Zero-Landfill Circular Municipal Solid Waste Management in Western Tokyo

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Abstract

The growing challenge of municipal solid waste (MSW) requires a transformation from the traditional linear economy to the circular economy. Japan is known as a pioneer in the circular economy, and Western Tokyo is recognized as a frontrunner in MSW management in Japan. Western Tokyo is also the only region in the world where the Eco-cement plant, a facility dedicated to producing Japanese Industrial Standardized cement using MSW incineration ash as the main ingredient, is operational. However, little is known about the region's MSW management methods. To explore effective MSW management methods for a circular economy, this study surveyed MSW treatment practices in Western Tokyo. Recyclables, such as cans, bottles, and paper, are recovered as materials for recycling. Non-recyclables are incinerated at intermediate treatment facilities, where energy and metals are recovered. All incineration ash generated at these facilities is recycled into cement at the Eco-cement plant and used as a raw material for concrete. Moreover, the region has adopted economic incentive measures, such as a volume-based waste fee system, and set the fees relatively high. The waste reduction and recycling rates in Western Tokyo are significantly higher than those in Central Tokyo and across Japan, and the region has achieved a zero-landfill circular system. The study results indicate that the region's MSW treatment methods effectively support the circular economy and that locating an upgraded eco-cement plant in urban centers is likely a viable option for many metropolises.

Keywords: municipal solid waste (MSW), incineration ash, Eco-cement, circular economy, resource recovery

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1. Introduction

Global annual municipal solid waste (MSW) generation is predicted to grow from 2.1 billion tonnes in 2023 to 3.8 billion tonnes by 2050 [1]. MSW management has been an urgent concern worldwide, posing significant environmental and socio-economic challenges [1]. The traditional linear economy model, characterized by a "take-make-dispose" approach, has led to unsustainable waste generation practices, contributing to resource depletion, climate change, and economic instability [2]. The circular economy concept offers a transformative approach to waste management, emphasizing the redesign of systems to minimize waste and maximize resource efficiency [2, 3]. The European Union (EU) has established the waste hierarchy, which prioritizes prevention, preparation for reuse, recycling, energy recovery, and disposal, such as landfilling [3].

Japan has been recognized as a pioneer and leader in supporting the circular economy [4-6]. Around the year 2000, Japan established a legal and policy framework to promote the transition from a society characterized by mass production and mass disposal to a "Sound Material-Cycle Society" [7]. The "Basic Act for Establishing a Sound Material-Cycle Society," enacted in 2000, formulated the priorities for the circular use of resources and waste management: (1) generation reduction, (2) reuse, (3) recycling, (4) energy recovery, and (5) proper disposal [7]. In addition to the legal and policy framework, technology for the circular economy has also progressed rapidly. Recycling technologies for certain materials, such as metals, paper, and plastics, have evolved. For non-recyclables, incineration technologies that combine effective pollution control measures with high energy recovery rates have been established and widely adopted [7, 8]. Consequently, Japan's waste generation and final disposal volumes have been steadily declining since the start of the 21st century [9].

Within such Japan, Western Tokyo, with a population of approximately four million, is considered a frontrunner in MSW management [10, 11]. Municipalities in Western Tokyo rank highest in the nation for waste reduction and recycling rates [9]. Western Tokyo is also the only region in the world where the Eco-cement plant, a facility dedicated to producing Japanese Industrial Standardized cement using MSW incineration ash as the main ingredient, is operational [12]. However, little is known about the region's MSW treatment methods. Accordingly, to explore effective MSW treatment methods for a circular economy, this study surveyed MSW treatment practices in Western Tokyo, with a particular focus on methods unique to this region.

This paper consists of five sections. The next section illustrates the region's MSW treatment processes primarily from a technological perspective. Section 3 presents data showing recent trends in waste treatment volume. Section 4 discusses the significance and historical background of the region's MSW management methods, as well as remaining challenges. The last section summarizes the study results.

2. Materials and Methods

The study area, Western Tokyo, also known as the Tama region, is located in the inland part of Tokyo Prefecture. As shown in **Figure 1**, the Tokyo Prefecture mainland comprises Central Tokyo and Western Tokyo. Central Tokyo, consisting of 23 special wards, is Japan's administrative and commercial hub, with a population of approximately 10 million. On the other hand, Western Tokyo is characterized as a satellite urban area of Central Tokyo, and its population density tends to decrease the farther one moves westwards from Central Tokyo.

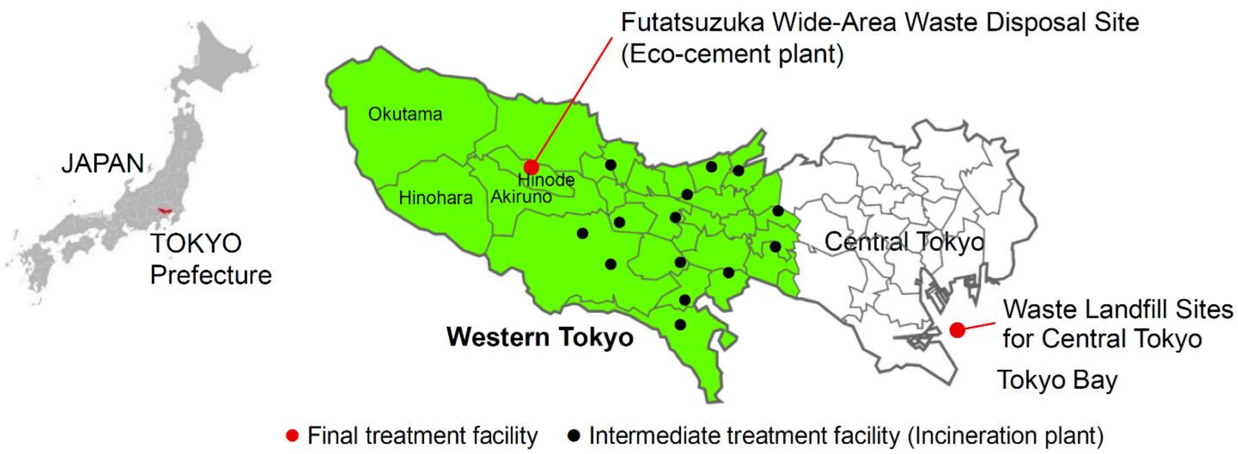

Figure 1. Locations of Western Tokyo and the final and intermediate treatment facilities.

Of the 30 municipalities in Western Tokyo, 26—excluding the four in the westernmost area (Okutama, Hinohara, Hinode, Akiruno)—are members of the "Tokyo Tama Regional Association for Waste Management and Resource Recycling" and treat MSW using the same methods. The main processes of the treatment methods are shown in **Figure 2**.

"Recyclables," such as cans, glass bottles, paper, and plastic bottles, are collected separately and recycled. "Bulky items and non-combustibles," as well as "combustibles," are collected and transported to intermediate treatment facilities. Bulky items and incombustibles are crushed, and metals are recovered. The remaining burnable materials are sent to the incinerator. Combustibles, such as paper waste, non-recyclable plastics, and kitchen garbage, are placed directly into the incinerator. Energy generated during incineration is recovered as electricity and heat. Metals recovered from crushed bulky items and incombustibles, as well as incineration residue, are recycled into metal products. All the incineration ash generated at the fourteen intermediate treatment facilities shown on the map (**Figure 1**) is transported to the final treatment facility, Futatsuzuka Wide-Area Waste Disposal Site, and recycled as raw material for "Eco-cement."

