Basic Theories of Composting

Utilizing Takakura Method Composting

for Improving Waste Management

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Koji Takakura, Ph. D. (Engineering),

CONTRACT EXECUTIVE TECHNICAL ADVISOR,

Kitakyushu International Techno-cooperative Association

Senior Fellow, Institute for Global Environmental Strategies

1. Introduction

1.1 Waste issues and our society

Wastes are always generated when we engage in production activities and consume goods, regardless of the country or region. In ancient times, however, only limited matters were treated as wastes because most wastes were derived from nature and the economic structure was that based on recycling of resources. For example, during the Edo Period in Japan, even human excreta were referred to as "*Kimpi* (golden fertilizer)," and were distributed as precious fertilizing components and traded at a fee. As can be seen, most of the objects were handled as precious resources. In later years, the economy and technologies developed and many products that are easy to handle and highly effective came to be offered at low prices, which changed the judgment criteria on valuables. As a result, objects that used to be distributed as precious resources came to be handled as wastes. Development of a large-scale waste disposal system was never necessary for Japan because the amount of wastes used to be so small, and thus wastes were abandoned on roadsides and vacant lots and were left in an unsanitary condition. Such a process that leads to an environmental issue caused by the increase of wastes seems to be common all over the world.

Under the circumstances, the solution Japan chose in the year 1900 was to enact a law stipulating "wastes shall be incinerated to the extent possible," thus recommending incineration treatment. This led to weight and volume reduction and hygienic treatment of wastes by incineration treatment thereafter in Japan. In the 2000s, the amount of wastes generated still continued increasing, preventing issues such as lack of final disposal sites from being solved only by weight and volume reduction through incineration treatment. Thus, it was decided to promote the 3Rs (Reduce, Reuse and Recycle (including thermal recycling)) and formation of a recycling-type society where wastes are treated appropriately.

Especially important are the 2Rs (Reduce and Reuse) and resource circulation. The concept that "we should not generate wastes. Wastes are to be sorted and turned into resources" was being practiced by our ancestors in the past years, so it is never difficult.

The table below summarizes issues in Japan related to waste treatment and a history of countermeasures implemented.

Table 1-1: History of Waste Treatment Issues and Countermeasures in Japan

Years	Situations and issues of waste treatment	Measures for solving the issues
Late 1800s to early 1900s	Wastes were to be disposed of by the person who generated them, or private-sector disposal companies collected them, sorted valuables and sold them, and the remaining wastes were abandoned on roadsides and open land lots, and accumulated in an unsanitary condition.	The "Sewage Cleansing Act" was enacted in 1900 for promoting public hygiene. Wastes were burnt at open land lots because the law stipulated that "wastes shall be incinerated to the extent possible."
1945 to 1950s	The amount of urban wastes surged as the economy developed and the population started gathering in large cities, and the wastes were dumped into rivers and seas or piled up in fields. Wastes were also scattered on streets when they are transferred from handcarts for waste collection to automobiles.	The "Public Cleansing Act" was enacted in 1954 to stipulate the responsibilities and obligations of the national government, regional government and citizens. After the enactment of the "Emergency Measures Act for Developing Living Environment Facilities" in 1963, construction of waste incineration facilities was promoted in each municipality.
1960s to 1970s	Urban wastes continued growing in the amount even further and were diversified, due to the changes in retail systems and consumption activities accompanying the rapid economic development and the consolidation of volume-production and volume-consumption-type economic structure. Industrial wastes also increased. Pollution issues became apparent.	The "Environmental Pollution Prevention Act" was enacted in 1967. The Public Cleansing Act was amended overall to the "Waste Management and Public Cleansing Act (hereinafter referred to as the Waste Disposal Act) in 1970, in order to develop basic systems for waste treatment. The acts promoted appropriate disposal facilities development through national subsidies, and optimized final disposal sites and enhanced the treatment capacity of incineration facilities.
1980s to early 1990s	Greater consumption and further expansion of production activities caused the waste amount to surge, and more combustible wastes came to be treated by landfilling. As a result, the remaining capacity and service years of final disposal sites decreased. Large-scale illegal dumping occurred due to the lack of awareness of compliance by business entities and disposal companies. Emission of dioxins from waste incineration facilities became an issue.	Measures were attempted for steady improvement in appropriate waste treatment. The emphasis of measures shifted from treatment to suppression of discharged waste amount, in order to deal fundamentally with the issues such as increase in waste generation and lack of final disposal sites.
1990s to 2000s	The amount of wastes generated increased even further, and insufficiency of final disposal sites continues to be a problem.	Recycling was added among the purposes of the Waste Treatment Act in 1991. Since 1997, measures against industrial wastes have been tightened by revising the Waste Treatment Act from time to time. Emission gas restriction and development of advanced incineration facilities started in 1997 for reducing dioxins. The "Basic Act on Establishing a Sound Material-Cycle Society" was enacted in 2000 for promoting the 3Rs and appropriate waste disposal. Incineration and recycling are being promoted in a planned and effective manner, for reducing the amount of finally disposed wastes.
Major future attempts		
Measures are to be promoted even further for the 2Rs that are of higher priority than recycling, in order to further promote the formation of a material-cycle society. Uses are promoted for recycled resources and biomass resources as energy sources. Japan intends to contribute toward the global reduction of environmental loads.		

