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Comparative Study of Solid Waste Treatment Techniques in Japan and Singapore: Incineration, Recycling, and Landfill Reduction Models

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Comparative Study of Solid Waste Treatment Techniques in Japan and Singapore: Incineration, Recycling, and Landfill Reduction Models

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1. Abstract

This paper makes a comparative analysis of solid waste treatment strategies used in Japan and Singapore based on the focus on incineration, recycling, and landfill reduction strategies. The aim is to examine the effects of divergent legal, institutional and technological frameworks on waste management outcomes in the two most urbanised land limited jurisdictions. Using a comparative legal-policy and technical analytical framework, the research evaluates statutory regulations, governance structures and working procedures that regulate municipal solid waste treatment in both countries. Results indicate that despite the fact that at the heart of waste management in both jurisdictions is incineration as a waste management tool, there exist significant differences in regulatory frameworks, recycling enforcement strategies, and long term landfill minimization strategies. The decentralized but comprehensive recycling laws in Japan are in sharp contrast to the centralized and efficiency-based waste-to-energy model in Singapore. The research reason is that successful landfill reduction is not determined only by the advanced technology but the strong legal regulations, institutional coordination, and binding duties of producers and consumers, thus, offering the policy-relevant information to other highly populated states.

2. Introduction

The increasing trend in the growth of urban populations, which are accompanied by an increasing consumption pattern and changing lifestyles, has brought about the continuous increase in the production of municipal solid waste at a worldwide scale. Therefore, solid waste management has become one of the central questions of the environmental regulatory system especially in areas where land is highly limited. In this regard, Japan and Singapore are two of the most advanced and highly studied waste treatment models[1]. The two countries have avoided the use of traditional landfilling to a great extent and instead emphasized on incineration,

[1] Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste: A Global Review of Solid Waste Management* (World Bank, Washington DC, 2012).

recycling and organized landfill minimization[2]. The rationale behind the comparative analysis of the two systems lies in their structural limitation being similar and the response by the law and institutions being different, which all serve as important sources of information on the role of law in shaping sustainable waste management patterns. Urbanisation increases the challenges associated with waste by increasing the amount of waste and at the same time limiting the disposal possibilities. The location and operation of waste-treatment facilities are challenging due to high population density, clashing land-use demands, and opposition to waste facilities by the population. These pressures make waste management a complex legal issue that involves not only environmental regulation but also the protection of the population's health, the administrative law as well as long-term planning. Laws regulating solid waste must be able to strike a balance between conflicting goals such as economic efficiency, environmental protection, energy recovery, and social acceptability. Volume reduction and energy recovery (e.g., incineration) can be accomplished, but this process also raises some issues related to air emissions, ash disposal, and exposing the community to these issues, all of which also demand strict regulation. Recycling regimes are based on the binding legal commitments, obligatory involvement of the population and clear distribution of the roles among producers, consumers, and government. The landfill reduction strategies also operate on the basis of statutory restrictions, pricing systems and the long term regulatory planning.

This paper will focus mainly on the legal and policy environment in both Japan and Singapore in the regulation of incineration, recycling, and landfill reduction and evaluates how these frameworks affect practical consequences. The research questions to be addressed are: (1) what is the embeddedness of waste-treatment technologies in statutory and regulatory regimes; (2) how are institutional arrangements relevant to the functioning of the systems; and (3) to what extent are the systems able to reduce environmental harm and operational efficiency. The paper has emphasized the importance of regulatory structure, institutional capacity, and accountability mechanisms in the success of waste-management strategies through its focus on legal design and not technical performance.

Comparatively, relating to environmental-law, the present research is also important because it clarifies the way through which the divergent models of governance react to similar environmental limitations. The waste-management system in Japan is typified by elaborate laws and decentralized efforts at local level and widespread enforcement of recycling laws, and producer-responsibility. By contrast, Singapore uses a much more centralized, state-based model, with an emphasis on administrative efficiency and integrated planning and regulation of waste-to-energy facilities and landfill. The juxtaposition of these strategies helps evaluate critical in the manner in which legal systems distribute power, deal with risk, and encourage compliance in the environmental-protection setting[3].