While the waste treatment methods in Western Tokyo and Central Tokyo are basically the same, there are two remarkable differences: (1) adoption of a volume-based waste fee system for non-recyclable waste, and (2) a method of treating incineration ash. In **Figure 2**, these two points are highlighted in yellow.

Whereas a volume-based waste fee system has been adopted for non-recyclable waste in Western Tokyo, it has not yet been adopted in Central Tokyo. In Western Tokyo, only non-recyclable waste placed in pre-purchased, municipality-designated collection bags is collected. On the other hand, in Central Tokyo, all waste placed in any bag is collected.

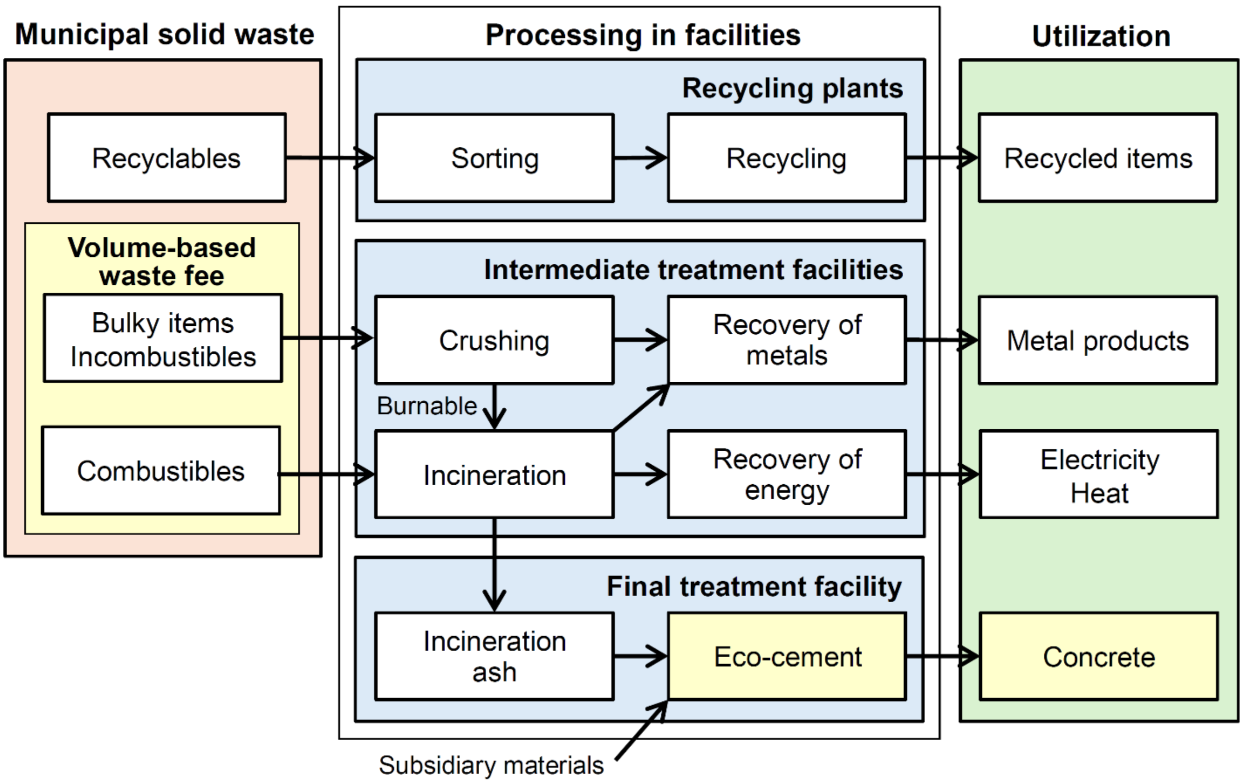

Figure 2. Main processes of treating municipal solid waste (MSW) in Western Tokyo.

The other significant difference concerns the treatment method for incineration ash generated at intermediate treatment facilities. In Western Tokyo, as described above, all incineration ash is recycled as raw material for Eco-cement and used for concrete. In contrast, the majority of incineration ash generated in Central Tokyo is disposed of at the Waste Landfill Sites in Tokyo Bay [13], shown in **Figure 1**.

The following three sub-sections provide a more detailed explanation of Western Tokyo's MSW treatment methods, categorized into three facility types: (1) recycling plants, (2) intermediate treatment facilities, and (3) the final treatment facility.

2.1. Recycling plants

Recyclables are first separated at homes and businesses into categories such as cans, glass bottles, paper, and plastic bottles. The separated recyclables are collected and processed in recycling plants. Additionally, the volume-based waste fee system does not apply to recyclables, so they are collected free of charge.

Cans are collected and sorted into steel and aluminum cans. After that, they are compressed into blocks using a press machine. Compressed steel and aluminum cans are transported to steel and aluminum recycling plants, respectively [14, 15].

Glass bottles are collected and sorted by color. After that, they are crushed into pieces named "cullet." Using cullet improves melting efficiency, thereby reducing the energy required for glass melting and CO_2 emissions [16]. Cullet prepared for remelting in glass furnaces serves as a crucial raw material in glass manufacturing.

Paper products, including newspapers, magazines, and cardboard, are collected and sorted. Proper sorting is significant because different types of paper are recycled into different products. For instance, newspapers are usually recycled into newsprint, while cardboard is used to make new boxes. The sorted paper is then compressed into bales and transported to recycling plants, where it is mixed with water and chemicals to break down into pulp. The pulp is cleaned to remove contaminants, such as ink, and then formed into sheets and dried to create new paper products [17].

Plastic bottles are collected and compressed into bales. The compressed plastic bottles are transported to a recycling plant, where they are shredded into flakes or pellets. These flakes or pellets are heated and processed into fibers or sheets for remanufacturing [8].

2.2. Intermediate treatment facilities

"Bulky items and incombustibles" and "combustibles" are collected for a fee and conveyed to intermediate treatment facilities, as shown in **Figure 2**. Only incombustibles and combustibles, placed separately in municipality-designated bags, are collected. While the cost of these designated bags varies by municipality, the majority charge 2 yen per liter for both types. This fee level is significantly higher than the average charged by other Japanese municipalities that have adopted a volume-based waste fee system. For bulky items, such as disused furniture, fees are determined based on the item and its size.

Bulky items and incombustibles are fragmented using two types of crushers: primary and secondary crushers. After that, metals, namely iron and aluminum, are recovered. The burnable residue remaining after the metal recovery is gathered for incineration.

Combustible waste collected from households and businesses is dumped into the waste pit. The burnable residue generated during the crushing process is also placed in the pit. The waste in the pit is then loaded into the incinerator by a waste crane.

Most intermediate treatment facilities in Western Tokyo utilize stoker-type incinerators (**Figure 3**). A stoker is a combustion system consisting of a series of stepped fire grates. The stepped grates move back and forth to promote efficient contact between the waste and air, ensuring stable waste combustion.

Steam produced in the waste-heat boiler powers the steam turbine generator. Electricity generated by the turbine is used at the relevant intermediate treatment facility, and any surplus is sold to a power company or supplied to surrounding facilities. The steam can be diverted as a heat source for various uses, such as heating and cooling systems, and heated swimming pools.