1.1.1 History of material-cycle society in Japan

Let us now take a brief look at the history of material-cycle society in Japan, and the future directions.

(1) Material-cycle society prior to 1900

As shown in Fig. 1-1, the cycle of artificial materials was incorporated in ecological and natural material cycles.

Japan was deficient in resources at the time, so people were always thinking about “using things carefully,” “using things repeatedly,” “repairing things that can be repaired,” and “seeking for other ways of use.” For this reason, only a very small amount of wastes was generated, and since these wastes were mostly derived from natural products, they were decomposed and returned to the ground as time went by.

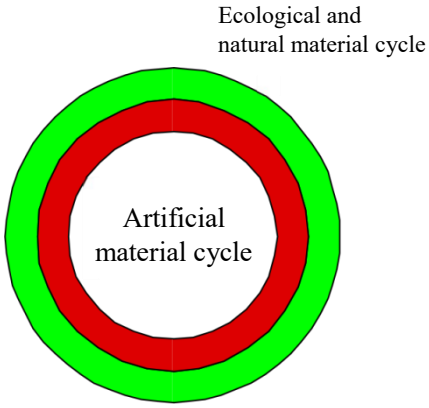

Fig. 1-1: Material-Cycle Society Prior to 1900

(2) Destruction, collapse and restoration of material-cycle society during the 1900s (20th Century)

The artificial material cycle not only protruded out of the ecological and natural material cycles and expanded, but also destroyed the cycle itself. Affected by the situation, the ecological and natural material cycles were destroyed, and investments were made and various measures were implemented for restoring the cycles. (Fig. 1-2)