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[2] Masaru Tanaka, "Recent Trends in Recycling Activities and Waste Management in Japan", *1* Journal of Material Cycles and Waste Management 10 (1999).

[3] Eric Bea, "Extended Producer Responsibility in Singapore's Resource Sustainability Act", *APCEL Working Paper Series* No. 19/01 (2019).

The article is designed such that it endorses this comparative study. After this introduction, the paper identifies the conceptual and legal framework that regulate solid waste management. It then looks at the waste-treatment systems of Japan and Singapore on separate basis, and then compares it in a detailed manner. The paper wraps up by establishing some of the major issues of law, drawing up lessons of policy relevancy, and making recommendations that can be applicable to other highly populated jurisdictions in an effort to establish sustainable and legally sound waste-management systems.

3. Conceptual and Legal Framework for Solid Waste Management

Solid waste management is regulated by a combination of legal concepts, regulatory tools and policy goals that all strive to reduce the impact on the environment, but by providing the possibility to dispose of the waste efficiently and recover the resources. Conceptually speaking, the municipal solid waste is normally conceived as the waste produced by the household, commercial buildings and institutional operations not including hazardous or industrial waste unless the statute specifically states otherwise. The jurisprudential accuracy of legal definitions is contingent in that it creates the area of the regulatory power, distributes the roles of the interested parties, and defines whether certain treatment and disposal specifications apply or not. Both in Japan and Singapore, differentiated regulation of incineration, recycling, and landfill utilisation are based on statutory categories of waste.

One of the central conceptual pillars of contemporary waste governance is the waste hierarchy that places waste prevention at the top, then after it comes reuse, recycling, recovery, and, as the last option, disposal[4]. Even though the hierarchy is often expressed in the course of policy documents, as opposed to binding legislation, the hierarchy has increasingly been encompassed within statutory and regulatory frameworks, thus affecting administrative decision-making as well as infrastructure planning. The focus of recycling and recovery is a wider trend to sustainable development and what could also be thought of as circular economy which views waste as a resource and not a residual burden. Contemporary legal systems are finding ways to institutionalise this move by making segregation compulsory, setting recycling quotas, and encouraging material recovery by incentives.

There are a number of core tenets of environmental law that form the basis of solid waste control. Polluter Pays Principle requires waste producers to pay the cost of managing their waste thus internalising environmental externalities and deterring overproduction of waste[5]. This principle is reflected in the waste disposal charges, landfill charges and long-term producer responsibility programs which subjects the manufacturers and importers to financial and operational requirements. Close to the Precautionary Principle is the so-called Precautionary Principle, where regulatory intervention can be justified in situations where there has been a lack of scientific understanding, especially potential emissions by incineration plants, and the long-term effects of landfill contamination. Waste law tries to ensure that irreversible damage is prevented even in cases where the risks associated with the waste cannot be fully quantified by setting strict standards of emissions, continuous monitoring, and prior environmental approvals[6].

The existing regulatory instruments used in solid waste management fall into two broad categories, namely, the command-and-control and market-based tools. The approach to

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[4] *Council Directive 2008/98/EC on Waste (Waste Framework Directive)*, art. 4.

[5] *Rio Declaration on Environment and Development*, Principle 16 (1992).

[6] *Rio Declaration on Environment and Development*, Principle 15 (1992).

command-and-control regulation is, in particular, the predominance of this approach in the context of licensing incineration facilities, indicating the amount of emissions, enforcing the separation of waste, and restricting landfills. As much as these tools have legal certainty and enforceable standards, they are administratively burdensome. Market-based policies such as variable pricing of waste disposal, recycling incentives and producer responsibility fees are used in addition to traditional regulation as they indicate economic incentives that alter behaviour. The success of these tools depends on legal thorough design, openness, and strong enforcement systems.

The Extended Producer Responsibility (EPR) has become one of the most relevant legal tools in the recycling and reduction of landfill paradigm[7]. EPR frameworks shift the burden of post consumer waste of municipalities to the producers who are then forced to fund or handle the recycling, collection or disposal safely of certain waste streams. EPR schemes are legally complicated issues when it comes to the distribution of liability, regulatory oversight and the coordination of the work of public authorities and the private actors. However, they are generally considered to be part of the solution to the higher recycling rates and reduced amount of the waste that needs to be disposed of in the end[8].