Up-to-date incineration plants are increasingly adopting advanced combustion systems that enhance energy efficiency while reducing the emission of harmful substances. Optimizing the amount of air supplied to the incinerator improves combustion efficiency and reduces the generation of dioxins and other pollutants. Flue gas recirculation conserves energy by reusing waste heat and reduces emissions of toxic substances, such as nitrogen oxides (NOx) [8, 18].

The ash generated from waste incineration is divided into bottom ash and fly ash. Bottom ash is a non-combustible residue that falls to the bottom of the incinerator after waste combustion. Metals, iron and steel, are recovered from bottom ash. Fly ash, namely ash carried by flue gas, is collected by dust removal systems such as bag filters. Collected incineration ash, both bottom and fly ash, is transported from the intermediate treatment facilities to the final treatment facility for the Eco-cement production.

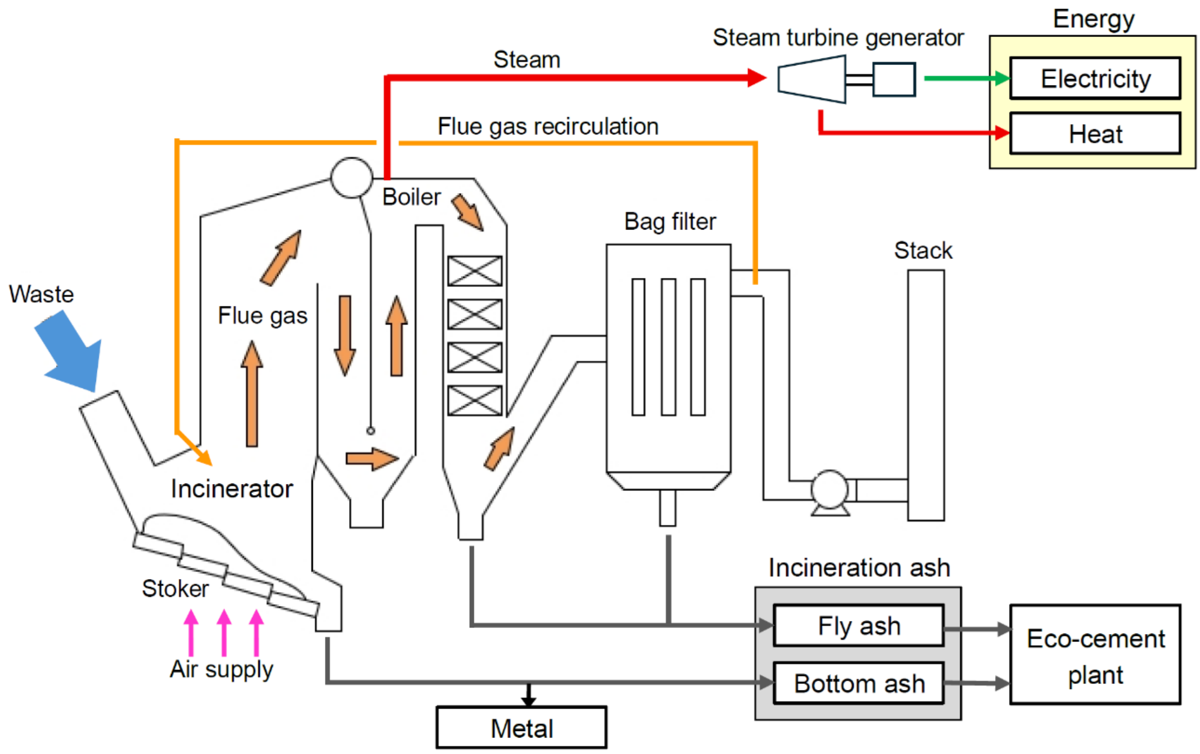

Figure 3. Resource recovery at stoker-type incineration plants in Western Tokyo.

2.3. Final treatment facility and Eco-cement production

In 1998, the Futatsuzuka Wide-Area Waste Disposal Site (**Figure 4a**) was established in Hinode Town as the final treatment facility for receiving incineration ash and non-combustible residues from the 26 municipalities in Western Tokyo. On the site, the Eco-cement plant (**Figure 4b**) was constructed and started operation in 2006.

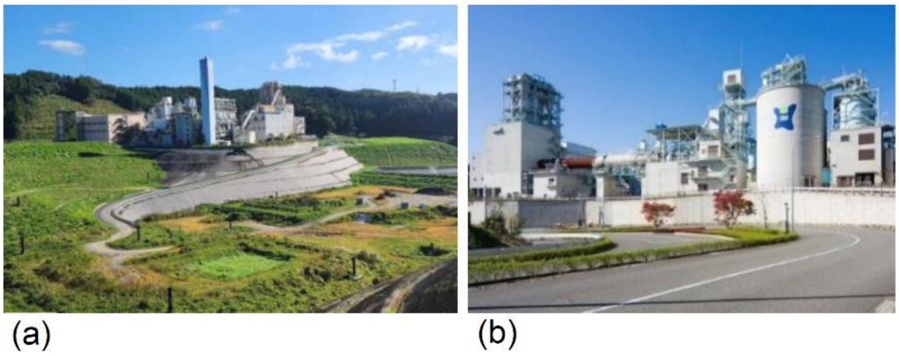

Figure 4. **(a)** Futatsuzuka Wide-Area Waste Disposal Site. **(b)** Eco-cement plant. ©Tokyo Tama Regional Association for Waste Management and Resource Recycling

2.3.1. Eco-cement production process

The final treatment facility receives all the incineration ash generated by the fourteen intermediate treatment facilities shown on the map (**Figure 1**). MSW incineration ash contains components necessary for cement production, such as calcium oxide (CaO) and silicon dioxide (SiO_2) [19, 20]. However, MSW incineration ash also contains high levels of chloride ions, which can corrode the steel reinforcement in reinforced concrete. It also contains trace amounts of heavy metals and dioxins [19, 20]. To remove these problematic substances while securing cement quality, a specialized production process has been developed (**Figure 5**).

The primary raw materials for Eco-cement are incineration bottom ash and fly ash, transported from intermediate treatment facilities. During the raw material blending stage, subsidiary materials such as limestone are added to enhance the concrete performance, including its strength. Regarding chloride ions, rather than removing them beforehand, the composition is adjusted so that chloride ions are volatilized and removed during cement production [19].