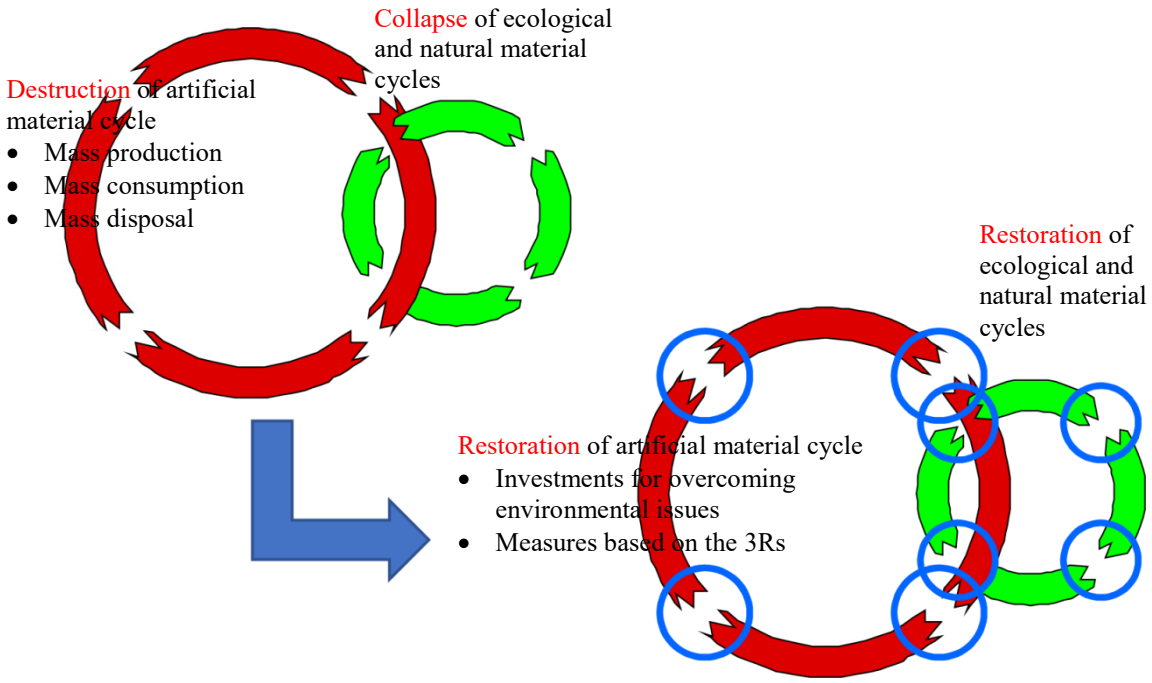

Fig. 1-2: Destruction, Collapse and Restoration of Material-Cycle Society in the 20th Century

The years during the 1900s featured a “society with priority on economic development,” where diverse new products emerged and material affluence was realized through the development of economy and technologies. The idea about things shifted from “using them to the end” to “purchasing new things,” and a belief that “consumption is a virtue” propagated. The contents of wastes also shifted, from those derived from nature to chemically synthesized (plastic) products. Hygienic treatment, weight reduction and volume reduction through incineration and landfill disposal were promoted for processing wastes. However, these measures were no longer effective to deal with wastes that continued growing in the amount, and a fundamental solution was needed.

In other words, the mass consumption society (mass production, mass consumption, mass disposal) led to the increase of environmental loads and consumption (wasting) of resources, which may be expressed as “continuously increasing wastes were accepted as is and simply disposed of.”

1.1.2 The future of material-cycle society in Japan

(1) Material-cycle society targeted in the 21st Century

As shown in Fig. 1-3, the capital scale of artificial materials may be reduced by skillfully using and spreading the potential capitals in the ecological and natural systems. If we could live side by side with the nature, materials would start cycling sustainably as we and the nature maintain balance like wheels of a car. In other words, formation of a material-cycle society will be promoted through the 3Rs (reduce, reuse and recycle) and proper disposal of wastes, drawing on past experiences and reflections. (Reduce (suppression of generation); reuse (using things repeatedly); and recycle (recycle and reuse, recycle into resources))

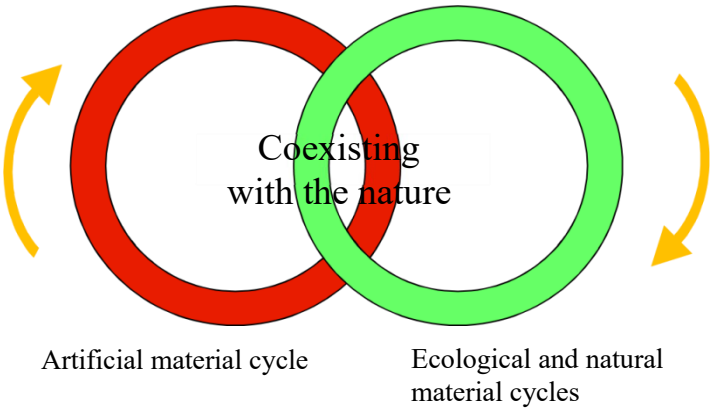

Fig. 1-3: Model Material-Cycle Society of the 21st Century

There is a point we need to keep in mind. That is, we tend to place too much emphasis on recycling among the 3Rs. We need to be aware that while iron and aluminum may be recycled repeatedly into resources, there are numerous materials like plastics that are used only once as a chair, a planter, a flexible container bag or other products and then disposed of in the process called One Way Recycle. Also, thermal recycling in which the heat from incineration is collected and used for generating power, etc., is also one way recycle as the heat would be gone when burnt. We should not use “recycling” as an excuse for consuming more products, because this way resources continue decreasing even if we threw wastes into a to-be-recycled box. Let me point out again, that the fundamentals of 3Rs is to reduce and reuse.

