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ORIGINAL ARTICLE

Economic growth and trends of municipal waste treatment options in Asian countries

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Abstract Many developing Asian countries are rapidly expanding their economies. Economic growth affects waste management policy development. Statistical analyses applied to Japan, Korea, and China indicate a positive correlation between gross domestic product (GDP) per capita and incineration rate. However, they show a negative correlation between GDP per capita and composting rate in Japan and China, and a positive correlation in Korea. Historical prefectural/provincial data indicate that in Japan and in China, although the incineration rate in a specific year differs due to regional conditions, the rate has increased in parallel with economic growth. An analytic hierarchy process was conducted with experts and government officials from Southeast and East Asian countries. The results statistically confirm the trend correlated with economic growth, which was suggested by previous studies and mentioned by experts based on their experience. For instance, social acceptance was important in upper middle-income countries (USD 4,036–12,475). These results support the possibility that economic growth affects the selection of waste treatment options.

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Introduction

The amount of waste generated in Asia is increasing due to rapid economic growth. If the amount of waste in the future is estimated based on the assumption that it increases at the current rate, it will increase from 400 million tons in 2006 to one billion tons by 2030 [16]. Countries in Asia are now facing challenges and difficulties managing waste. Not only does the increasing amount cause difficulties, but so too do the rapidly changing compositions and fractions of waste (e.g., volume of packaging waste and e-waste). In response, Asian countries are now trying to expand their waste treatment and disposal capacities. National and local governmental officers in Asia also face difficulty selecting appropriate treatment options. The increase of waste generated is much more rapid than the pace of social infrastructure development and public awareness of the environment.

How and to what extent does economic growth affect waste management? Regarding waste generation, studies have been conducted to examine the environmental Kuznets curve for waste generation in Asian countries, e.g., Khajuria et al. [9] for India and Kaneko [8], Song et al. [20] for China. [1] These studies reveal that economic growth has

[1] The environmental Kuznets curve is a hypothesized relationship between various indicators of environmental degradation and income per capita. At the early stages of economic growth, degradation and pollution increase, but beyond some level of income per capita (which will vary for different indicators), the trend reverses so that at high-income levels economic growth leads to environmental improvements [21].

increased waste generation in Asia. However, the authors could not find any study other than Bertolini [1] that assessed economic growth and changes in waste treatment options. Bertolini [1] observed positive relationships between gross national income (GNI) per capita and incineration rate among countries at the different economic levels in 2000. Although Bertolini's study was based on rough estimations and a cross-sectional (non-time-series) examination, it suggests that in countries with a high GNI such as Switzerland, Denmark, and Japan, the incineration rate is high; on the other hand, in countries with a GNI of less than USD 20,000 or 10,000, the incineration rate is less than 10 %. In addition, from the experience of waste treatment in Japan, incineration becomes popular when GDP per capita reaches about USD 3,000 or 4,000 [22].

Many factors affect the selection of waste treatment options, including both economic and noneconomic factors, e.g., regulatory, cultural, technological, and perceptional aspects. For example, if the calorific value of waste is very low because of the food culture, incentives for introducing incineration decrease. If there is little space for disposal sites, incineration becomes more attractive. At a micro level, various economic and noneconomic factors have been taken into account by practitioners. However, in many cases, practitioners consider only current economic and noneconomic factors and do not consider long-term changes of such factors. The future important requirements for waste management are ignored by such decision making, especially in cases where economic conditions at a macro level (GDP per capita, etc.) are changing rapidly. A treatment option selected could become obsolete within a decade, and this point could be disregarded by practitioners in reality. Practitioners should consider waste treatment options with a long-term vision. From this perspective, insights about selecting waste treatment options in the past would be useful. This is because the economic growth of target developing countries is very rapid and those countries come to be able to afford to introduce the various expensive waste treatment options introduced in developed countries in Asia, such as Japan, Republic of Korea (hereafter Korea), Singapore, etc. This study, therefore, aimed to test whether there is a relationship between economic growth and waste treatment options, and to analyze the extent to which economic growth has influenced the selection of waste treatment options in selected Asian countries.

In most of the target developing countries in this study, landfills are a dominant option and promoting appropriate landfill use is an urgent issue [4]. However, this study focused on intermediate treatment, which refers to treatment after waste is collected and before waste is transferred to a final disposal site. This is because the economic growth of target developing countries was very rapid, and these countries did come to consider various waste treatment options other than landfills. Also, statistics on waste disposal in target countries are not established sufficiently for a statistical analysis and are not clearly classified in accordance with waste disposal methods. As shown in Table 1, little historical data are available on disposal in Malaysia, Thailand, Indonesia, the Philippines, Vietnam, and Laos. Reliable waste treatment statistics for certain years are also not provided in the Philippines, Vietnam, and

