 dealt a blow to global society and the economy, and Japan is no exception. The lockdown has adjusted the population's lifestyle; the volume of household waste has increased due to the quarantine regime, but the volume of industrial waste has decreased [40]. However, the amount of plastic used has increased due to disposable masks and infection testing kits. In the fight for public health and the preservation of the environment, the Ministry of Environment has published Guidelines for the Prevention of COVID-19 [40].

Table 2 provides more detailed information in chronological order on regulations, technologies, significant situations, and events.

Table 2. Chronology [23,24].

Period	Year	Activities Related to WM		Major Issues	Social Context
		Legislation	Technology		
Late 19th to Early 20th Centuries: Meiji Restoration	1900s	1900 Waste Cleaning Act		Transformation of WM; protecting public health.	Pacific War in 1941
1945 to 1950s: Post-War	1950s	1954 Public Cleansing Act		Managing waste to ensure environmental cleanliness; preserving a healthy and pleasant living space.	1954–1973 High Economic Growth
1960s to 1970s: Rapid Economic Growth	1960s	1963 Act on Emergency Measures concerning the Development of Living Environment Facilities 1967 Fundamental Law for Environmental Pollution Control		Growth in industrial waste and rising pollution issues due to swift economic expansion.	1964 Tokyo Olympic Games
	1970s	1970 Waste Management Law (WML) 1976 Amendment of WML	1979 Waste Treatment Facility Structure Guideline 1979 Final Disposal Site Structural Guidelines	Environmental conservation through effective waste management.	1970 Tangible Pollution 1970 Osaka Expo 1971 Tokyo War against Waste 1973 Oil Crisis 1975 Okinawa Expo 1979 2nd Oil Crisis 1979 Tokyo Summit
1980s to Early 1990s: Rapid Economic Growth to the Bubble Economy Period	1980s	1981 Wide-area Coastal Environment Development Center Act 1983 Private Sewerage System Act		Advancement of waste management infrastructure development; necessity of environmental safeguards in waste management.	1985 Tsukuba Expo 1986 Tokyo Summit 1986–1991 Bubble Economy Period

Table 2. *Cont.*

Period	Year	Activities Related to WM		Major Issues	Social Context
		Legislation	**Technology**		
1990s to 2000s: A Sound Material-Cycle and Low-Carbon Society	1990s	1991 Amendment of WML 1991 Law for the Promotion of Effective Utilization of Resources 1992 Act to Promote the Development of Specified Facilities for the Disposal of Industrial Waste 1992 Japanese Basel Act 1993 Fundamental Environment Act 1995 Containers and Packaging Recycling Act 1997 Amendment of WML 1998 Home Appliance Recycling Act 1999 Act on Special Measures against Dioxins 1999 Act on Promotion of Private Finance Initiative	1994 1st Fundamental Environmental Plan (FEP) 1997 Guidelines for Prevention of Dioxin Emissions from Waste Management 1998 Waste Treatment Facility Performance Guidelines 1999 Fundamental Guidelines for the Promotion of Measures against Dioxins	Controlling waste generation and enhancing recycling. Setting up multiple recycling systems; managing hazardous substances like dioxins; introducing a comprehensive waste management system for diverse waste types.	1993 Tokyo Summit 1995 Great Hanshin Earthquake 1997 Kyoto Conference 1998 Nagano Olympic Games
	2000s	2000 SMCS Act 2000 Construction Recycling Act 2000 Food Recycling Act 2000 Food Waste Recycling Law 2000 Amendment of WML 2001 Act on Special Measures concerning Promotion of Proper Treatment of PCB Wastes 2002 Automobile Recycling Act 2003 Act on Special Measures concerning Removal of Environmental Problems Caused by Specified Industrial Wastes 2003-6 Amendment of WML 2009 Act on Promoting Treatment of Marine Debris	2000 Final Disposal Site Performance Guideline 2000 2nd FEP 2003 1st SMCS Plan 2005 Manual for Calculation of Remaining Capacity of Final Disposal Sites 2006 3rd FEP 2006 Gudline for Living Environment Impact Assessment of Waste Management Facilities 2008 2nd SMCS Plan	Promoting 3R initiatives for a sustainable society; improving industrial waste management; tightening laws against illegal dumping.	2000 Kyushu/Okinawa Summit 2001 Reorganization of Central Ministries 2005 Aichi Expo 2009 Eco Point System