(2) Re-arranging the sensitivity of Edo Period to suit today's society

During the Edo Period when only a few resources and products were available, the people used things carefully over long years while repairing them. Even human excreta, which is today a target of loathing, were used as precious fertilizers for producing food materials, and was commercialized and marketed as golden fertilizers (purchased at a fee by farmers). The basics of agriculture at the time was to extract crops such as rice and vegetables from the soil, and remnant products other than the crops, weeds, their ashes, fallen leaves, excreta, wasted fishes, oil meals and other fertilizing components were mixed into farmlands. The soil, which is the capital for agriculture, was never exploited and only the interest was taken out. This way, sustainable agriculture was made possible in coexistence with the nature, at a level suited to science and technologies at the time.

In the future, our society needs to re-arrange the sensitivity of Edo Period to suit the society of our times, and aim at building a material recycling society while achieving economic development, in side by side with the nature, suppressing consumption of natural resources, reducing the environmental loads and building a carbon-free society.

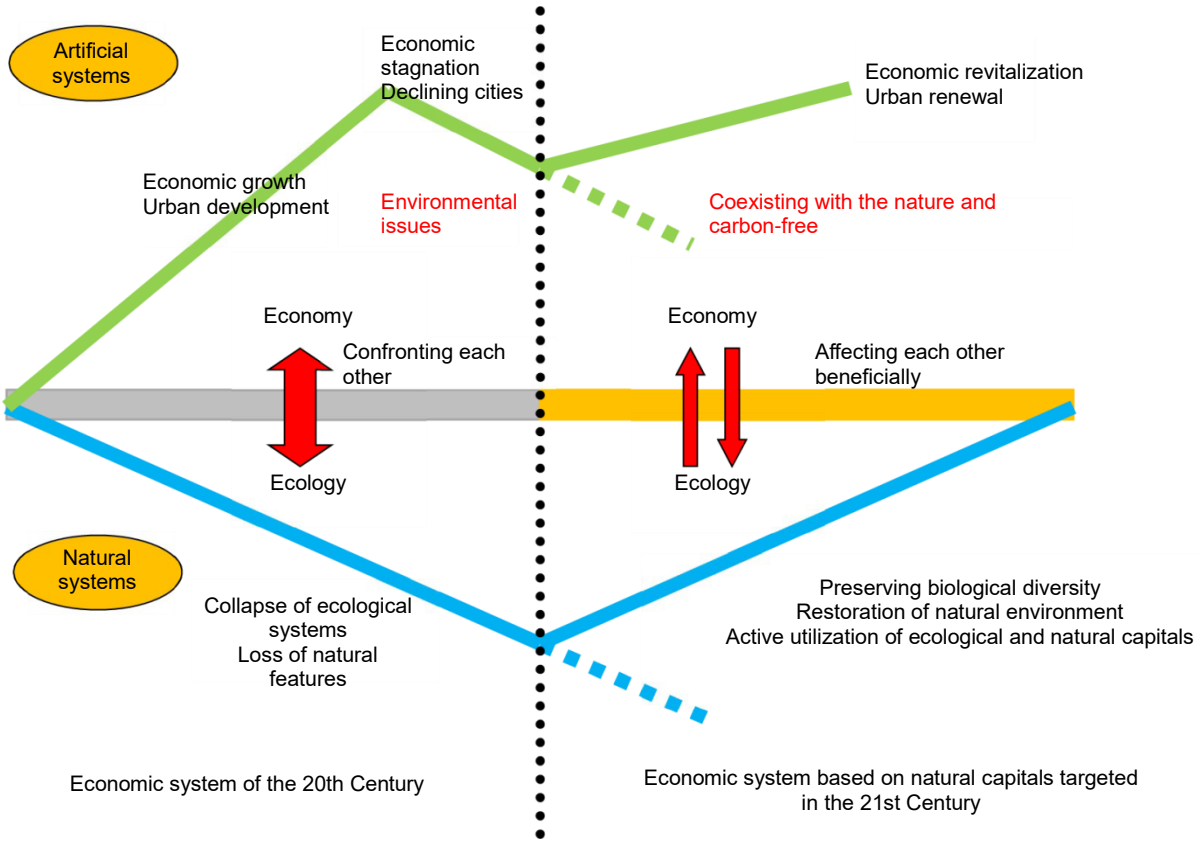

Fig. 1-4: Transition in the Economic System

1.2 Current situations of wastes and waste issues of developing countries

The amount of wastes generated in developing countries have steadily increased, due to “rapid urbanization and economic growth” and “flow of population into urban areas.” However, the issue has been dealt with only with measures that are socially, economically and technical inappropriate. This is because the waste disposal issues that Japan experienced in 100 years from 1900 to 2000 have occurred almost at the same time in developing countries, and these countries have been unable to catch up with the situation.