Table 1 Waste generation and management in target countries

	Waste generated/collected		Waste treated/disposed			
	Generated (kg/cap/day)	Collected (kg/cap/day)	Incinerated (%)	Open burned (%)	Composted (%)	(Direct) landfilled (%)
Singapore	0.87 (2011)[a]	–	41[ac]	–	–	2[ac]
Japan	–	0.98 (2011)[a]	79.3[a]	–	0.4[a]	1.4[a]
Korea (ROK)	1.04 (2007)[a]	–	18.6[a]	–	26.5[a]	
Malaysia	0.64 (2004)	0.49 (2004)	Negligible	–	Negligible	76
Thailand	0.65 (2009)	–	4	–	7	37[d]
China	–	0.32 (2009)[a]	13[a]	–	1[a]	57[a]
Indonesia	1.01 (2010)[a]	0.13 (2010)	0	5	7	–
Philippines	0.32 (2010)[a]	–	–	–	–	–
Vietnam	0.72 (2009)	-[b]	–	–	–	–
Laos	0.59 (2005)	–	–	–	–	–

[a] Historical data are provided by governments or related institutions

[b] Rate of municipal solid waste collection increases from 71 % in 2000 to 80 % in 2009, this ratio is very low in rural areas with 20–30 % (2009)

[c] Including industrial waste

[d] Rate of sanitary landfilled waste

Laos. This study, therefore, focused on treatment, in particular on incineration and composting because among the various waste treatment options, composting and incineration are major options in Asian countries [16, 18], taking analytical tractability into account. Rapid economic growth is forcing target developing countries to consider these options in the very near future. This study has implications for these countries and recommends that they consider long-term policy development. An analysis of landfilling is left for future studies.

Materials and methods

Two approaches of the study

Subject countries of the study were Southeast and East Asian countries including China, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. As shown in Fig. 1, the study adopted two approaches. First, the study examined whether and to what extent the incineration rate (i.e., Bertolini's statement [1]) and the composting rate changed with an increase of GDP per capita in the selected countries. For example, incineration is costly to implement, operate, and maintain, so it can be introduced only where people can afford such high costs. Second, the study examined to what extent other environmental and social factors, as well as economic factors, affected the selection of waste treatment in target countries. The study conducted contains an statistical analysis to test the first point and an analytic hierarchy process (AHP) analysis to examine the second point. Furthermore, interviews were conducted to corroborate circumstantial evidence for the results of statistical and AHP analyses.

Approach 1: statistical analysis

The first approach is an statistical analysis using historical data. The statistical analysis examined the idea based on experience such as that of Bertolini [1]. Ideally, an analysis should be done for all target countries of the study; however, most of the countries did not have sufficient historical data on waste treatment. Considering the difficulties involved in conducting cross-countries analyses and data constraints, it was decided to analyze historical data at both national and regional levels for three selected countries: Japan, Korea, and China.

In this study, the incineration rate was defined as incinerated municipal waste from households divided by collected municipal waste and composting rate as composted municipal waste divided by collected municipal waste. In an analysis of historical data at a national level, data on GDP per capita, incineration rate, and composting rate from 1970 to 2004 were used for Japan. Data from 1993 to 2007 were used for Korea and data from 2003 to 2009 were used for China.

The crossregional analysis used data on incineration rate, composting rate, and income per capita/GRP per capita, as well as agricultural production per capita and population density for all 47 prefectures of Japan and all 31 provinces and special municipalities/cities of China (In the case of China, landfill usage rate and population density in city area were also considered). Data for 2010 were used for Japan and data for 2009 were used for China. We could not acquire data for Korea at a regional level.

In the analysis of historical data at a prefecture/province level, data on incineration rate, composting rate, and income per capita/GRP per capita provided by all 47 prefectures of Japan and all 31 provinces and special municipalities/cities of China were used for the analysis.

Approach 2: AHP analysis

Second, an AHP analysis was applied to determine how experts judge different criteria for the selection of waste treatment options. AHP is a measurement based on pairwise comparisons and relies on the judgment of experts to derive priority scales [19]. Several studies have used AHP

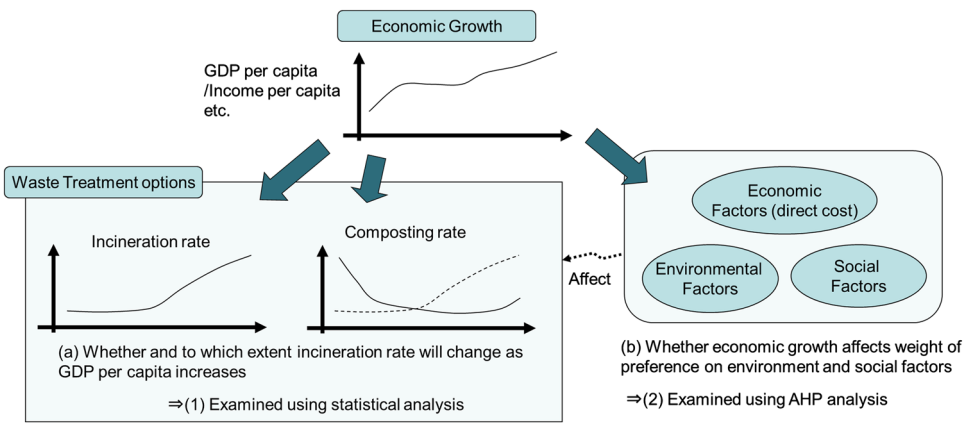

Fig. 1 Structure of study

for waste management and some have used AHP for assessing waste treatment options For example, Contreras et al. [2] used AHP to assess the introduction of refuse derived fuel and biogases in the city of Boston. Koizumi et al. [11] used AHP to evaluate policy options for a global recycling model. Fujita and Tamura [5] used it to select land for establishing an incineration plant for municipal waste.