Institutional and governance structures are also key to the law on solid waste management. One of the most significant impacts of the distribution of regulatory powers among the national, regional and local levels is the effect on policy coherence, enforcement capabilities and sensitivity to local conditions. The absence of regulatory piecemeal is essential, and it is achieved through clear statutory mandates, clearly defined administrative roles, and proper inter-agency coordination. The legitimacy and effectiveness of waste governance is further upheld by the public participation, and transparency requirements, such as the access to environmental information and consultation requirements.

Combined, these conceptual and legal concepts give the structure of operation of certain waste treatment methods. The full picture of this framework is necessary to consider the legal framework of incineration, recycling and landfill-reduction models in Japan and Singapore, as well as to evaluate the general implications of the models on sustainable environmental management.

4. Solid Waste Treatment Framework in Japan

The developed solid waste treatment system in Japan has come about as a result of a convergence of forces and they are firstly the dense population of the country, the limited landfill space, the highly developed concern citizens have with the quality of the environment and secondly the historical focus on administrative control. The nation produces a large amount of solid waste at the municipal level; therefore, the country employs little landfill disposal. Rather, Japan has developed a legality and institutional thickening that puts an emphasis on incineration and recycling, whose foundation is based on the elaborate statutory rules and decentralized application at the local governments[9].

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[7] Thomas Lindhqvist, "Extended Producer Responsibility in Cleaner Production", *The IIIEE Dissertations* (Lund University, 2000).

[8] Aliz Vuk et al., "Waste Management and Plastic Waste Recycling in Japan, China, Singapore and South Korea", *16* International Review of Applied Sciences and Engineering 118 (2024).

[9] *Waste Management and Public Cleansing Act*, Act No. 137 of 1970 (Japan).

The solid waste management in Japan is typified by a distinct distribution of the roles within the various levels of government. The legislative framework, policy direction, and technical standards are executed by national authorities and the prefectural and municipal governments have the major role of implementation, operation of facilities and enforcement. In special, municipalities play a key role in the collection, segregation and treatment of waste. Such a decentralised system is flexible to local conditions, but at the same time, this structure brings about heavy administrative and financial costs to the local governments and this has triggered the necessity strong legal directions and controls at the national level[10].

The Japanese waste treatment system is mainly composed of incineration. Most of the municipal solid waste is undergone as incinerations, thus contributing a significant cut in the amount of waste and restricting the use of landfills. The incineration facilities are highly regulated by law and include licensing factors, environmental impact assessment as well as adherence to strict emission standards. These norms touch on dioxins, sulphuric particles, and nitrogen oxides, which represent domestic health concerns of the populace, as well as international environmental obligations[11]. Facility operators are subject to continuous monitoring and reporting requirements and failure to comply may lead to administrative penalties or fines or operational discontinuation. Besides, most incineration plants are also built to provide reclaimed energy in form of electricity or heat to address the energy and climate policy goals on waste treatment on a larger scale.

The second pillar of the waste management system in Japan is recycling, which is backed with a large number of laws. Japan has been well known in its elaborate waste segregation regulations, requiring households and businesses to segregate wastes into various categories[12]. Such responsibilities are binding by law and they are also backed by the city ordinances, effort to educate and, programmes to collect trash. The characteristic of the recycling regime in Japan is the establishment of the so-called Extended Producer Responsibility schemes that present legal requirements to manufacturers and importers to take responsibility of recycling certain products and packaging[13]. The purpose of these schemes is to relieve the local waste systems and encourage the eco-design and material recovery.

Speaking of legal aspects, the recycling system in Japan is characterized by its particularity and breadth. Various waste streams, including packaging, electrical equipment and construction materials, fall under different statutory regimes, and each has a customized compliance system and enforcement framework[14]. Although this way allows focusing on regulation, it also creates regulatory complexity and increases compliance costs. However, the aggregate effect of such actions has brought a relatively high recovery of the material and a corresponding decrease of the waste that should be disposed of.

The use of landfill in Japan is highly controlled and it is minimised. The use of landfills is mainly in incineration residues e.g. ash and waste streams that are otherwise inaccessible. Siting, design and operation of landfills are regulated by the law, which includes the use of liners, control of leachate and long-term monitoring. Since there is limited availability of appropriate

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[10] *Local Autonomy Act*, Act No. 67 of 1947 (Japan).