Photograph 1-1: Wastes piled up like a mountain

Most of the developing countries have enacted laws related to waste disposal, which stipulate that an appropriate waste disposal system suited to the country shall be constructed and operated. However, the reality has been harsh as exemplified by the failure to properly operate the collection and transport system for wastes, which resulted in wastes that remain uncollected and piling up on streets, or being dumped illegally. Since the people rely on landfill for waste disposal, construction of new disposal sites is difficult even though vacant ones get filled in a short period of time, and wastes are being carried in at a volume greater than the design volume, and piled up like a mountain. As a result, a tragic accident has taken place in some countries where the pile of wastes collapsed and numerous waste pickers were swept away, killing and injuring many of them.

Photograph 1-2: Leachate from landfill disposal sites is dark-colored because the wastes contain raw garbage

Photograph 1-3: Leachate cannot be treated by a reservoir alone, and causes water pollution

Photograph 1-4: Leachate treatment facility at a landfill disposal site

Most of the disposal sites are of an open dumping-type without any environmental measure being provided, and water seeps out from the ground when a rain falls. If a water shielding sheet was not laid, the water penetrates into the ground and no one might notice it, but the leachate is dark-colored and contains harmful organic pollutants. Therefore, hygienic disposal sites need to be built that are provided with a water shielding sheet, a leachate collecting system, drainage treatment facilities, etc.

Why does dark-colored and highly polluted leachate seeps out from landfill disposal sites? It is because 50% or more of the wastes carried in is raw garbage. Leachate seeps out from the raw garbage, and affects the environment around the disposal site adversely, by causing organic pollution of groundwater and rivers, generation of odor, outbreak of pests, etc. Furthermore, methane gas that is one of the greenhouse gases is also generated, through metabolism of anaerobic microorganisms. We should all recognize that simple reliance on landfill disposal could gravely affect not only the regional environment but also the global environment.

Landfill disposal sites are usually constructed by farmlands, in mountainous areas and coastal areas remote from the city center. Since they are among the troublesome facilities, it is difficult to secure a land lot for constructing a new one. Even if a landfill disposal site was full, trucks that are fully loaded with wastes arrive relentlessly, every day. As a result, wastes are carried into a landfill disposal sites at a volume greater than the design volume, and are piled up like a mountain.

Photograph 1-5: Waste collection and transport truck loaded with a huge amount of raw garbage

In the unsanitary environment filled with piles of wastes, odors and pests, a large number of waste pickers make a living by collecting recyclable wastes. Some of them are children, who might spend most of their lives at the landfill disposal site.

Photograph 1-6: Landfill disposal site beside a farmland

Photograph 1-7: Landfill disposal site in a mountainous area

Photograph 1-8: Waste pickers collect recyclable wastes

Photograph 1-9: Waste pickers waiting for unloading of wastes

★Situations of waste management in Japan during the 1940s

Waste management was premature at the time, and there was no waste collection system operated by municipalities. For this reason, private-sector companies performed the task on behalf of the municipalities, and many people buried household wastes in their garden or dumped them in a vacant land lot or a river. There were also waste pickers who collected recyclable wastes.

Photograph 1-10: Children also work as waste pickers

In later years, municipalities started collecting and transporting wastes regularly, and wastes were disposed of by landfill along the coast. However, wastes were piled up like a mountain at many disposal sites, and trucks still arrived daily all the time, to carry in a huge amount of wastes.

Odors, polluted water, methane gas and flies rose from landfill disposal sites, and many residents in the neighborhood sent in claims especially about flies. In response, pesticides were sprayed in the air regularly from helicopters, and extreme measures such as spraying heavy oil over a landfill disposal site and setting the site on fire was conducted, under the name “scorched-earth strategy.”

Japan also faced waste issues just as developing countries do today, but has an experience of overcoming them. The author believes the experiences need to be shared with diverse people.