Items evaluated in these studies varied, and detailed items selected differed even within the same category of evaluation items. Contreras et al. [2] used greenhouse gas (GHG) emissions as an environmental factor, operating cost as an economic factor, and health risk as a social factor. Koizumi et al. [11] used energy use and resource utilization/resource consumption. Fujita and Tamura [5] used air, noise, odor, negative impact on landscape, obstacles to electronics, construction cost, cost of real estate, environmental impact, impact on cultural properties, ease of transportation, and ease of transfer.

Not only did the items selected in the previous studies differ, but the weighting factor of each item also differed. Even in a single study (e.g., Contreras et al. [2]), different groups of stakeholders, such as citizens, local governments, and nongovernmental organizations, have different patterns of weighting factors.

This study assumed that the weighting factors of preferences of experts change with economic growth. To examine the assumption, a questionnaire survey was conducted covering local and national government officials and researchers. Respondents selected were 17 local and national government staff and 14 researchers from Southeast and East Asian countries such as China, Indonesia, Japan, Korea, Laos, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. In Asian countries, according to interviews with governmental officers from these countries, as shown in Table 2, local and national government staff and researchers mainly decide waste management policies. Many of them recently participated in international conferences related to waste management and technologies: Asia 3R Promotion Forum, Society of Solid Waste Management Experts in Asia and Pacific Islands (SWAPI), and World Congress of International Solid Waste Association 2011. Therefore, for this study, questionnaires were distributed to participants of these conferences. The study was intended to collect views from those were in responsible positions and had extensive knowledge and deep insights about waste management in their own countries.[2]

Table 2 Respondent for AHP analysis

	Government staff	Researcher
Singapore	5	
Japan	1	
Korea (ROK)	2	1
Malaysia	4	4
Thailand	1	2
China		1
Indonesia	2	1
Philippines		3
Vietnam	1	2
Laos	1	
Total	17	14

For this study, three factors, the so-called triple bottom lines, were used for categories of factors and then factors were selected as shown in Table 3 in consideration of those used in existing studies [2, 5–7, 10, 11, 13, 14]. Cost of waste management (initial cost, operation, and management cost) and benefits of waste management (revenue from energy recovery, revenue from composting) were selected as economic factors. Global and regional environmental impacts (GHG emissions, transboundary movement of hazardous wastes), local environmental impacts (air pollution, water pollution, soil pollution), and resource utilization (amount of reduction of waste disposal, amount of reused/recycled materials) were selected as environmental factors. Social acceptance (acceptance by local residents, political acceptance) and social welfare (creating jobs, promoting decent work) were selected as social factors.

To identify whether the influences of the three factors vary according to the degree of economic growth, respondents were categorized into country groups according to the World Bank classification. The World Bank classifies countries into four groups: low income USD 1,025 or less; lower middle income, USD 1,026–4,035; upper middle income (UMIC), USD 4,036–12,475; and, high income, USD 12,476 or more. In this study, no respondent belongs to the low income group; therefore, the respondents are categorized into three groups: lower middle income countries (LMIC), UMIC, and high income (HIC). In this study, Indonesia, Laos, the Philippines, and Vietnam are categorized in LMIC; China, Malaysia, and Thailand, are categorized in UMIC; and, Japan, Korea, and Singapore are categorized in HIC.

[2] Otherwise, respondent's ignorance or misunderstanding of the correct meanings of factors would mislead the AHP survey on the views of various stakeholders in a specific country or community because they would be informative for participatory regional planning, but this was outside the scope of the study.

Table 3 Economic, environmental, and social factors used for AHP analysis

Economic factors	
Cost of waste management	Cost required for waste management
Initial cost	Reduction of initial investment on waste management, e.g., land cost, construction cost for building, equipment cost
Operation and management cost	Reduction of operation and management costs for waste management, e.g., labor cost, expenses for consumable supplies and materials
Benefits of waste management	Benefits of waste management
Revenue from energy recovery	Revenue from selling electricity/heat from waste incineration
Revenue from composting	Revenue from selling compost to farmers
Environmental factors	
Global and regional environmental impacts	Negative impact on global and regional environments
Greenhouse gases (GHG) emissions	Amount of greenhouse gases generated (e.g., CO2, methane, etc.)
Transboundary movement of hazardous wastes	Amounts of exports/imports of hazardous wastes restricted by Basel Conventions
Local environmental impacts	Negative impact on local environment in the region (this environmental impact also includes health impact on people in the region)
Air pollution	Amount of air pollutants generated such as dust, aldehyde, and formaldehyde from recycling, and NO_x/SO_x from incineration.
Water pollution	Amount of water pollutants generated by leaching from disposal sites, etc.
Soil pollution	The amount of soil pollutants generated by leaching from disposal sites, etc.
Resource utilization	Increased resource efficiency
Amount of reduction of waste disposal	Amount of waste reduced by preventing generation, using waste materials, etc.
Amount of reused/recycled materials	Amount of used material reduced by separating waste flows and recycled materials made by recycling companies, etc.
Social factors	
Social acceptance	Whether waste policy, procedure, and technology, are socially accepted
Acceptance by local residents	Degree of support/opposition from local presidents
Political acceptance	Degree of political acceptance of waste policy, procedures, and technologies, e.g., collaborationamong ministries on policy options
Social welfare	Social benefits of waste management
Creating jobs	Number of new jobs created relating to waste management. Jobs in informal sector arealso included in this category
Promoting decent work	Progress of decent worka for workers involved in waste management (collection, separation, treatment etc.)