Table 2. *Cont.*

Period	Year	Activities Related to WM		Major Issues	Social Context
		Legislation	**Technology**		
2010s up To Current Years: Domestic and Global Challenges Period	2010s	2010 Amendment of WML 2011 Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities 2012 Small Home Appliance Recycling Act 2015/17 Amendment of WML	2012 4th FEP 2013 3rd SMCS Plan 2014 Guideline for Disaster WM 2016 Guideline for Formulation of Fundamental Waste Treatment Plan 2017 Mercury Waste Guidelines 2018 5th FEP 2018 4th SMCS Plan 2018 Manual for Treatment of Infectious Waste	Preserving the environment during and post disasters.	2011 The Great East Japan Earthquake 2019 COVID-19 Pandemic
	2020s	2020 Amendment WML 2022 Plastic Resource Recycling Promotion Act	2020 Guidelines for Prevention of COVID-19 Infection related to Waste	Preventing environmental harm in the face of infectious diseases.	2021 Tokyo Olympic Games

4. Current Waste Management Situation in Japan

Japan faces several environmental issues, including waste management and global warming. The leading cause of global warming is carbon dioxide emissions, and the volume of emissions in a given country is based on that country's production and consumer activities [41]. In the fiscal year 2021, Japan's CO_2 emissions were 1064 million tons, showing an increase of 22 million tons from the previous year [42,43]. Waste also contributes to carbon dioxide emissions due to disposal methods such as incineration and landfilling, decomposition of organic waste, and others. According to Table 3, in Japan, the share of CO_2 emissions from waste disposal over the past 30 years peaked in 2005 at 32 million tons. In subsequent years, a slight decrease to 30 million tons became noticeable due to waste control initiatives and the implementation of the Fundamental Plan for Establishing a "Sound Material-Cycle Society" (SMCS Plan) [42]. These figures highlight Japan's ongoing efforts to address environmental issues during its development.

Table 3. Breakdown of carbon dioxide emissions in Japan [42,43] (million tons).

	1990	**2005**	**2010**	**2015**	**2020**	**2021**
Total	1163	1293	1217	1225	1042	1064
Industrial	503	467	431	430	354	373
Transport	208	244	229	217	183	185
Commercial industry	131	220	200	218	184	190
Residential	129	171	178	187	167	156
Energy transformation	96	98	99	93	79	84
Industrial processes and product use	65	56	47	47	42	43
• Waste (incineration, etc.)	24	32	29	30	30	30
Other	7	5	4	3	3	3

It is essential to look at the latest statistics and compare them with previous years to track current changes and understand Japan's current waste management situation. The white paper (2022–2023) by the Japanese Ministry of Environment (MoE) [43] provides a comprehensive analysis of Japan's current state of waste management. It includes data up to fiscal year 2021 for general waste and up to 2020 for industrial waste and represents the fundamental dynamics of waste management in the country.

4.1. General Waste

Figure 1 shows a noticeable fluctuation in the total amount of waste generated between 1990 and 2021. The peak was in 2000, with 54.83 million tons, followed by a consistent decrease. By 2021, it had declined to 40.95 million tons.

Corresponding to the amount of waste generated, the daily volume per person peaked in 2000 at 1185 grams. After the gradual decline, this amount reduced to 890 g. The data show that in 2021, the amount of waste was significantly lower than at its peak [43].