1.3 Improvement in waste management and raw garbage recycling

1.3.1 Adverse effects of reliance on landfill disposal of wastes

Everyone is aware that the more affluent our lives become, the greater the amount of garbage that is thrown away. However, we tend to think "there is nothing we can do about the problem because we want to pursue economic development and comfort." Since landfill disposal sites are usually located far away, waste treatment is no longer a part of our lives and many of us feel that someone must be taking care of it. However, landfill disposal sites have become full before we notice it and much wastes are being left without anywhere to go. If we fail to provide an effective measure, wastes might fill up the towns we live in. In order to avoid such an abnormal situation, each one of us needs to address the issue of waste management improvement, being aware of the issue in each action we make in our daily lives. Diverse technological development and social system innovation are to be realized, incorporating precedent examples that suit the situations of the region, for promoting a material-cycle society.

One of the methods for waste management improvement that may be mentioned here is recycling of raw garbage. Raw garbage accounts for more than 50% of the wastes carried into landfill disposal sites. If we could recycle raw garbage, significant improvement might be realized for waste management and the environment. Recycling of raw garbage also extends the service lives of disposal sites, reduces the running costs of drainage treatment facilities by reducing organic pollutants, and suppresses odors, pests and methane gas (one of the greenhouse gases). Landfill disposal of raw garbage has adverse effects not only on the regional environment, but also on the global environment.

Raw garbage recycling plant

Fig. 1: Raw garbage – from landfill disposal to recycling

1.3.2 Composting of raw garbage and waste reduction

Typical recycling methods (into resources) for raw garbage includes “converting to a biogas (methane gas),” “converting to livestock feeds,” “composting,” “carbonization,” and “converting into a fuel (RDF).” Among these, “composting” is a method worthy of attention. This is because of the example in Surabaya, a large city with the population of more than 3 million in the Republic of Indonesia, where the amount of wastes was reduced significantly in a short period of time. This was realized through the technical cooperation by Kitakyushu City of Japan concerning composting. The whole city of Surabaya addressed the issue of waste management improvement, by optimizing the method to suit the local situations.

During the 1990s, the beautiful urban landscape of the city of Surabaya was appraised highly, both within Indonesia and abroad. In 2001, however, a pollution issue arose at the city’s only landfill disposal site, which led to a protest movement by the residents and sudden closing of the site. Consequently, a new landfill disposal site that was under construction went into service as an urgent measure. However, wastes filled the city and waste management lost its control. Vulnerability of the waste management, which used to support the city, was exposed. Then, the entire city of Surabaya attempted reduction of the amount and recycling of wastes, and the waste reduction project started in 2004 under the collaboration between Kitakyushu City and Surabaya City for inter-city environmental cooperation, with assistance by a local NGO. “Takakura Composting Method” was developed in the project, and the Surabaya City government adopted “Takakura Composting Method” with enthusiasm as the major composting method, in its administrative measure. The project promoted recycling or raw garbage at once, which used to progress only very slowly. As a result, the average amount of garbage generated per day was reduced to 1,150 tons in 2011 from 1,819 tons in 2005 (reduction by 36% from 2005). Not only that, greening was promoted in all the communities, parks and along the streets using the compost produced, at the same time reducing the waste amount. Thus, Surabaya City was renewed as a beautiful city full of greeneries.

Photograph 1-11: Surabaya City filled with garbage

Photograph 1-12: Surabaya City filled with greeneries

1.3.3 Example of waste management improvement in Surabaya City

Did the amount of wastes continued declining in Surabaya City after 2011 also? Fig. 1-3 shows the change in the amount of wastes carried into Benowo landfill disposal site in Surabaya City, also showing the situations of wastes carried in thereafter. In Surabaya City, all the wastes are being carried into Benowo landfill disposal site, and the amount carried in equals the amount of wastes generated.

The amount of wastes generated was 1,819 tons in 2005, which continued declining for six years, to 1,150 tons in 2011 (reduction by 36% from 2005). To our regret, the amount has increased again since 2013.

Fig. 1-2 Change in Amount of Wastes Carried into Benowo Landfill Disposal Site

It is generally believed that "the amount of wastes increases in line with the expansion of economic scale," and the similar trend might be found with Surabaya City also. But here, the economic growth has not been considered. Taking into consideration the economic growth also, Table 1-1 shows the amount of wastes landfilled per unit gross regional product (GRP). From Table 1-1, the landfilled amount (generated amount of waste) per unit GRP may be evaluated as showing a declining trend.