[a] Decent work involves opportunities for work that is productive and delivers a fair income, security in the workplace and social protection for families, better prospects for personal development and social integration, freedom for people to express their concerns, organize and participate in the decisions that affect their lives and equality of opportunity and treatment for all women and men (ILO website http://www.ilo.org/global/topics/decent-work/lang–en/index.htm)

Results and discussion

Results of approach 1: statistical analysis for Japan, Korea, and China

Analysis of historical data at a national level

As shown in Fig. 2, positive correlations between incineration rate and GDP per capita were found in historical data for Japan, Korea, and China. In contrast, negative correlations were found between composting rate and GDP per capita in historical data for Japan and China; however, a positive correlation was found in Korea. In Japan, the incineration rate increased from 1970 to 2004. The composting rate in Japan decreased rapidly in 1970 with rapid economic growth and remained at a lower rate after 1980. In Korea, the incineration rate increased from 1993 to 2007; and the composting rate also increased from 2000 to 2007. In China, the incineration rate increased, while the composting rate decreased from 2003 to 2009.

Crossregional analysis (prefectural/provincial data in one specific year)

The study examined whether the same trend at a country level whereby a high economic level results in a high

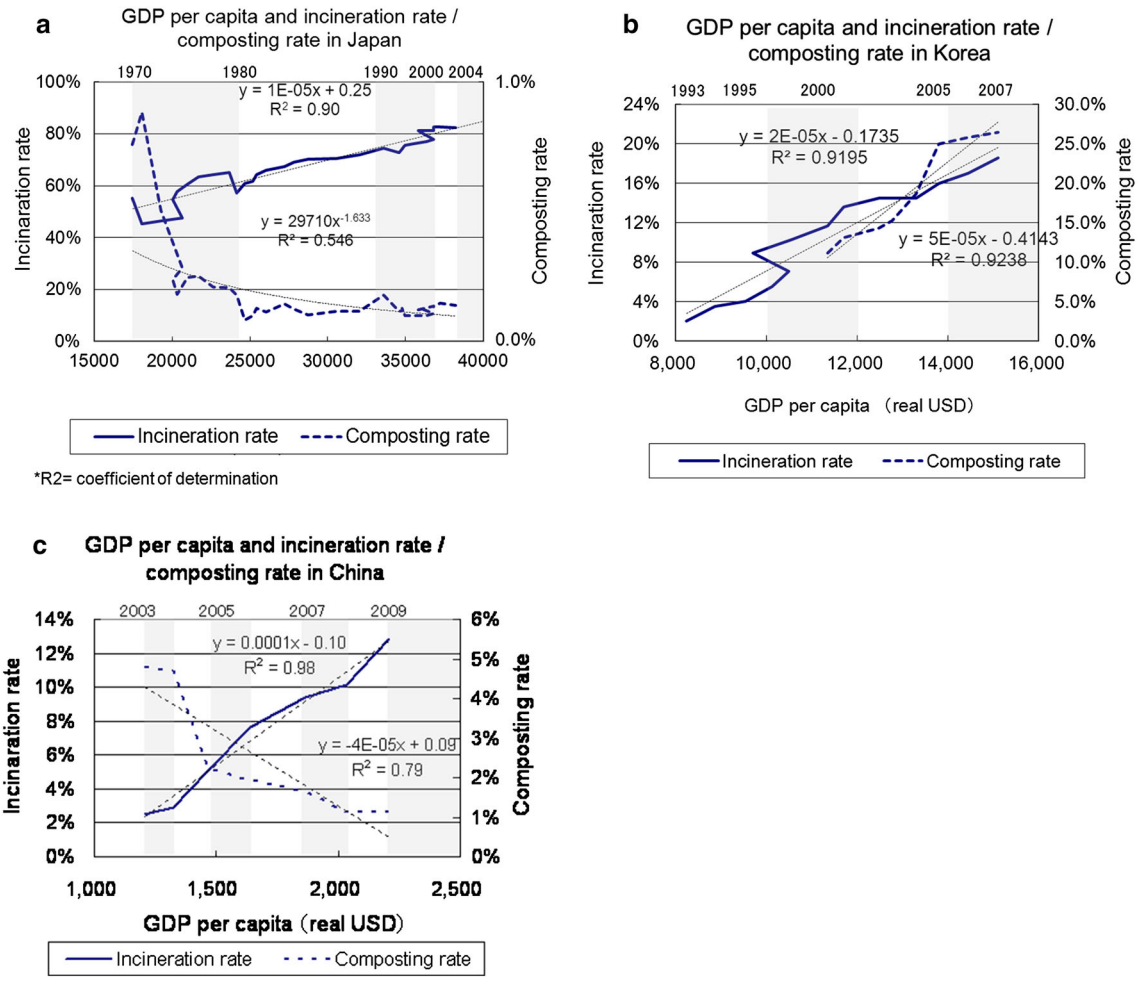

Fig. 2 GDP per capita and waste management options in Japan, Korea, and China. *Left figure* (**a**), *center figure* (**b**), and *right figure* (**c**)