Notable reductions over the years in total waste and daily waste per person are analyzed in the previous table. More details on waste disposal in 2020–2021 are given in the Ministry of Internal Affairs and Communications (MIC) statistics provided in the Japan Statistic Yearbook 2024 [44]. According to Table 4, In 2020, Japan's total waste generation was 41.67 million tons, which decreased to 40.95 million tons in 2021, representing a 1.7% reduction. Similarly, the waste generation per person per day decreased from 901 grams in 2020 to 890 grams in 2021, a reduction of 1.2%. This decrease in waste generation can be attributed to several factors, including enhanced public awareness, better waste segregation practices, and government policies promoting waste reduction.

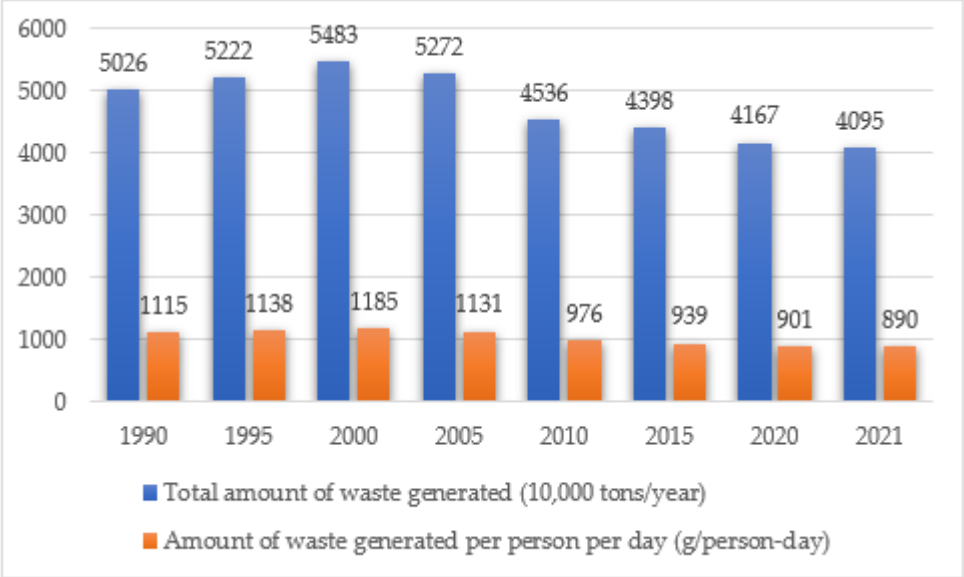

Figure 1. Trends in waste generation [43]. Note: Starting from 2012, the total population includes foreign residents.

Table 4. Disposal of general waste [43,44].

	2020	2021	Change
Planned collection population (1000)	126,733	126,062	671 ↓
Total waste matter (10,000 t)	4167	4095	72 ↓
Daily waste matter per person (g)	901	890	11 ↓
In-house disposal (1000 t)	8	6	2 ↓
Total waste disposal (10,000 t)	4008.5	3942.1	66,4 ↓
Rate of reduced disposal (%)	99.1	99.1	0
Recycled volume after intermediate disposal (10,000 t)	476.1	467.3	8.8 ↓
Rate of recycled (%)	20.0	19.9	0.1 ↓
Final disposal (10,000 t)	363.8	342.4	21.4 ↓
Daily waste-processing capacity at incineration facilities (t)	176,202	175,737	465 ↓

One of the significant contributors to the overall reduction in waste was the decrease in landfill waste. The amount of waste sent to landfills decreased by 5.9%, from 3.64 million tons in 2020 to 3.42 million tons in 2021. This reduction is partly due to improved recycling and waste processing technologies. Japan has been actively promoting the 3R (Reduce, Reuse, Recycle) initiative, which has played a crucial role in minimizing the amount of waste requiring final disposal.

The volume of recycled waste after intermediate disposal also saw a slight decline from 8.33 million tons in 2020 to 8.16 million tons in 2021, a decrease of 2%. Although the recycling rate slightly dropped from 20.0% to 19.9%, overall efforts toward recycling remain robust, supported by policies such as the Containers and Packaging Recycling Act.