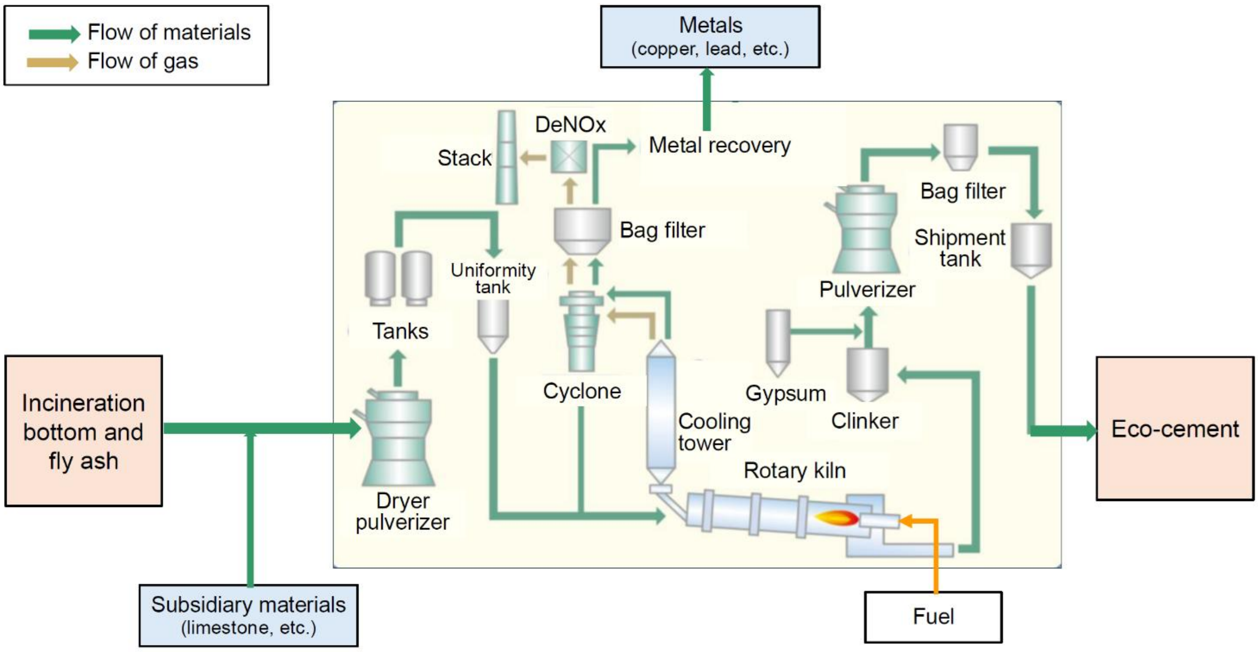

Figure 5. Eco-cement production process in the final treatment facility (adapted from [20]).

The blended raw materials are fed directly into the rotary kiln. Inside the rotary kiln, materials are calcined at temperatures exceeding 1350°C, completely decomposing dioxins. After calcination, kiln exhaust gas is rapidly cooled to approximately 200°C in the cooling tower, preventing the resynthesis of dioxins. Furthermore, when chloride ions volatilize and are removed during calcination, heavy metals can also be removed as chlorides. Additionally, this Eco-cement production process does not include a preheater, which is typically located immediately before the rotary kiln in most cement plants. The preheater was excluded due to the high chlorine content in the incineration ash, which could cause preheater blockage [19].

Heavy metals in the chloride dust are recovered by auxiliary equipment and then recycled as metals, such as copper, lead, and zinc, at smelting works. Therefore, no new waste is generated from the manufacturing process [19].

After the clinker is calcined in the rotary kiln, gypsum is added to adjust the cement's hardening rate. The composition-adjusted clinker is then pulverized and shipped as Eco-cement [19].

2.3.2. Eco-cement quality and standards

Alongside the technological development of Eco-cement, efforts to standardize it also progressed. Consequently, the Japanese Industrial Standard (JIS) for Eco-cement was established and certified as JIS R 5214 in 2002. JIS R 5214 (2019), the fourth revised version, defines Eco-cement as "cement produced by using municipal solid waste incineration ash as the main raw material for cement clinker, supplemented as necessary by waste such as sewage sludge, with at least 500 kg of these wastes per ton of product used on a dry basis" [21]. Note that while JIS R 5214 specifies both ordinary Eco-cement and rapid-hardening Eco-cement, only ordinary Eco-cement is currently manufactured at the Eco-cement plant [19].

Table 1 compares the quality specifications for ordinary Eco-cement with those for ordinary Portland cement (JIS R 5210). The standard values for ordinary Eco-cement and ordinary Portland cement are largely identical. However, the chloride ion standard is relaxed for ordinary Eco-cement. Additionally, the standard value for sulfur trioxide (SO_3) is set higher than for ordinary Portland cement. The higher SO_3 standard is necessary for controlling Eco-cement setting because MSW incineration ash contains high levels of Al_2O_3 and Fe_2O_3 [19].

Table 1. JIS Standards for ordinary Eco-cement and ordinary Portland cement (adapted from [19]).

Properties		**Ordinary Eco-cement** (JIS R 5214)	**Ordinary Portland cement** (JIS R 5210)
Specific surface area (cm^2/g)		2,500 or more	2,500 or more
Setting time	Initial	60 minutes or more	60 minutes or more
	Final	10 hours or less	10 hours or less
Soundness	Pat test	Sound	Sound
Compressive strength (N/mm^2)	3 days	12.5 or more	12.5 or more
	7 days	22.5 or more	22.5 or more
	28 days	42.5 or more	42.5 or more
Chemical constituent (%)	Magnesium oxide (MgO)	5.0 or less	5.0 or less
	Sulfur trioxide（SO_3）	4.5 or less	3.5 or less
	Loss on ignition	5.0 or less	5.0 or less
	Total alkali	0.75 or less	0.75 or less
	Chloride ion	0.1 or less	0.035 or less

2.3.3. Utilization of Eco-cement

Eco-cement is widely used in concrete products and construction, including roads, parks, buildings, and other structures [12, 20]. It has been confirmed that the slump, air content over time, and strength properties of concrete produced with Eco-cement are equivalent to those of concrete produced with ordinary Portland cement [19, 20].

In addition to developing and standardizing Eco-cement, measures to promote its use were also taken [19]. In 2004, Eco-cement was selected as a "specified procurement item" under the national Green Purchasing Law [19]. Similar initiatives were also promoted at the local government level. For example, the Tokyo Metropolitan Government designated concrete products made with Eco-cement as environmentally friendly products. It also stipulated in its construction specifications that Eco-cement products should be used as a matter of priority [19]. Products made with Eco-cement are also marked with the emblem shown in **Figure 6a**. **Figures 6b-d** show examples of precast concrete products made with Eco-cement. **Figure 6e** and **Figure 6f** show instances of interlocking blocks made with Eco-cement and installed interlocking blocks, respectively.

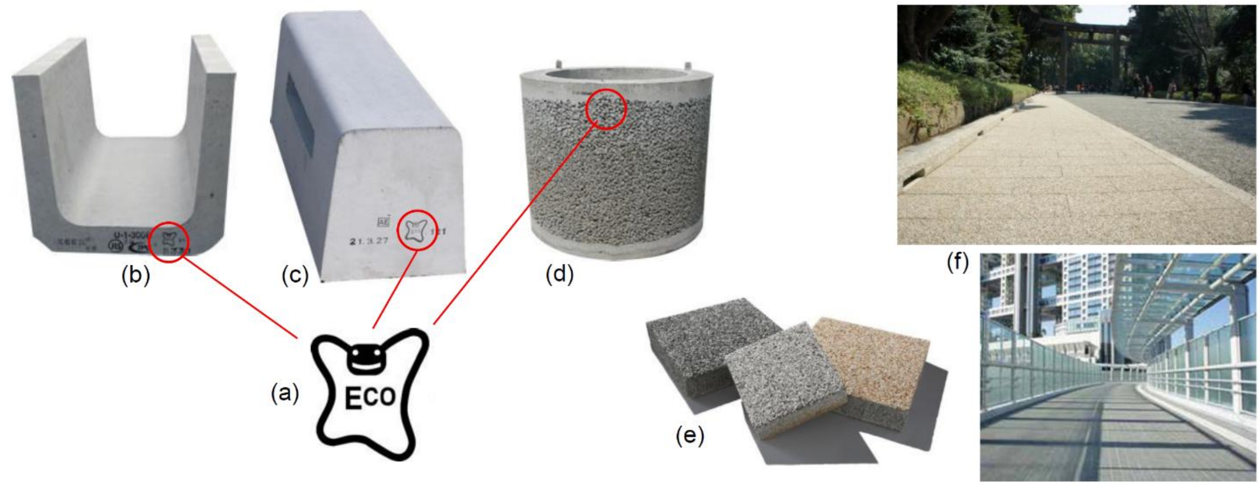

Figure 6. (a) Emblem of Eco-cement. (b) U-gutter. (c) Street drainage block. (d) Porous concrete product. (e) Permeable interlocking blocks manufactured with Eco-cement. (f) Examples of interlocking block installation. ©Taiheiyo Cement Corporation.