Table 4 Matrix of correlation coefficients between social and economic parameters and waste management of prefectures in Japan in 2010

	Incineration rate	Composting rate	Income per capita	Agricultural production per capita (Japanese Yen)	Population density (persons per m^2)
Incineration rate	1.00*				
Composting Rate	−0.28	1.00*			
Income per capita	0.01	−0.30*	1.00*		
Agricultural production per capita	−0.20	0.36*	−0.60*	1.00*	
Population density	0.23	−0.17	0.63*	−0.55*	1.00*

* $P < 0.5$

incineration rate and a low composting rate could be observed when looking at data by region. The study analyzed data at a regional level such as prefectures in Japan and cities in China.

Table 4 shows the results of a crossregional analysis by prefecture in Japan for 2010. Table 4 shows correlation coefficients between income per capita, agricultural production per capita, population density, incineration rate, and composting rate. The results show that the correlation coefficient between income per capita and incineration rate was not significant at the 5 % level. This suggests that the incineration rate at a prefectural level does not increase with income per capita when compared by prefecture. This is not consistent with the correlation at a country level.

Table 5 Matrix of correlation coefficients between social and economic parameters and waste management of provinces in China in 2009

	Sanitary landfill rate	Composting rate	Incineration rate	GRP per capita	Agricultural production per capita (Chinese yuan)	Population density (persons per m^2)	Population density in city area(persons/km^2)
Sanitary landfill rate	1.00*						
Composting rate	0.20	1.00*					
Incineration rate	0.05	−0.22	1.00*				
GRP per capita	0.11	0.26	0.51*	1.00*			
Agricultural production per capita (Chinese yuan)	−0.10	0.28	−0.23	−0.38*	1.00*		
Population density (persons per m^2)	0.18	0.10	0.39*	0.84*	−0.43*	1.00*	
Population density in city area(persons/km^2)	0.10	−0.09	−0.23	−0.28	0.16	−0.06	1.00*

* $P < 0.5$

On the other hand, the result indicated a negative correlation between income per capita and composting rate. This means the composting rate decreased as income per capita increased in different prefectures. This is in line with the result of the country level analysis. There is also a significant positive correlation between agricultural production per capita and composting rate. Waste is composted if there is demand from farmers. The result then is very reasonable.

The study contained a similar crossregional analysis for China. Table 5 shows the correlation coefficients between GRP per capita, agricultural production per capita, population density, landfill use rate, incineration rate, and composting rate.

The results show that the correlation coefficient between GRP per capita and incineration rate was significant at the 5 % level. The correlation coefficient between population density and incineration rate was also significant at the 5 % level. In contrast, no social or economic factors selected for the study correlated sanitary landfilling and composting rate. At a national level, the composting rate decreased with an increase in GRP per capita; however, this was not found in a crossprovincial analysis in China.

The results both from Japan and China indicate that, when looked at in a certain year, not all trends revealed in a country level analysis apply in a crossregional comparison of Japanese prefectures and Chinese provinces. Positive correlations between economic level and incineration rate are found among Chinese provinces, but not among Japanese prefectures. Negative correlations between economic level and composting rate are found among Japanese prefectures, but not among Chinese provinces.

Analysis of historical data (prefectural/provincial time-series data)

Prefectural/provincial data are available for a historical analysis of regions both in China and Japan. Figure 3 presents correlation coefficients between incineration rate/composting rate and income per capita/GRP per capita for historical data of each prefecture/province.

In most provinces of China, the composting rate decreased and the incineration rate increased from 2003 to

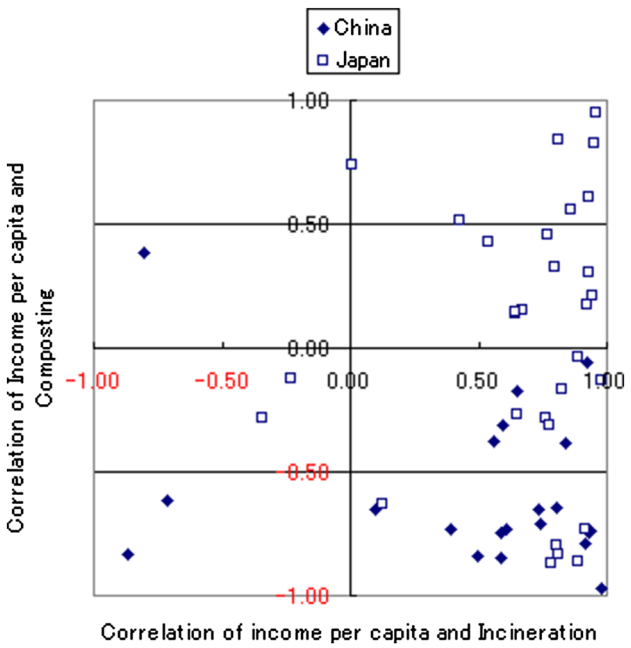

Fig. 3 Correlation coefficient, *r*, between GRP per capita and composting/incineration for historical data of each prefecture/province in China