Table 1-1: Economic growth and amount of wastes generated in Surabaya City

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Landfilled amount (ton/day)	1,819	1,641	1,480	1,259	1,229	1,242	1,150	1,149	1,395	1,400
Population (thousand persons)	2,740	2,784	2,830	2,903	2,938	2,930	3,024	3,118	3,200	3,121
GRP (billion Rp)	-	125,360	142,986	162,833	178,559	205,034	235,034	264,335	302,756	351,509
Landfilled amount per unit GRP (kg/ billion Rp-day)	-	13.09	10.35	7.73	6.88	6.05	4.89	4.35	4.61	3.98
Reduction rate of landfilled amount per unit GRP (based on 2006)	-	-	20.93	40.94	47.44	53.78	62.64	66.77	64.78	69.59

In order to further evaluate the level of suppression of wastes generated in Surabaya City, a graph is presented that compares Surabaya City with other cities in Asia and Latin America having a similar economic scale (population of 2 million or more and GRP per person of 20,000 US dollars or less, in 2008 or 2009). The graph also shows that "the amount of wastes increases in line with the expansion of economic scale." Here, the changes shown for Surabaya City are those from 2006 to 2014.

When Surabaya City started attempting reduction of the waste amount around 2006 and 2007, the reduction rate was about the same with other cities of similar GRP per person. The reduction rate remained low between 2008 and 2010, without showing any significant difference. The difference with other cities started showing clearly in 2011, and the difference stabilized thereafter, and the waste amount has remained less than half that of other cities since 2013.

In other words, the amount of wastes has decreased slightly in Surabaya City along with the economic growth, instead of increasing, indicating the difference with other cities clearly.

Attempts relating to composting contributed greatly toward the success in improving waste management in Surabaya City.

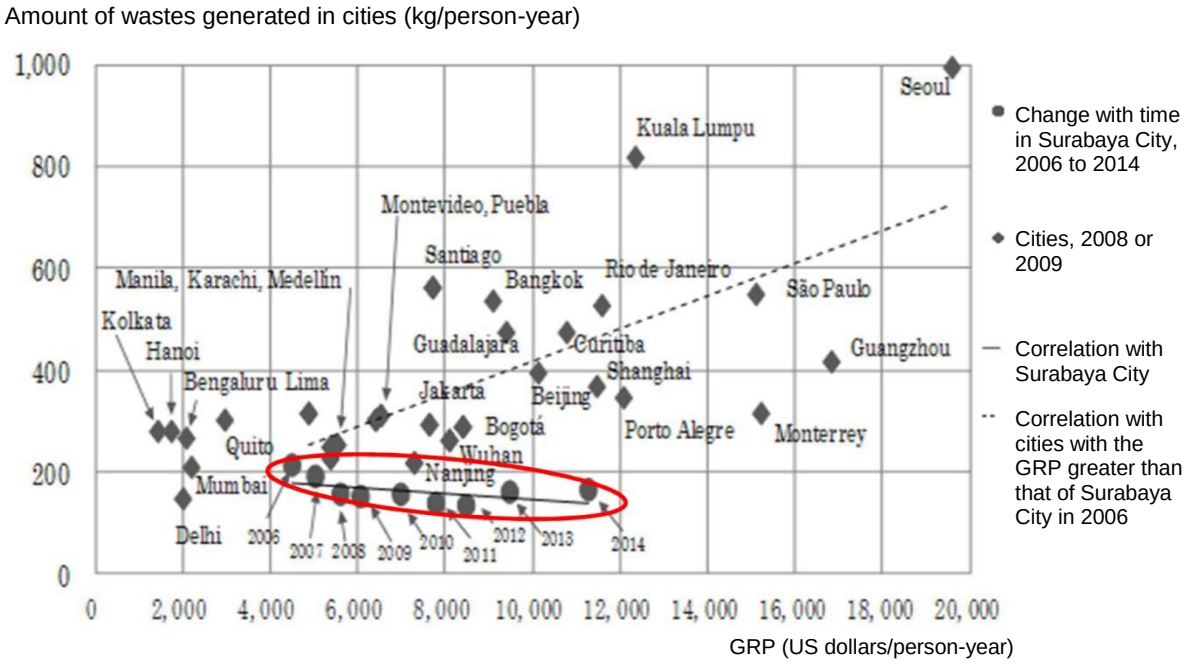

Fig. 1-3: GRP and amount of wastes generated per person in cities, and change with time in Surabaya City