The plant in the Futatsuzuka Wide-Area Waste Disposal Site can produce approximately 130,000 tonnes of Eco-cement annually [20]. The plant uses approximately 90,000 tonnes of incineration ash annually as the primary raw material for the Eco-cement [20]. In 2024, eighteen years after the plant began operations, cumulative shipments of Eco-cement surpassed 2,000,000 tonnes [12]. Eco-cement is primarily used in the Tokyo metropolitan area [12].

3. Results

This section presents data showing recent trends in waste treatment volume in Western Tokyo. It also compares recycling rates and waste generation, comparing trends in Western Tokyo with those in Central Tokyo and across Japan.

3.1. Changes in landfill volume at the final disposal site

Figure 7 shows the trend in landfill disposal volume at the Futatsuzuka Wide-Area Waste Disposal Site. After its establishment, this final treatment facility accepted and landfilled incineration ash and non-combustible residues from the 26 municipalities. In 2000, the landfill volumes of incineration ash and non-combustible residues were approximately 85,000 m^3 and 74,000 m^3, respectively.

Regarding incineration ash, the commencement of operations at the Eco-cement plant in 2006 resulted in zero landfill disposal of ash-derived materials starting in 2007. Meanwhile, landfill disposal of non-combustible residues decreased rapidly after 2000, reaching zero in 2017. The zero landfill disposal level has been maintained since then and continues to this day.

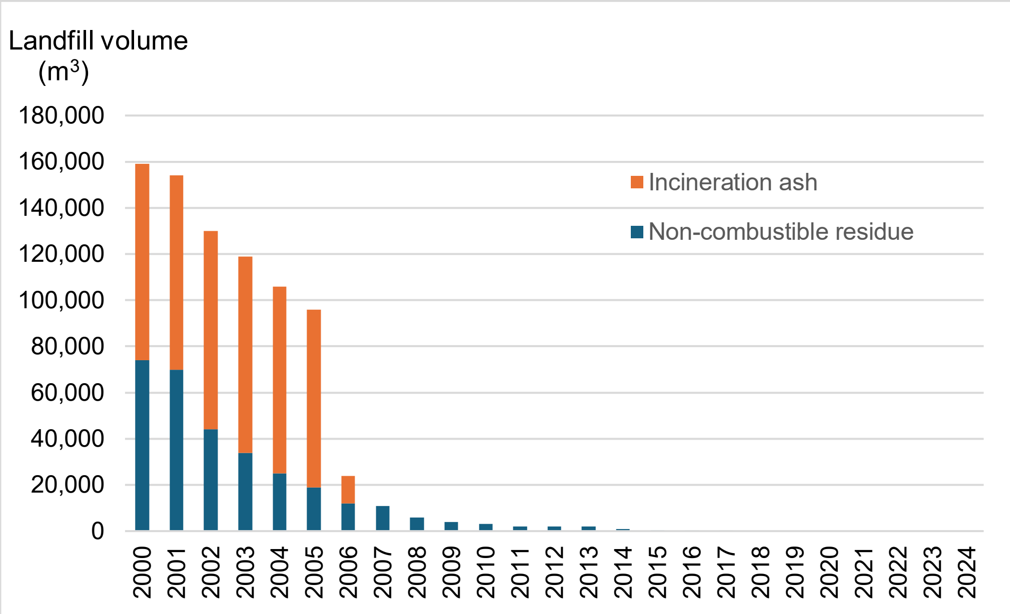

Figure 7. Changes in landfill volume at the Futatsuzuka Wide-Area Waste Disposal Site.

3.2. Changes in recycling rates

Western Tokyo has a significantly higher total recycling rate than Central Tokyo and Japan (**Figure 8**). The total recycling rate in Western Tokyo rose sharply until around 2010 and has since remained at around 37%. In contrast, Japan's total recycling rate has remained around 20%. Similarly, while the rate in Central Tokyo increased until 2009, it has since remained at around 17–20%. Note that the total recycling rate is calculated as the total amount recycled divided by the total waste generated. In addition, the total amount recycled includes Eco-cement.

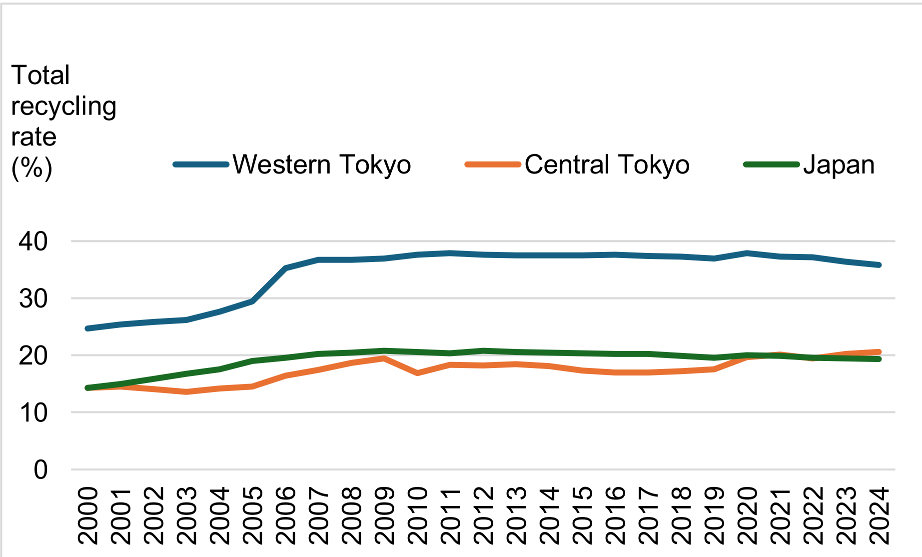

Figure 8. Changes in total recycling rates (Western Tokyo, Central Tokyo, and Japan).

3.3. Changes in waste generation

Figure 9 shows changes in waste generation in Western Tokyo alongside trends in Central Tokyo and across Japan. The vertical axis represents "waste generation per person per day (in grams)." In this context, "waste" includes both recyclables and non-recyclables. First, it is notable that Western Tokyo's waste generation is significantly lower than that of Central Tokyo and Japan. Comparing 2000 figures, Western Tokyo's waste generation per person per day was 1,016g, which is equivalent to 75.7% of Central Tokyo's 1,343g and 85.7% of Japan's 1,185g. Based on 2024 data, Western Tokyo's level was 671g, equivalent to approximately 80% of Central Tokyo's 836g and Japan's 839g. Furthermore, regarding the long-term trend in waste generation, a steady decrease is observed in Western Tokyo, Central Tokyo, and Japan.