Japan's waste management system includes a well-developed network of waste incineration plants. In 2021, the number of incineration plants decreased slightly to 1028 from 1056 in 2020. Despite this reduction in number, the incineration capacity per plant increased from 167 tons per day in 2020 to 171 tons per day in 2021. This increase in efficiency highlights the advancements in waste-processing technologies and the ability to handle more waste with fewer facilities.

Additionally, the number of plants equipped with power generation facilities increased, contributing to a more sustainable waste management system. In 2021, 38.5% of incineration plants had power generation capabilities, up from 36.6% in 2020 [44]. This integration of waste-to-energy processes not only reduces the volume of waste but also

provides a renewable source of energy, aligning with Japan's goals for a sustainable and carbon-neutral future.

These trends and data underscore the effectiveness of Japan's comprehensive waste management strategies, which include robust recycling programs, efficient waste processing technologies, and continuous public engagement in waste reduction efforts. The country's commitment to the 3R (Reduce, Reuse, Recycle) initiative and advancements in waste-to-energy technologies play crucial roles in maintaining and enhancing waste management performance.

Urbanization and industrial development in Japan have increased waste categories like plastic, electronic, and construction waste. Japan is a top generator of plastic packaging waste per capita, largely due to high consumption of packaged goods [43]. Electronic waste has also surged, driven by the proliferation of devices, despite regulations for proper recycling. Construction and demolition waste have grown with urban development projects.

These activities contribute to CO_2 emissions from incineration and landfills, which produce greenhouse gases such as CO_2 and methane. Waste transportation also adds to CO_2 emissions, mainly due to fossil fuel usage. While recycling is more environmentally friendly, it still involves CO_2 emissions from the energy needed for processing.

Effective strategies, including improving recycling rates and waste-to-energy technologies, are crucial for reducing the environmental impact and CO_2 emissions associated with waste management in Japan.

4.2. Industrial Waste

Intensive industrialization has led to several environmental problems in Japan. Issues of production and consumption, as well as industrial waste, affect the quality of life in the country. This has led to the development of preventive and corrective measures [45]. Thus, industrial waste management is included in the framework of the 3Rs and SCMS Plan.

The Statistical Handbook provided by the Statistic Bureau, Ministry of Internal Affairs and Communications (MIC), represents trends in industrial waste management in Japan from 1990 to 2020 (Table 5) [42]. These data show a strategic shift toward sustainability. The total volume of waste generation grew, peaking in 2005 at 422 million tons, finally declining to 374 million tons in 2020. Recycling efforts markedly increased from 151 million tons in 1990 to a peak of 219 million tons in 2005. The latest data show a slight decrease to 199 million tons by 2020. With 80% (sludge, animal excrement, and debris) of total industrial waste now being recycled into construction materials, the final landfill volume has fallen from 89 million tons in 1990 to 9 million tons in 2020 [42]. These trends underscore Japan's progress in reducing industrial waste, increasing recycling rates, and improving overall treatment efficacy. As mentioned, focusing on minimizing waste, enhancing recycling, and optimizing resource utilization has substantially advanced waste management practices [46]. The data suggest effective waste reduction strategies over these years and increased awareness and public involvement in sustainable development practices.

Table 5. Industrial waste generation and disposal [42,43] (thousand tons).

	1990	2000	2005	2010	2020
Total volume of waste generation	394,736	406,037	421,677	385,988	373,818
Recycling	150,568	184,237	218,888	204,733	199,022
Treatment for waste reduction	154,443	176,933	178,560	167,000	165,708
Final disposal	89,725	44,868	24,229	14,255	9089

5. A Sound Material-Cycle Society and the 3Rs

As noted in the previous section, the Japanese government has developed many pieces of legislation to solve environmental problems. However, one of the most significant is the SMCS Act enacted in 2000 [47] and the 3Rs (Reduce, Reuse and Recycle) [48], which aim to reduce waste and use resources efficiently. Notably, Japan's transition to a circular economy is also being implemented through the SMCS Act [33].