[11] *Act on Special Measures concerning Countermeasures against Dioxins*, Act No. 105 of 1999 (Japan).

[12] Act on the Promotion of Sorted Collection and Recycling of Containers and Packaging, Act No. 112 of 1995 (Japan).

[13] Act on Recycling of Specified Kinds of Home Appliances, Act No. 97 of 1998 (Japan).

[14] Construction Material Recycling Act, Act No. 104 of 2000 (Japan).

land and people are not in support of landfill development, landfill capacity is considered as one of the strategic environmental resources. As a result, the legislation underlines the focus on volume reduction at the initial levels of the treatment chain, which strengthens the first place of incineration and recycling[15].

Although it has been effective overall, the waste treatment structure in Japan is faced with a number of challenges. The costs of capital and operations of incineration facilities are high creating a concern to financial sustainability in the long run, especially among the smaller municipalities. Though diluted by strict environmental protection measures, public opposition to incinerator location is still a legal and political issue. Although a very comprehensive system, recycling systems require active participation of the people and lasting administrative control. Furthermore[16], the processing of incineration ash, its categorization, and its possible re-use are subjects of changing legal issues regarding the safety of the environment and responsibility.

Evaluatively speaking, the solid waste treatment system in Japan, has shown that a comprehensive legislation, decentralised governance and the ability to invest in technology can significantly decrease the reliance on landfills. The strong points of the system are the legal clarity, methods of its enforcement, and correlation of waste management with the environmental protection objectives. At the same time, its dynamism and high cost makes the factor of institutional capacity and continued involvement of the people significant. In that vein, the model of Japan can be a good reference to examine the legal aspects of the development of waste treatment systems at the high population density jurisdiction level[17].

5. Solid Waste Treatment Framework in Singapore

The solid waste treatment system of Singapore is influenced by the lack of land, high population density, and strong culture of centralised administrative governance. Singapore being a small island city-state that practically has no possibility of using conventional land-fill techniques, has embraced a very integrated and efficiency-based waste management paradigm, which is based mainly on incineration (that is complemented by recycling and stringent oversight on ultimate disposal). The law and policy are decisive in the organization of this system whereby regulatory certainty, institutional coordination and long term planning are highly emphasized.

In Singapore, waste management is very centralised with the national authorities having the main control in policy formulation, regulation and planning of infrastructural planning. This is unlike the decentralised systems where the local governments have a major responsibility, but the Singapore system is indicative of its unitary administrative system and relatively small size of territories. This centralisation allows equal application of waste policies and allows big-scale investment of infrastructure. The law works by having comprehensive statutes and subsidiary legislation governing waste collection, waste treatment, waste emissions and disposal that are supported with solid enforcement processes[18].

The incineration forms the basis of the solid waste treatment plan in Singapore. Most of the municipal solid wastes are sent to enormous burning plants, which cut back on the quantity of

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[15] Basic Act for Establishing a Sound Material-Cycle Society, Act No. 110 of 2000 (Japan).

[16] Renbi Bai and Mardina Sutanto, "The Practice and Challenges of Solid Waste Management in Singapore", *22* Waste Management 557 (2002).

[17] Douglas L. Tookey, "Singapore's Environmental Management System: Strengths and Weaknesses", *23* William & Mary Environmental Law and Policy Review 169 (1998).

[18] Environmental Public Health Act, Cap. 95 (Singapore).

wastes by a significant margin as they produce electricity by means of waste-to-energy. There is tight licensing and operational control on these facilities such as environmental impact assessment, emission standards and mandatory constant monitoring. Legal regulation is aimed at protection of air quality, occupational safety, and residual by-products like bottom ash, fly ash[19]. The combination of energy recovery and incineration indicates a policy option that seeks to integrate waste management with energy and climate goals at the national level, and also cope with the challenge that comes with the lack of sufficient space. Recycling plays a growing role in the waste governance regime in Singapore, despite the fact that it has always had a secondary role to incineration. Laws advance recycling by obligating the segregation of garbage in specific industries, statutory obligations on collection of garbage, and the creation of the national recycling goals. Over the last few years, Singapore has reinforced its recycling framework by the implementation of the Extended Producer Responsibility requirements of certain types of waste especially those related to packaging and electrical goods[20]. Such laws are supposed to reduce some of the waste management responsibility on the state and put it on the producers, thus making producers design more sustainable products and minimizing the amount of waste going to the incineration system.