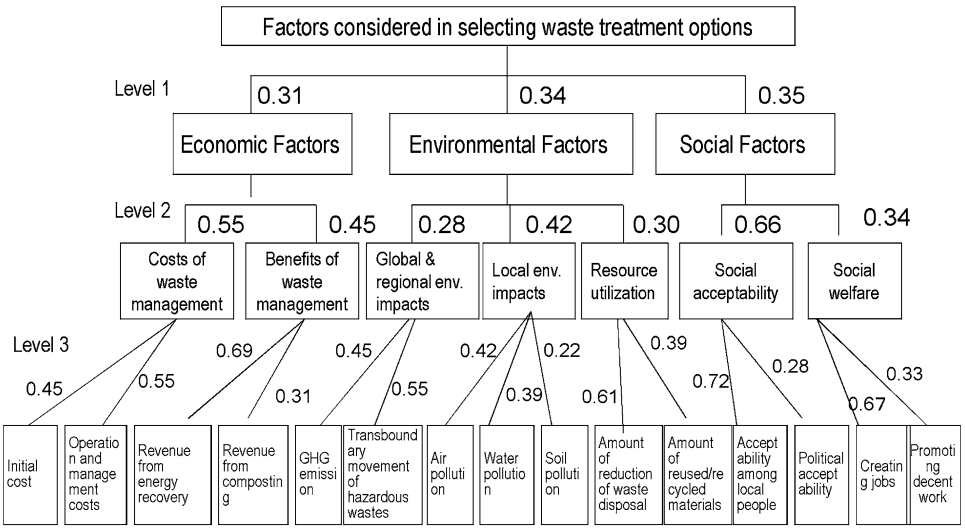

Fig. 4 Results of weight of preference calculated from AHP analysis

2009, as shown by the black dots in Fig. 3. In particular, the incineration rate increased rapidly in coastal provinces. In most prefectures of Japan, the composting rate remained low from 1982 to 1997 (the number of prefectures where the change in composting rate was between −0.001 and 0.001 was 32 of 47 prefectures).

The composting rate decreased in several prefectures (e.g., Nagasaki, Nagano, and Aichi), while it increased in several prefectures (Iwate, Yamagata, and Kanagawa). In most prefectures, the incineration rate increased from 1982 to 1997 (the ratio of prefectures where incineration rate increased to those where it decreased was 43:4). In particular, prefectures where the incineration rate was low in 1982, increased rapidly (e.g., Hokkaido, Ishikawa, and Kagoshima).

The results of the crossregional analysis indicate that the incineration rate in a certain year differed by regional conditions. However, historical data (prefecture/province level data) indicate that although incineration rates in the year were affected by regional conditions, incineration rates increased in line with economic growth in most cases. In China, the composting rate increased, although the composting rate in the first year in specific terms differed by regional conditions.

Results of approach 2: AHP analysis

The weighting factors of respondents were calculated from the responses to questionnaires.[3] Figure 4 shows the average weighting factors for the three aspects. At the top level, they were almost equal: economic factors were 0.31, environmental factors were 0.34, and social factors were 0.35. The weighting factors were also similar among LMIC (USD 1,026–4,035), UMIC (USD 4,036–12,475), and HIC (USD 12,476>). The weighting factors of economic factors, environmental factors, and social factors were 0.29, 0.36, and 0.35 for LMIC; 0.34, 0.31, and 0.36 for UMIC; and, 0.30, 0.36, and 0.34 for HIC. At the second level, the weighting factor of social acceptability was higher than that of work. At the third level, that of revenue from energy recovery was higher than that of revenue from composting, which reflected the current trend of experts and government officials having a strong interest in waste-to-energy technologies.[4] The weighting factor of acceptance by local residents was higher than that of political acceptance.

The results of average weighting factors at the second level for the three income categories are shown in Fig. 5. The average weighting factor of benefits of waste management increases with economic growth. This is reasonable because, according to the increase in awareness in line with economic growth, people regard recycling to be more important and the benefits of recycling come to be regarded as more valuable. The weighting factor of global and regional environmental impacts also increased with economic growth because the awareness of citizens of environmental issues increases with income. The weighting factor of social acceptance increased from 0.60 in LMIC to 0.81 for UMIC and decreased to 0.51 for HIC. Environmental problems are most serious in rapidly industrializing countries, such as those categorized as UMIC; and, people in those countries also become aware of pollution and often criticize their governments. Social acceptance is, therefore, very important in such countries. Experts and government officials mentioned these points as well, based on their experiences.

[3] The weighting factors indicate how much the respondent regards one alternative to be more important than other alternatives.

[4] Revenue depends on waste fractions. This question asked respondents for their general impression of these two options based on the assumption that both are applicable under the same conditions.