The SMCS Act promotes the development of a sustainable society by reducing the use of natural resources, promoting cyclical use of products, and lessening environmental burdens. It is achieved through a collaborative effort involving national and local authorities, businesses, citizens, nonprofit organizations (NPOs), and nongovernmental organizations (NGOs). These stakeholders are encouraged to actively contribute to establishing a SMCS through shared responsibility and cooperation [49,50].

The influence of the 3Rs in achieving a SMCS and low-carbon society is significant and multifaceted. The 3Rs refer to the practices of reducing, reusing, and recycling. Reducing involves using items carefully to create less waste. Reusing is about using items or their parts again when they are still functional. Recycling turns waste into usable resources. The most effective strategy for minimizing waste is reducing, reusing, and finally recycling [48].

The SMCS Act outlines a set of actions to maintain a proper cycle of materials: (1) reduce, (2) reuse, (3) recycle, (4) thermally recycle, and (5) ensure proper waste disposal.

Within the framework of the SMCS Act, four plans were enacted, one each in 2003 [50], 2008 [51], 2013 [52], and 2018 [53].

5.1. Fundamental Plan for Establishing a Sound Material-Cycle Society (2003)

In March 2003, the Fundamental Plan for Establishing a Sound Material-Cycle Society (SMCS Plan) was formulated based on Article 15 of the SMCS Act (2000) [49]. It involves sustainable manufacturing (DfE, long-life products, lease/rental) and efficient waste management (cyclical use, proper disposal). Goals include reducing solid waste, doubling the related market, and tracking resource productivity, cyclical use rates, and disposal amounts.

The SMCS Plan marked a significant step in Japan's commitment to sustainable resource management and aimed to tackle pressing waste management challenges and promote the development of a circular economy [50]. One of the primary issues addressed was the need for enhanced waste management practices. The SMCS Plan set specific targets to boost recycling rates and reduce waste generation. Implementing solutions grounded in the 3R principles (reduce, reuse, and recycle) was pivotal to achieving these objectives. Japan sought to optimize resource utilization, minimize environmental impact, and create a more sustainable waste management framework. Implementing the SMCS Plan led to a notable improvement in waste management practices nationwide. Recycling efforts were intensified, leading to a significant increase in the recycling rate. Reducing waste generation also contributed to a more sustainable and environmentally conscious society.

Moreover, the SMCS Plan was crucial in raising public awareness about the importance of sustainable practices [54]. Japan addressed immediate difficulties and promoted a shift in culture towards responsible resource consumption by incorporating the principles into trash management legislation. The SMCS Plan's success in improving waste management and instigating a broader awareness of sustainable practices laid the groundwork for subsequent initiatives. It demonstrated Japan's leadership in the pursuit of a Sound Material-Cycle Society.

5.2. Second Fundamental Plan for Establishing a Sound Material-Cycle Society (2008)

The second SMCS Plan enacted represented a strategic continuation of Japan's commitment to sustainable resource management by building upon the accomplishments of its predecessor. This iteration of the second SMCS Plan maintained a steadfast emphasis on the crucial goals of waste reduction and recycling. Targets were crafted to fortify the recycling infrastructure for a more robust and efficient system to handle the increasing volume of waste [51]. The second SMCS Plan made a dedicated effort to reduce the environmental impact of waste management activities. Japan tried to guarantee that the improvements resulting from the first SMCS Plan were maintained and built upon to attain even more considerable ecological advantages. To this end, the country set goals and concentrated on improving recycling procedures. A vital feature of the second SMCS Plan was its recognition of the necessity of collaborative efforts involving the government,

industries, and the public. Understanding that effective waste management requires a multi-stakeholder approach, the second SMCS Plan emphasized cooperation as a vital solution. This collaborative model aimed to leverage the strengths and resources of each sector for synergy in waste reduction and recycling initiatives. The public's engagement in these efforts contributed to the second SMCS Plan's success and increased environmental awareness at the community level. Hence, the second SMCS Plan facilitated continued waste reduction and recycling progress. It highlights the efficacy of collaborative strategies in achieving sustainable material-cycle practices in the country.