Regulatory-wise, the recycling system of Singapore is defined by its focus on administrative effectiveness and compliance over the large-scale presence of decentralisation. Recycling requirements are usually introduced with the conditions of license, reporting regulations, and punishment in case of non-conformity. Legal requirements are used to complement the public education and behavioural change programs, but the system is mostly state-based. Even though the recycling rates have risen in some sectors, there still remains issues concerning the involvement of households, pollution of recycling materials, and fluctuation of recovered materials in the market.

The use of landfills in Singapore is strictly regulated and kept at a minimum. With no natural landfill sites, the ultimate disposal is limited to a highly designed offshore landfill which can only take non-incinerable waste and incineration residues. Landfill operations are highly controlled by law regarding the waste acceptance requirements, the environmental protection, and monitoring requirements. Landfill is considered a key national capital and lifespan of landfill is a major factor to be considered during waste policy planning. Therefore, the decrement of the amount of waste to be discarded in landfills is one of the major legal and policy goals, which makes incineration dominant and reinforces the significance of recycling[21].

The waste treatment structure of Singapore has some legal and policy problems even with its efficiency in operations. The high dependency on incineration poses some issues on the sustainability in the long term, as well as the control of emissions and how to treat the remaining ashes. Recycling programs should not be hindered by behavioural barriers and cost-effectiveness, especially in an environment, where incineration is a relatively easy and an approved mode of disposal[22]. Also, the centralised form of governance, which is efficient, restricts local experimentation and community innovation of waste reduction.

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[19] Environmental Pollution Control Act, Cap. 94A (Singapore).

[20] Resource Sustainability Act 2019, Act 29 of 2019 (Singapore).

[21] Lye Lin Heng, "Environmental Law and Policy in Singapore", *Singapore Journal of Legal Studies* (2008).

[22] Hiroaki Takiguchi and Kazuhiko Takemoto, "Japanese 3R Policies Based on Material Flow Analysis", *12* Journal of Industrial Ecology 792 (2008).

On the whole, the sound waste treatment system in Singapore reveals that a highly centralised system of legal and institutional model is strong enough to provide efficient waste management results within very limited space conditions. Its advantages are regulatory transparency, enforcement, and strategic planning of the infrastructure. Simultaneously, the system emphasizes the necessity to constantly redefine the legal priorities in order to balance both efficiency and environment and sustainability. In that way, the experience of Singapore offers an opposite, but a complementary example to the decentralised system used in Japan, and it can be valuable to compare the two countries to provide comparative information about the legal regulation of solid waste management.

6. Comparative Analysis of Japan and Singapore

● Comparative Assessment of Incineration-Based Waste Treatment

The background technique of solid waste management in Japan and Singapore is incineration, which is mainly due to similar limitations of high population density and limited landfill space. However, the law and institutional factors underlying the incineration operation have strong dissimilarities. The incineration system in Japan is characterised by high capacity to have many municipally owned facilities, which reflect the decentralised system of governance. The local authorities save much freedom in the design of facilities, operational procedures, and the combination between waste treatment and community services and, at the same time, follow the nationally set standards on environmental protection. Such decentralisation promotes local adjustment but creates disparity in the performance efficiency and cost forms across municipalities.

In Singapore on the other hand, there are only a few large-scale centrally-planned incineration plants which are integrated into a larger national waste-to-energy policy. The legal framework implies even-handed licensing terms, central control, and long-term capacity planning. Regulatively, Singapore is concerned with administrative efficiency and economies of scale, which is not the same case in Japan where the system focuses on local autonomy and public acceptability. Both systems impose strict regulations of emission and surveillance; but, the Japanese system has a greater rate of community level participation as compared to Singapore that is still largely dependent on central government regulation[23].