1.4 Raw garbage composting and the SDGs

1.4.1 What are the SDGs?

SDGs stands for Sustainable Development Goals. The SDGs are recognized to represent diverse problems of our societies to be addressed by all the people of the world, and target at both developed and developing countries and regions, with a pledge to leave no one behind on the Earth. The common goal for the world is to realize a sustainable society where the three aspects, namely the economy, society and environment, are well-balanced. The SDGs comprise 17 goals and 169 targets, to be attained by the year 2030.

Each of the 17 goals comes with a logo mark that conveys the idea at a glance. In the table below, 12 goals out of the 17 goals that relate at least to the environment are marked with a double circle (◎). Furthermore, the author has added a star mark (☆) to each of the seven goals that the author believes as relating to composting, indicating the target and its outline also.

Logo mark	The 17 SDGs (indicating the target and summary for those relating to the environment)
	End poverty in all its forms everywhere
 ◎・☆	End hunger, achieve food security and improved nutrition and promote sustainable agriculture Target: To secure sustainable food production systems and implement resilient agricultural practices. Outline: Soil improvement is promoted by using compost, contributing toward the securing of sustainable food production systems and practice of resilient agriculture.
 ◎・☆	Ensure healthy lives and promote well-being for all at all ages Target: To reduce the number of cases of deaths and sicknesses caused by environmental pollution. Outline: Easily decayed organic substances in raw garbage, etc. are composted, thereby contributing toward the improvement of hygiene in living environments and suppressing organic pollutant leachate from landfill disposal sites. Composting, if conducted properly, does not generate wastewater.
 ◎	◎ Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

	Achieve gender equality and empower all women and girls
 ◎・☆	Ensure availability and sustainable management of water and sanitation for all Target: To improve water quality by diverse means. Outline: Illegal dumping is reduced and leaching of organic pollutants from landfill disposal sites is suppressed by composting organic wastes, and appropriate composting that prevents generation of drainage helps improve the water quality. Target: To support and promote participation by the people of regional communities in attempts to improve the water quality and sanitation. Outline: Raw garbage composting has been conducted by each regional community, and participation and collaboration by the residents of the community promotes composting.
 ◎	Ensure access to affordable, reliable, sustainable and modern energy for all
 ◎	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
 ◎	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation Target: To enhance sustainability by introducing and expanding technologies and industrial processes that consider for the enhancement of resource-use efficiency, cleanliness and environment. Outline: The composting technology that may be optimized easily by each community is an environmentally considerate technology and enhances the sustainability of organic waste recycling in the region.
	Reduce inequality within and among countries

 ◎・☆	Make cities and human settlements inclusive, safe, resilient and sustainable Target: To manage the atmosphere and wastes, for reducing adverse effects of urbanization to the environment. Outline: Composting assumes that wastes are sorted, and therefore promotes waste management. Target: To offer accesses to green spaces and public spaces. Outline: Composting helps promote greening of parks and along streets in cities. Target: To support mutually beneficial ties among urban areas, urban fringes and rural areas. Outline: Production of high-quality compost is possible from sorted raw garbage of cities, and helps make up for the deficiency of composts in rural areas.
 ◎・☆	Ensure sustainable consumption and production patterns Target: To realize sustainable management and efficient use of natural resources. Outline: Organic wastes are recycled by composting, which helps especially the management of phosphorous resources that are exhaustible. Target: To properly manage chemical substances and wastes for reducing their emissions into the atmosphere, water and soil. Outline: Composting assumes that wastes are sorted, and promotes waste management. Target: To reduce the amount of wastes generated.
 ◎	Take urgent action to combat climate change and its impacts
 ◎・☆	Conserve and sustainably use the oceans, seas and marine resources for sustainable development Target: To prevent and reduce marine pollution. Outline: Suppression of organic pollutant leachate from landfill disposal sites and appropriate composting that eliminates drainage help prevent pollution caused by activities on land.
 ◎	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reserve land degradation and halt biodiversity loss

	Promote peaceful and inclusive societies for development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

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