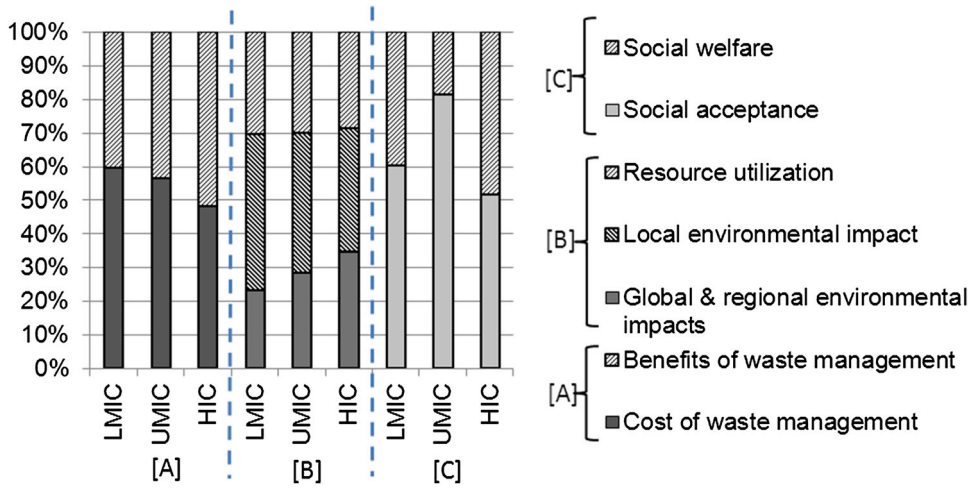

Fig. 5 Average weighting factors at the second level of Fig. 4 for three income categories

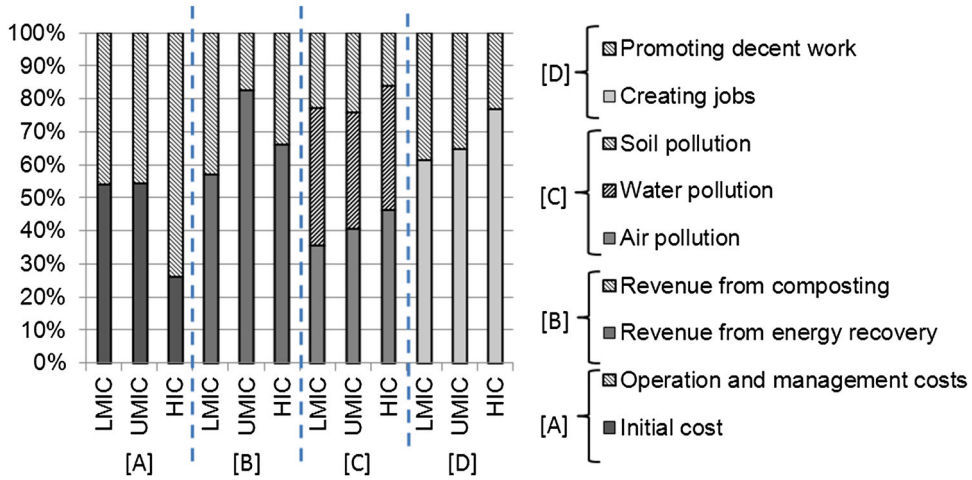

Fig. 6 Average weighting factors at the third level of Fig. 4 for three income categories

The results for the average weighting factor at the third level are shown in Fig. 6. The weighting factor on initial cost decreased from 0.54 in UMIC to 0.26 in HIC. The cost of equipment is the same, but wages for human resources needed for operation and management are high for HIC; therefore, various forms of automation are introduced into waste management facilities in HIC. This also supports the comments of experts based on their experience. Revenues from energy recovery increased from 0.57 in LMIC to 0.82 in UMIC and decreased to 0.66 in HIC. Weighting factors on air pollution and creating jobs increased with economic growth.

The limited number of respondents made it difficult to demonstrate statistical significance. Most assumptions that there were significant differences among groups were rejected. Only the difference between average weighting factors of revenue from composting/revenue from energy recovery between UMIC and LMIC was considered to be significant at 5 %. However, when respondents are divided into two groups, statistical significance could be found between groups. The result of the t test show that the difference in average weighting factors of social acceptability between HIC and LIC and MIC was significant at 5 % (P value = 0.006). Regarding initial cost, the average weighting factor also differed between HIC and UMIC and LMIC with a statistical significance of 5 % (P value = 0.034). The difference between the average weighting factor of revenues from energy recovery for HIC and LMIC and UMIC was significant at 5 % (P value = 0.009). Therefore, in conclusion, social acceptance, initial cost, and revenues from energy recovery affected preferences for waste treatment options and were related to economic growth for the three income categories in the Southeast and East Asian countries (China, Indonesia, Japan, Korea, Laos, Malaysia, the Philippines, Singapore, Thailand, and Vietnam).

Discussion

The results of the first approach (time-series analysis) indicate that economic growth is positively collated with

the introduction of incineration in Japan, Korea, and China. However, this only applied to historical trends. In the comparison among different regions in Japan and China at a specific time, only in China was there a positive relation between economic growth and incineration. The Chinese experts participating in SWAPI and the Forum for promoting oversea activities of Japanese waste management and recycling companies pointed out in the interviews that incinerators in China were growing in popularity, but their growth was often driven artificially by subsidies [15, 23]. The Chinese experts pointed out in the interviews that in cities such as Beijing and Shanghai, where GRP per capita was high and there was little space and many subsidies for incineration, incineration rates were relatively high. They also commented that provinces with low economic development and spare land had relatively low incineration rates. The results of the cross-regional analysis show a positive correlation between economic level and incineration rate. However, other regional differences such as the amount of subsidies affect incineration rate more critically.