● Recycling Frameworks and Extended Producer Responsibility

Recycling is a major area of dissimilarity between the two jurisdictions. Japan has developed an expansive and well detailed recycling regime, which is based on legal requirements of waste separation and a number of Extended Producer Responsibility (EPR) regimes. Such legal tools introduce certain responsibilities on the part of producers, importers, and consumers, thus making recycling a part and parcel of the daily social and economic lives. The model of the Japanese is strong because it is legally binding and because the waste-segregation norms are internalised in the Japanese culture. However, this complexity increases compliance expenses and administrative overloads especially to the small businesses and local governments.

The recycling system of Singapore, although becoming stronger, is more centralised and policy-oriented. The legal requirements focus on the controlled industries and are realized primarily with the help of the licensing conditions and national goals. EPR has been implemented in a rather selective way and this is a sign of a cautious and incremental legal strategy. As much as

[23] Hirotaka Kumamaru and Kenji Takeuchi, "The Recycled Content of Plastic Products: Estimating the Impact of Japan's Container and Packaging Recycling Law", *Discussion Paper No. 2119*, Kobe University (2021).

this increases clarity in regulations and makes them easy to enforce, this has never led to the high rates of household recycling as in Japan. Therefore, the recycling system in Japan is more institutionalised legally and in practice, whereas the Singaporean system is in its developmental phase to become more producer and consumer responsible.

- **Landfill Reduction Strategies and Residual Waste Management**

Reduction of landfills is one of the similar policy purposes in the two jurisdictions, but approaches followed towards the same vary significantly as the geographical and legal conditions are different. Although Japan has a greater land area than the state of Singapore, it faces strong community resistance to landfill development and legal barriers against landfill location and operation. This means that the use of landfills is highly restricted and it is mainly confined to incineration wastes. The legislative system is more concerned with reducing the quantity of waste at the source and thoroughly regulates ash disposal with long-term monitoring requirements.

The policy of Singapore is predetermined by the absence of landfill space, which is almost complete. Such final disposal is limited to one highly designed landfill which is managed as a national strategic resource. Legal restraints on access to landfills are strict, and policy planning is specifically aimed at increasing the lifetime of the facility. Such orientation has strengthened the high dependency of incineration in Singapore and has promoted the unceasing investment in waste-to-energy facilities. Relative to this, the landfill reduction strategy of Japan is more decentralised and localised, as compared to that of Singapore that is highly centralised and nationally coordinated.

7. Legal Challenges and Emerging Issues

Along with the fairly high effectiveness of their solid-waste management systems, both Japan and Singapore also face a range of legal problems and emerging issues that question the long-term sustainability and validity of their waste governance systems. Technological dependency, changing environmental expectations, changing social expectations, and cross-border factors are some of the issues which lead to these challenges.

The legal issue of main concern is the environmental compliance and control of emissions in regard to incineration. Although the two jurisdictions are imposing severe emission standards and monitoring policies, growing scientific understanding on the subject of ultra-fine particulates, persistent organic pollutants and cumulative health effects casts serious doubts on the effectiveness of current legal limits. Regulatory frameworks should thus continuously adjust to the changing scientific knowledge and this requires a regular update of standards, increased openness, and stronger enforcement. The lack of such adjustments may be challenged by the courts, the population, and the weakening of trust in the regulatory bodies. One more topical concern is the participation of the population, transparency, and accountability. The decentralised form of governance in Japan provides a chance to the community to involve themselves, but it equally increases the likelihood of procedural wrangles, especially when site and approvals of incineration plants are being made. Legal issues are often related to the supposed flaws in environmental impact assessments or in the process of conducting a consultation. On the other hand, the centralised government in Singapore has contributed to efficiency in regulation, but has created fear about limited channels of involvement and reviewing of the judiciary. Therefore, achieving administrative efficiency and procedural fairness, as well as participatory rights, is a legal dilemma.

There is also the aspect of environmental justice that has gained prominence. The treatment plant of waste particularly the incinerators and the ash disposal sites might have disproportionately high levels of burden on specific communities. Both jurisdictions have had increased scrutiny in terms of their ability to deal with unequal exposure to environmental risks, and their ability to evenly distribute the environmental burdens and benefits. Integrating environmental justice practices in waste management is a challenge both doctrinally and practically, especially in situations where geographical restrictions limit land-use decisions.