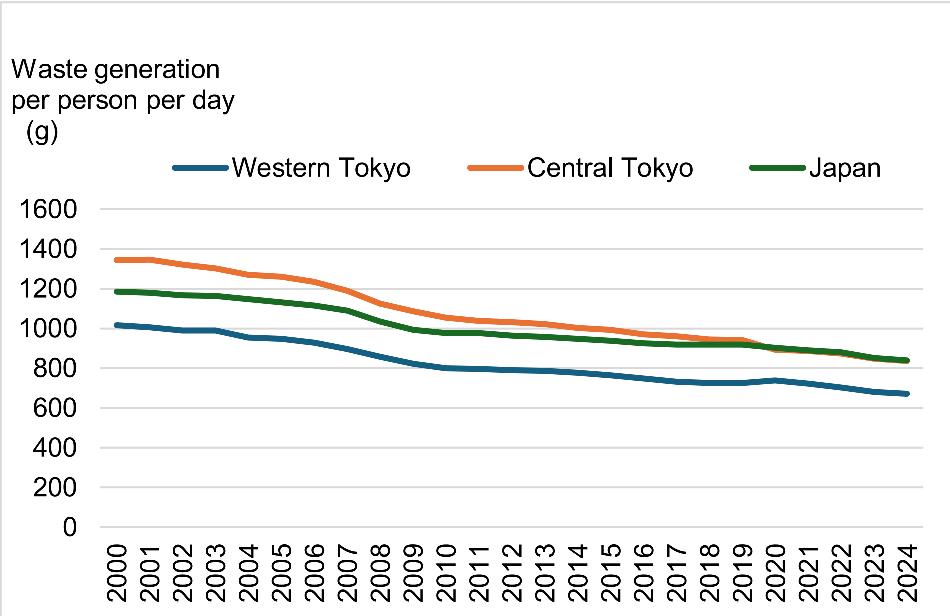

Figure 9. Changes in waste generation volume per person per day (Western Tokyo, Central Tokyo, Japan).

4. Discussion

4.1. Key findings and their implications

This study surveyed MSW management methods in Western Tokyo and recent quantitative changes in the region's waste treatment. Section 2 illustrated the MSW treatment processes conducted in the three facility types. In recycling plants, separately collected recyclables are further sorted and processed for recycled products. The intermediate treatment facilities accept and process non-recyclable waste collected under the volume-based waste fee system. Metals are recovered during crushing and incineration, and the energy generated by incineration is used to produce electricity and heat. All incineration ash is collected and transported to the final treatment facility, where Eco-cement is produced and shipped as a raw material for concrete.

Section 3 examined recent trends in waste treatment volumes and recycling rates in Western Tokyo. Regarding landfill disposal at the final treatment facility, the volume of incineration ash sent to landfills dropped to zero in 2007, and the volume of non-combustible residue delivered also declined rapidly, resulting in zero landfill disposal by 2018 (**Figure 7**). Regarding the "recycling rate," Western Tokyo is significantly higher than Central Tokyo and Japan, reaching nearly double the level (**Figure 8**). Western Tokyo's "per capita waste generation" is approximately 80% of the level observed in Central Tokyo and across Japan (**Figure 9**).

Trends in landfill disposal volumes at the final treatment facility indicate that the Eco-cement plant's operation has eliminated the need for landfilling incineration ash. Furthermore, the sharp decline in the volume of non-combustible residue delivered to landfills during the 2000s indicates that recycling efforts advanced rapidly in the region's municipalities during this period. These findings are consistent with the sharp increase in Western Tokyo's total recycling rates during the 2000s.

Furthermore, the higher-priced, volume-based waste fee system for non-recyclables implemented in Western Tokyo is believed to influence both the low per-capita waste generation and the high recycling rate. The volume-based waste fee system motivates residents to reduce the amount of waste they generate [22-24]. Furthermore, by limiting the waste fee to non-recyclables, residents become more proactive in waste separation, recycling, and composting [22-24]. In Western Tokyo, the effects of this system have been particularly pronounced because local governments set waste fees at high levels [23, 24].

4.2. Background and impetus for the zero-landfill circular system

This study revealed significant differences in MSW treatment methods and volumes between Western Tokyo and Central Tokyo, despite both being part of Tokyo Prefecture. This section discusses the historical background and circumstances that led to these differences.

The significant progress in waste reduction and resource recovery in Western Tokyo was driven by the urgent need to manage the limited remaining capacity at final disposal sites. In the 1990s, the final disposal sites that had been accepting incineration ash and non-combustible residues faced a severe shortage of landfill capacity due to the rapid increase in waste. However, developing a new landfill site was extremely difficult under the prevailing circumstances [10, 25]. One key factor was fierce opposition stemming from concerns about water pollution caused by wastewater leakage from the final disposal sites [25]. In contrast to inland-located Western Tokyo, the situation was different in Central Tokyo, which has coastal waters. Since landfill sites could be secured within Tokyo Bay (**Figure 1**), there was relatively ample capacity to accept waste [25].

The shortage of landfill capacity in Western Tokyo has brought about the following changes, which did not occur in Central Tokyo: (1) disclosure of information on waste generation and disposal by the municipality, (2) adjustment of municipal cost-sharing based on the volume of waste delivered to the final disposal site, (3) higher-priced volume-based waste fee system for non-recyclables, and (4) introduction of Eco-cement technology. These four changes served as the impetus for establishing the zero-landfill circular system in Western Tokyo.

"Disclosure of information on waste generation and disposal by the municipality" served as a strong motivator for local governments to promote waste reduction and recycling [11]. In 1992, the Institute for Tokyo Municipal Research began publishing the "Survey on Waste Disposal in the Tama Region." This annual survey report examined and disclosed information on waste generation and disposal in municipalities across Western Tokyo. Additionally, the citizens' group, "Gomi & Kankyo Vision 21," published annual comparative data on waste generation, recycling rates, incineration volumes, and landfill volumes for each municipality. These publications visualized each municipality's progress, thereby encouraging competition among them to reduce waste and promote recycling [11].

"Adjustments to municipal cost-sharing based on the volume of waste delivered to the final disposal site" also encouraged competition among municipalities to reduce waste and promote resource recovery. First, each municipality's allocation for the delivery of incineration ash and non-combustible residues to final disposal sites was determined by population. If the actual volume delivered exceeded this allocation, an excess fee was levied. Conversely, if the delivered volume fell below the allocation, a contribution payment was made [10, 25]. This mechanism provided a strong incentive for each municipality to promote waste reduction and recycling [11, 25].

"The higher-priced volume-based waste fee system for non-recyclables" served as a key incentive for residents to reduce waste and promote resource recovery. Today, in Western Tokyo, all 26 municipalities organizing the Tokyo Tama Regional Association for Waste Management and Resource Recycling have adopted a volume-based waste fee system. One municipality adopted the system in 1998, seventeen in the 2000s, seven in the 2010s, and the final one in 2022. Moreover, waste fees were set at a high level. When comparing the prices of pre-purchased, municipality-designated collection bags, the average price in Western Tokyo is nearly twice the nationwide average among municipalities that have implemented this system [11, 25].

"The introduction of Eco-cement technology" was advanced through public-private partnerships in the 1990s. The Ministry of International Trade and Industry (now the Ministry of Economy, Trade and Industry) led the research and development, with participation from private-sector cement and plant manufacturers. During the development phase, Taiheiyo Cement Corporation, which played a central role in the project, also conducted trial production at a demonstration plant from 1994 to 1999 [19]. Subsequently, the Eco-cement plant, as described in Section 2.3, was fully implemented in the final treatment facility.