5.3. Third Fundamental Plan for Establishing a Sound Material-Cycle Society (2013)

The third SMCS Plan demonstrated a forward-thinking approach by addressing emerging challenges, particularly growing concerns about electronic waste and the need for effective product lifecycle management. The third SMCS Plan's targets aligned strategically with these challenges, enhancing the 3R framework and promoting sustainable consumption practices. Japan attempted to promote a cultural change toward more ecologically friendly choices by emphasizing the importance of responsible consumption habits, which helped to advance the overall objective of an SMCS. Innovative solutions were implemented to achieve the goals of the third SMCS Plan. Notably, the third SMCS Plan introduced the concept of extended producer responsibility, placing accountability on manufacturers for the entire lifecycle of their products [52]. This approach aimed to reduce the environmental impact of products from creation to disposal.

Additionally, incorporating eco-labelling was a significant step toward informing consumers about the environmental footprint of products and empowering them to make informed, sustainable choices. These solutions led to an improved handling of specific waste streams, especially electronic waste, and contributed to the increased availability of eco-friendly products on the market. Thus, the third SMCS Plan showed Japan's adaptability in addressing contemporary environmental challenges through a comprehensive and proactive approach to sustainable material-cycle practices.

5.4. Fourth Fundamental Plan for Establishing a Sound Material-Cycle Society (2018)

The fourth SMCS Plan represented a strategic response to persistent challenges and evolving environmental dynamics. In recognizing the need for ongoing adaptation, this plan set ambitious targets that extended beyond the accomplishments of its predecessors. Key objectives included reducing waste, promoting a circular economy, and actively engaging with global environmental issues. Japan committed to playing a role in the broader ecological landscape by broadening its scope to address international concerns. The innovative solutions it proposed were central to the plan's success. The fourth SMCS Plan acknowledged the transformative power of adopting advanced technology by envisioning its integration into waste management processes to enhance efficiency and sustainability [53]. The strategy also stressed the significance of international cooperation, acknowledging the intrinsic interconnectedness of environmental concerns. Collaborative efforts with other nations and global organizations were integral to tackling shared ecological issues. Moreover, public engagement emerged as a critical element, indicating a shift towards inclusivity and the recognition of citizens as active participants in building a sustainable material-cycle society. These insights highlight Japan's commitment to continual improvement, embracing advanced technology, global collaboration, and public involvement as essential pillars for achieving a more sustainable and resilient material-cycle society.

Establishing a society based on the 3Rs (Reduce, Reuse, Recycle) requires multiple strategies. These include raising awareness through educational campaigns, collaborating with different organizations, exchanging information, investing in technology, and offering incentives. Linking these varied approaches can effectively lead to enhanced and synergistic results, facilitating the successful promotion of the 3Rs [48].

Japan is actively participating in the internationalization of the 3Rs to achieve sustainability worldwide. Heads of state agreed to use the 3Rs to construct an International SMCS

at the G8 Sea Island Summit in the U.S. in June 2004 [55]. However, for global results, each individual effort must introduce 3R into its waste management processes [54].

Various discussions exist on the relationship between SMCS (including the 3Rs) and the circular economy. Arai (2023) [56] conducted research showing a significant conflict between SMCS and CE as a discourse; some consider that the concepts are similar, and others deem them different. However, research indicates that both concepts have different approaches to achieving circularity. Furthermore, the Ministry of the Environment (MoE) and the Ministry of Economy, Trade and Industry (METI) agree that their concepts do not clash and should be advanced. However, they acknowledge a difference between the two: the MoE's SMCS focuses more on social and ecological factors, whereas the METI's conceptualization of the circular economy highlights economic aspects [56].

The Japanese government aims to transition to a circular economy. As an essential step toward that end, it has set out the 3Rs + Renewable (reduce, reuse, recycle, renewable energy) in the Global Warming Countermeasures Plan revised in October 2021. In September 2022, the Ministry of the Environment published the Circular Economy Roadmap, created in response to the 2050 Carbon Neutrality Declaration; it clearly states that the transition to a circular economy is the country's core ambition. This roadmap indicates circular economy goals for 2050 and specific measures for 2030, aiming for integrated environmental, economic, and social improvements. Circular industries are considered an engine of growth and aim to expand the market size of circular economy-related businesses from approximately JPY 50 trillion to over JPY 80 trillion. These initiatives are an essential step toward achieving carbon neutrality in 2050 and are expected to contribute to solving environmental problems both domestically and internationally [43].