As regards composting, China is a country that uses chemical fertilizers extensively. According to the interviews, ensuring quality control of composting was difficult, and compost tended to be more expensive than chemical fertilizer. Besides, a lack of awareness of the importance of segregation, presence of heavy metals, and high moisture content made composting difficult [25]. A similar problem was also mentioned by a government official in Malaysia. In addition, farmers require high-quality compost [23, 24]. The composition of waste becomes more complex as an economy grows, and it becomes more difficult to make high quality compost. Due to these two reasons, the composting rate decreased with economic growth in China. On the other hand, in Korea, the national government introduced a strong policy to promote composting from the early 1990s and prohibited direct disposal of food waste in landfills from 2005 [3, 12]. Food waste has been collected separately from other waste; and it is easier to avoid contamination from hazardous waste. This can contribute to improving the quality of compost; therefore, in Korea, unlike Japan and China, the composting rate has been increasing recently.

This time-series analysis observed a correlation between economic growth and waste treatment options to some extent. But, the analysis in a certain year for Japan and China indicated that factors such as geography, culture, etc., other than economic growth, also affect the selection of waste treatment options. According to our interviews with experts and government officers who attended the Asia 3R Promotion Forum and SWAPI, the national government decided the direction of waste management policies in these countries; but in practice, local governments were in charge of municipal solid waste management. They also commented that local government officials selected policy options for appropriate waste treatment in consultation with stakeholders upon giving consideration to regional conditions, which differed among prefectures. This supports the results of our crossprefectual analysis, which could not identify clear (strong) relationships between the degree of economic growth and selected waste treatment options (composting and incineration).

Regarding the results of the second approach (AHP analysis), a preference for revenue from energy recovery was actually high in UMICs such as China, Thailand, and Malaysia. With a high demand for energy during rapid economic growth, policies for developing alternative domestic energy sources have been encouraged. Of course, even though these countries have a strong preference for waste-to-energy technology, its introduction depends on many factors such as calorific value of waste, etc. (Food waste in Thailand and Malaysia contains more moisture than average East Asian countries because of their food culture).

In China, waste-to-energy is singled out as an important renewable energy [17]. The preference of Chinese government officials for incineration is thus becoming high. In 2010 and 2011, the Chinese government regarded incineration plant manufacturing as an important industrial sector, and published various guidelines to promote and support incineration. This strong preference for incineration accelerates the introduction of incinerators.

Conclusion

The results of the study support the hypothesis that economic growth influences the selection of waste treatment options; but it only applies to a historical trend. The statistical analyses of time series data in this study confirm that there is a positive correlation between GDP per capita and incineration rate at a country level in Japan, Korea, and China. The results regarding incineration rate support the trend mentioned by Bertolini [1]. The trend can also be applied in one country's historical economic development. The regional historical analysis for most prefectures/provinces in China and Japan supports it. On the other hand, the study confirms that there is a negative correlation between the GDP per capita and the composting rate in Japan and China, but a positive correlation in Korea. This indicates that economic growth increased incineration rate, but did not always decrease composting rate. The regional analyses cannot explain if the incineration rate in a specific year was determined by economic conditions.

The AHP analysis conducted with experts and government officials in Southeast and East Asian countries showed that economic growth affected the weight of preference on environment and social factors. Average weighting factors of economic, environment, and social aspects were almost equal, ranging from 0.31 to 0.35. However, it revealed that the balance among economic, environmental, and social aspects changed with economic growth. The results of the study statistically confirm various trends associated with economic growth, which were mentioned by experts such as Tame [22], based on their experience. Environmental problems become most serious in rapidly industrializing countries such as MIC, and social acceptance is very important in such countries (0.60 in LMIC–0.81 in UMIC). However, with the implementation of pollution controls, social acceptance becomes less serious (0.51 in HIC). The other results support the straight-line trend of waste treatment against economic growth. The cost of equipment is the same, but wages for human resources needed for operation and management increase with economic development. Thus, operation and management become more important with economic growth (0.46 in LMIC and UMIC, 0.74 in HIC).

These results, both the inverted U-shaped trend and the straight-line trend of stakeholders' preferences, suggest that economic growth affects the selection of waste treatment options in terms of not only direct costs, but also preferences for factors considered. The economic growth of most Asian developing countries is very rapid, and trends of stakeholders' preferences also change rapidly. When a waste management policy is designed in such rapid economic growth countries, this U-shaped trend and the straight-line trend should be taken into account to minimize gaps between preferred and applied treatment options in the coming years.

The study focused only on knowledgeable governmental staff and researchers who most affect policy decisions. An analysis including different stakeholders such as citizens and business sectors would provide a good reference for actual policy decisions, especially when the policy process is oriented to stakeholder participation. Such a study would require questionnaires in local languages and detailed instructions, otherwise respondents could not properly understand the factors specified in the questionnaires.

For the cross-country analysis in this paper, we used data on agricultural production and population density. Other aspects such as subsidies in China should be considered in a further study. In addition, a study with more data on factors might be useful for further discussion. If data are limited for other factors, an interview survey might be useful to identify other important factors. These further studies would contribute to illustrating why there is a negative correlation between economic growth and composting rate in Japan and China, but not in Korea. They would also more clearly explain the different results between historical data at a national level and crossregional analysis.

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