4.3. Remaining challenge: Aiming for the next-generation eco-cement plant

4.3.1. Challenges in the Eco-cement production

The MSW management system in Western Tokyo appears to be ideal in both technological and institutional terms. However, there are a few challenges, including the "fuel used for the Eco-cement production" and the "location of the Eco-cement plant."

First, large amounts of fossil fuels are used in the production of Eco-cement. The stage that consumes the most fuel in cement production is the clinker production process in the rotary kiln (**Figure 6**, bottom) [26, 27]. This Eco-cement plant uses heavy oil as fuel for clinker production because it does not accept waste materials that could serve as fuel substitutes, such as waste oil and waste plastic. Massive use of heavy oil poses problems for natural resource consumption and environmental impacts, and also leads to high plant operating costs [28].

In addition to the energy required for Eco-cement production, the plant's location is also problematic. When determining the facility's location, generally, it is necessary to examine both its "relationship with land attributes, such as biodiversity, disaster risk, and topography" and its "spatial relationships among city components, such as facilities" [29]. From the latter perspective, there is a challenge regarding the location of this Eco-cement plant. In terms of freight transportation, it is advantageous for production facilities to be located near both "sources of raw materials and fuel" and "markets for finished products." Based on this premise, **Figure 1** shows that the location of the Eco-cement plant is inefficient for freight transport. The current location involves transporting raw materials and fuel from urban areas—where they are sourced—to the production plant located to the west, and then transporting the finished products back to the urban areas where they are consumed. The location results in longer transport distances, which pose problems for both cost and the environment, particularly for heavy goods such as cement [27].

4.3.2. Next-generation eco-cement plant for extended-area processing

It has been 20 years since this Eco-cement plant began operations, and preparations for renovation work are currently underway [30]. It is also necessary to consider long-term plans for the plant's future, such as rebuilding or upgrading equipment; accordingly, this section discusses the plant's future direction. In conducting the discussion, this study takes into account not only the incineration ash treatment needs of Western Tokyo but also those of a broader area, including Central Tokyo.

In Central Tokyo, there are 21 MSW incineration facilities that generate approximately 270,000 tonnes of incineration ash annually (190,000 tonnes of bottom ash and 80,000 tonnes of fly ash) [31]. The majority of this ash is currently landfilled at the final disposal sites within Tokyo Bay (**Figure 1**). However, because securing shipping lanes in Tokyo Bay is necessary, it is no longer possible to develop new disposal sites [32]. Consequently, the recycling of incineration ash is being considered, with the primary approach being to deliver it to existing cement plants. However, this approach faces the following difficulties. First, existing cement plants receive numerous acceptance requests from other municipalities; therefore, incineration ash from Central Tokyo is not given priority [28, 31]. Second, there are a few cement plants in the Tokyo area, so increasing the volume of waste delivered would require transporting it to distant plants [28]. Furthermore, since incineration ash (especially fly ash) contains high levels of chlorine, dechlorination is required for its acceptance by existing cement plants, thereby inevitably increasing treatment costs [28].

Regarding the incineration ash in Central Tokyo, research recommends constructing an eco-cement plant in the region rather than transporting the ash to remote facilities [28, 33]. In this research, simulations were conducted by varying conditions, including the capacity of existing cement plants to accept incineration ash, transportation distances, and dechlorination costs. The results showed that, under all conditions, the method for constructing and operating an eco-cement plant yielded the lowest processing costs [28, 33]. The major strengths of eco-cement production include "no constraints on the amount of incineration ash that can be accepted," "short transport distances," and "no need for dechlorination treatment." Furthermore, this research analyzed the relationship between the volume of incineration ash processed at the eco-cement plant and the cost-benefit ratio. The results indicated that processing a larger volume of incineration ash in collaboration with neighboring municipalities yields greater benefits than processing it solely within Central Tokyo [28, 33].

Based on the above research findings, a joint operation of a single eco-cement production plant across Central Tokyo and Western Tokyo appears to be a strong option. In that case, given the distance to existing incineration plants, the optimal location for the eco-cement plant would be Tokyo's urban area. Tokyo's urban area generates a large volume of waste beyond incineration ash, making it well-suited to increasing the use of waste as raw materials and fuel. Moreover, since the plant would be built in the heart of the Tokyo metropolitan area—Japan's largest cement-consumption market—it would be advantageous for product transportation. Additionally, transportation methods for the products will likely be considered when selecting the location for the eco-cement plant. If access to rail or water transportation is considered alongside road transport, energy consumption and environmental impacts can be reduced.

When designing the future eco-cement production plant for large-scale processing, cutting-edge technologies will be introduced to address the challenges currently faced by the existing plant. By accepting waste materials other than incineration ash as raw materials, the facility is expected to further increase waste utilization rates while ensuring sufficient cement quality. Furthermore, it will be possible to use waste-derived fuels or biomass fuels.

5. Conclusions

Western Tokyo is recognized as a frontrunner in MSW management in Japan, a nation considered a leader in supporting the circular economy. Western Tokyo is also the only region where the Eco-cement plant operates. To explore effective MSW management for a circular economy, this study surveyed the region's MSW treatment methods. Recyclables, including cans, paper, and bottles, are recovered as materials for recycling. Non-recyclables are incinerated at intermediate treatment facilities, where energy and metals are recovered. All incineration ash generated at the facilities is recycled into cement at the Eco-cement plant and used as a raw material for concrete. In addition to these technological measures, due to the shortage of landfill capacity, economic incentive measures, such as a higher-priced volume-based waste fee system for non-recyclables, have been introduced. Consequently, the waste reduction and recycling rates in Western Tokyo are significantly higher than those in Central Tokyo and across Japan, and a zero-landfill circular system has been achieved. These study results indicate that the region's MSW management methods, including the cement production from incineration ash and economic incentive measures, are effective in supporting the circular economy.

However, the Eco-cement plant in Western Tokyo faces a few challenges, including being located far from both waste generation sites and cement demand areas, and the use of large amounts of heavy fuel oil in cement production. Meanwhile, Central Tokyo also faces the challenge of recycling incineration ash rather than landfilling it. Therefore, when a "next-generation eco-cement plant" is constructed in the future, it is expected to be located and equipped to address these challenges comprehensively. In terms of location, it would be preferable to build the facility near the center of the Tokyo metropolitan area, which generates the highest volume of waste and consumes the most cement in Japan. Regarding cement production equipment, there is also an expectation to develop a production process that can accept other types of waste as raw materials and fuel, in addition to MSW incineration ash. Such a next-generation eco-cement plant will also serve as a final resource-recovery hub. Accordingly, locating such an upgraded eco-cement plant in urban centers will likely be a viable option for promoting the circular economy, not only in Tokyo but also in many other metropolitan areas.