6. Future Prospects

Annual per capita waste generation continues to increase worldwide. Japan is one of the rare exceptions, where waste generation is declining yearly [57]. Despite this, Japan has one of the lowest recycling rates among OECD countries [58], with an indicator of 19.9% for 2021 [43,44], proving that the country still has room to develop in waste management. In this regard, several aspects are necessary for the country's future development in the environmental field.

Technological Innovation: One of the crucial areas to focus on is researching objects and materials that can be sorted, recycled, and reused and creating new technological possibilities for them [59]. Like most developed countries, Japan is moving towards developing digital technologies and intelligence that improve waste management efficiency and aim for sustainable development [60]. In this regard, Society 5.0 is a practical plan for the future society that Japan should strive for [61]. The goals of sustainable development, the SMCS, and Society 5.0 are moving in the same direction, achieving an economically and socially stable human-centered society [62] Furthermore, if the role of the SDGs and SMCS in environmental issues is evident, as mentioned before, then Society 5.0 is an innovative approach to solving environmental issues using the IoT (Internet of Technology), AI (artificial intelligence), and robots, which will ultimately contribute to the creation of new technologies with built-in sensory, processing, and intelligence functions to process waste for recycling and reuse [63].

Public Awareness and Participation: Japan actively promotes environmental awareness and education at the national level. The Ministry of Environment prepares and coordinates programs to increase awareness, disseminate education and promote sustainability through various initiatives [64]. Notably, ESD (Education for Sustainable Development) was first proposed by Japan at the 2002 World Summit on Sustainable Development and aims to acquire all the skills and knowledge necessary to promote sustainable development by 2030 [65]. Japan expects that attention to education and community participation in sorting and reducing waste will increase, which will influence the growth of recycling rates and the reduction of waste generation.

7. Conclusions

This paper has examined the development of waste management in response to emerging challenges in Japan over time, following its inception during the Meiji Restoration and up to the present day. Japan's waste management practices have changed dramatically due to environmental awareness, economic expansion, and public health concerns. Japan's waste management history demonstrates dynamic responses to social and environmental changes, establishing the country as a pioneer in sustainable practices and ethical waste management worldwide.

Visually presented tables and figures for the flow of materials show the dynamics of waste generation and disposal, changes in the amount of waste produced, and the composition of recycled materials to date. These show the effectiveness of Japan's policies in achieving a sustainable society by introducing the principles of a Sound Material-Cycle Society.

Despite the excellent performance of the system and a noticeable reduction in waste generated, Japan still has room for improvement, and here are some recommendations:

1. Increase recycling rates: expanding public education campaigns, making recycling more convenient, and incentivizing recycling through rewards programs could help boost recycling participation and rates.
2. Reduce single-use plastics: Japan generates a significant amount of plastic waste. Implementing stronger measures to discourage the use of disposable plastic items, such as bags, packaging, and takeout containers, could substantially cut down on plastic waste. This may involve bans, taxes, or requiring retailers to charge for plastic bags.
3. Improve waste separation: Japanese municipalities often have complex waste separation rules which can lead to confusion and contamination of recyclables. Simplifying and standardizing separation categories across the country could make proper sorting easier for residents.
4. Technological innovation is key to advancing Japan's waste management sustainability and efficiency. Research into recyclable materials, digital technologies, AI, and Society 5.0's vision of a human-centered future converges to create intelligent waste-processing solutions that facilitate recycling, reuse, and a more sustainable society.

These measures could build on Japan's existing strengths in waste management to further advance sustainability and resource efficiency. An integrated approach spanning waste prevention, reuse, recycling, biological treatment, energy recovery, and safe disposal is optimal.

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