Lastly, there are also emergent cross-border and transboundary problems that make the domestic waste governance even more complicated. There are international restrictions on waste exports, resource-recovery markets and transboundary pollution requirements that have an effect on national waste policies[24]. With the growing globalisation of recycling markets, and with the constraints on waste trade growing, local legal frameworks need to be modified to guarantee that they meet international environmental standards, but retain their ability to treat waste effectively. All of these legal issues illuminate the need to have a dynamic, adaptive waste regulation that is responsive to technological change, societal expectations, and changing environmental risks. The challenges of solid-waste governance systems in both Japan and Singapore will be addressed in the future to guarantee the resilience of the system.

8. Policy and Legal Recommendations

Technology and law and regulation systems should collaborate to ensure that solid waste is handled in densely populated and strained land. Based on the comparative discussion about Japan and Singapore, various policy and legal suggestions can be used to make the waste governance systems more sustainable and legitimate.

The regulations governing incineration are to be updated in accordance with the emerging emissions and research on the health of the people. The assignment of emission standards should be scheduled and revised with prudent limits as to the development of the contaminants and data on monitoring should be made publicly available. Non-compliance liability parts should be included to enhance credibility and trust of the regulator and the populace.

Second, more specific and stricter legislative responsibilities should be strengthened by recycling systems. In Japan, it is possible to harmonize conflicting recycling rules and achieve improved administrative complexity and maintain high recovery rates. In Singapore, by implementing Extended Producer Responsibility programmes to cover a wider range of goods and packaging they would disperse more responsibility on the part of manufacturers and reduce reliance on burning. Setting legal goals of recycling and fines against unchanging non-compliance can also affect the behaviour of households and companies.

Third, landfill reduction approaches should be included in the long-term statutory planning. Since landfill has a strategic constraint of space, the laws must be clear in promoting the time span of landfill to the reduction of upstream waste and recycling programmes. Diversion could also be promoted by landfill charges and the obligatory waste-to-landfill diversion targets.

Fourth, there should be institutional coordination and governance capability that should be addressed. More financial and technical support of municipalities by the decentralised system like the one in Japan may enhance the uniformity and effectiveness of regulations. Development of some form of institutionalised channel of public participation and stakeholder input could promote procedural legitimacy in such a centralised system like that of Singapore, without

[24] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989).

necessarily affecting administrative efficiency[25]. The two jurisdictions must incorporate the principles of environmental justice in waste management. This can include necessary evaluation of community effects when locating facilities, more open points of public objection and community redress or mitigation of the people who have been impacted. Altogether, these suggestions emphasize the critical position of the legislation in harmonizing the waste treatment technology with the wider environmental, social, and governance goals, which allows transferable insights to other urbanised states facing comparable setbacks.

9. Conclusion

In this paper, we have tried to make a comparative study on solid-waste treatment methods in Japan and Singapore, with reference to incineration, recycling, and reduction of landfill in the legal and institutional system. The analysis shows that the two jurisdictions have been able to reduce the use of landfilling by maintaining an investment in incineration facilities and the creation of complementary regulatory frameworks. However, the success of these systems cannot be explained by technology only but the interaction between law, policy designing and the institutional capacity defines the environmental and governance results. The example of Japan can demonstrate how well-developed legislation, decentralism, and high levels of recycling can be organised with the help of producer responsibility schemes. Meanwhile, it also exposes the issues of the regulatory complexity, unequal municipal capacity, and excessive cost of compliance. The Singaporean strategy, in turn, puts more emphasis on the benefits of centralized planning, regulatory effectiveness, and effective enforcement in an environment where land supply is more extreme of a factor, and risks linked to long-term reliance on incineration and a slower rate of household recycling uptake is also revealed.

Comparatively within the setting of environmental law, the research highlights the idea that the waste governance should be contextual but with general legal principles that include the precaution approach, the polluter-pays approach and sustainable development. The experiences of Japan and Singapore indicate that a combination of regulation mix of incineration and strict recycling requirements, strong environmental protection and institutional responsibility are necessary to achieve effective reduction of landfills.

[25] Florence Barbara Awino and Sabine E. Apitz, "Solid Waste Management in the Context of the Waste Hierarchy and Circular Economy Frameworks", *20* Integrated Environmental Assessment and Management 9 (2024).

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