References

[1] United Nations Environment Programme (UNEP). Global Waste Management Outlook 2024: Beyond an age of waste – Turning rubbish into a resource. UNEP;2024:115p. doi: https://wedocs.unep.org/20.500.11822/44939

[2] Daga, S., Yadav, K., Singh, P., Mishra, V. Beyond the Take-Make-Dispose Model—Unlocking the Power of Circular Economy for an Environmentally Resilient Future. In: Singh, P., Daga, S., Yadav, K., Mishra, V. (eds) Circular Economy and Environmental Resilience. Springer;2025. doi: https://doi.org/10.1007/978-3-031-93091-1_1

[3] European Commission. Closing the loop - An EU action plan for the Circular Economy. 2015 [cited 2026 June 2]. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0614&from=EN

[4] European Commission. Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains. 2014 [cited 2026 Jun 2]. Available from: https://ieep.eu/wp-content/uploads/2022/12/Circular_economy_scoping_study_-_Final_report.pdf

[5] Geng Y, Sarkis J, Ulgiati S, Zhang P. Measuring China's circular economy. Science. 2013;339-6127:1526–1527. doi: https://doi.org/10.1126/science.1227059

[6] Negrete-Cardoso, M., Rosano-Ortega, G., Álvarez-Aros, E.L. *et al.* Circular economy strategy and waste management: a bibliometric analysis in its contribution to sustainable development, toward a post-COVID-19 era. Environ Sci Pollut Res;2022;29:61729–61746. doi: https://doi.org/10.1007/s11356-022-18703-3

[7] Ministry of Environment, Japan. History and Current State of Waste Management in Japan. 2014 [cited 2026 Jun 2]. Available from: https://www.env.go.jp/en/recycle/smcs/attach/hcswm.pdf

[8] Ministry of the Environment, Japan. Solid Waste Management and Recycling Technology of Japan: Toward a Sustainable Society. 2012 [cited 2026 Jun 2]. Available from: https://www.env.go.jp/en/recycle/smcs/attach/swmrt.pdf

[9] Ministry of the Environment, Bureau of Environmental Restoration and Resource Circulation. Waste Management in Japan 2024. 2026 [cited 2026 Jun 2]. Available from: https://www.env.go.jp/recycle/waste_tech/ippan/r6/data/disposal.pdf (In Japanese)

[10] Tokyo Tama Regional Association for Waste Management and Resource Recycling. Regional Plan for Promoting a Sound Material-Cycle Society in the Tama Region, Tokyo. 2022 [cited 2026 Jun 2]. Available from: https://www.env.go.jp/recycle/waste/3r_network/5_region/project_list/13_tokyo/20_tamachiiki_r4.pdf (In Japanese)

[11] Onodera I. Overview of waste management measures and future challenges in local governments in the Tama Region. 2026 [cited 2026 Jun 2]. Available from: https://gomikan21.com/sinchaku/20260121tamakongo.pdf (In Japanese)

[12] Taiheiyo Cement Corporation. Tokyo Tama Eco-Cement Corporation. [cited 2026 Jun 2]. Available from: https://www.taiheiyo-cement.co.jp/group-recruit/articles/article023/index.html (In Japanese)

[13] Landfill Site Management Office, Bureau of Environment, Tokyo Metropolitan Government. Tokyo Metropolitan Government Waste Landfill Sites: Central Breakwater Outer Landfill Site & New Sea Surface Disposal Site. 2025 [cited 2026 Jun 2]. Available from: https://www.kankyo.metro.tokyo.lg.jp/documents/d/kankyo/english_pamphlet2024

[14] Japan Steel Can Recycling Association. Annual Report on Steel Can Recycling 2025. 2025 [cited 2026 Jun 2]. Available from: https://steelcan.jp/wp-content/uploads/2026/02/2025-AnnualReport.pdf

[15] Japan Aluminum Association. Aluminum cans: Recycling data. 2024 [cited 2026 June 2]. Available from: https://www.aluminum.or.jp/box/junkan_new/recycle.html (In Japanese)

[16] US Environmental Protection Agency. Glass: Common Wastes & Materials. 2026 [cited 2026 Jun 2]. Available from: https://web.archive.org/web/20120617135636/http://www.epa.gov/osw/conserve/materials/glass.html

[17] National Institute for Environmental Studies. Used paper recycling technology. 2022 [cited 2026 Jun 2]. Available from: https://tenbou.nies.go.jp/science/description/detail.php?id=65 (In Japanese)

[18] Takuma Co., Ltd. Stoker-type incinerators. [cited 2026 Jun 2]. Available from: https://www.takuma.co.jp/english/business/msw/stoker_msw.html

[19] Tanaka S, Hirao H, Hoshino S. Eco-cement: An innovative technology that contributes to establishing a sustainable and recycling-based society. Concrete Journal. 2016;54-5:496-501. doi: https://doi.org/10.3151/coj.54.5_496 (In Japanese)

[20] Taiheiyo Cement Corporation. Ecocement System. [cited 2026 Jun 2]. Available from: https://www.taiheiyo-cement.co.jp/english/service_product/recycle_mw/eco/index.html

[21] Japanese Standards Association. JIS R 5214 (2019) Ecocement. JIS R 5214: 2019. [cited 2026 Jun 2]. Available from: https://kikakurui.com/r5/R5214-2019-01.html (In Japanese)

[22] UN Environment Programme. Korea Environmental Policy Bulletin - Volume-Based Waste Fee System. 2003 [cited 2026 Jun 2]. Available from: https://www.unep.org/resources/report/korea-environmental-policy-bulletin-volume-based-waste-fee-system

[23] Yamaya S. Waste Collection Fees. Tokyo: Maruzen Publishing; 2007. p. 244. (In Japanese)

[24] Yamaya S. Waste Reduction Measures. Tokyo: Maruzen Publishing; 2020. p. 264. (In Japanese)

[25] Kurishima H. Analyses and Perspectives of Municipal Solid Waste Management in Tokyo. Journal of Geography. 2014;123-4:556-574. doi: https://doi.org/10.5026/jgeography.123.556 (In Japanese)

[26] Marmier, A., Decarbonisation options for the cement industry, EUR 31378 EN, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/174037, JRC131246.

[27] Barbhuiya S, Kanavaris F, Das B.B, Idrees M. Decarbonising cement and concrete production: Strategies, challenges and pathways for sustainable development. Journal of Building Engineering. 2024;86-108861. doi: 10.1016/j.jobe.2024.108861

[28] Iino S, Arai Y, Inakazu T, Koizumi A. Model analysis of cement recycling system of municipal waste incineration main ash in and around the metropolitan area. Journal of JSCE. 2016;72-6:35-44. doi: https://doi.org/10.2208/jscejer.72.II_35 (In Japanese)

[29] Fujihira K. Systematic method for identifying unsuitable land for development: biodiversity, disaster risk, and topography. Academia Environmental Sciences and Sustainability. 2025;2(2). doi:10.20935/AcadEnvSci7647

[30] Taiheiyo Cement Corporation. Contract execution for core equipment improvement work and operation services at the Eco-cement plant. 2025. [cited 2026 Jun 2]. Available from: https://www.taiheiyo-cement.co.jp/news/news/pdf/250819_2.pdf (In Japanese)

[31] Clean Association of Tokyo 23. The Sixth Basic Plan for General Waste Management: Incineration Ash Recycling Projects and Projections for Final Disposal Volumes. 2024 [cited 2026 Jun 2]. Available from: https://www.union.tokyo23-seisou.lg.jp/kikaku/ippaikeikaku_6/documents/02_r5.pdf (In Japanese)

[32] Tokyo Metropolitan Government, Bureau of Port and Harbor. Landfill Disposal Plan for Waste, etc. [cited 2026 Jun 2]. Available from: https://www.kouwan.metro.tokyo.lg.jp/basic/plan/umetatekeikaku (In Japanese)

[33] Iino S, Arai Y, Okada M, Inakazu T, Koizumi A. Cement recycling model in consideration of dichlorination cost of municipal waste incineration ash. Journal of JSCE. 2016;73-6:179-188. doi: https://doi.org/10.2208/jscejer.73.II_179 (In Japanese)