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Thomas C. Kinnaman
Bucknell University, kinnaman@bucknell.edu

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Thomas C. Kinnaman
Department of Economics
Bucknell University
Lewisburg, PA 17837

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Guest Editor
Dr. Nlandu Mamingi
Professor of Economics
University of West Indies, Barbados

Abstract

Increases in population, urbanization, and per-capita incomes in the Caribbean over the past century have magnified the traditional challenge of managing household refuse. This paper will discuss the historical evolution of solid waste management practices, summarize the current state of waste management in the Caribbean, consider the future growth of waste production, highlight options for future waste management, and finally consider policies available to change current household waste disposal practices. Solid waste planners might find this information useful to prepare long-term strategies for waste management in the Caribbean.

Keywords: Solid waste management, refuse, solid waste policy, economic costs of waste management, recycling.

1. Introduction

Increases in population, urbanization, per-capita incomes, and the importation of finished goods over the past century in the Caribbean have increased the variation and complexity of waste composition and thus have magnified the traditional challenge of managing household refuse. Traditional practices of reusing valuable waste materials and composting organic waste materials have been replaced by convenient and free (to households in the Caribbean) municipal collection programs. Each household's waste, increasingly comprised of plastics, cardboards, and assortments of other materials, is collected and transported for disposal at a distant dump site.

But because these remote dump sites have the potential to transmit diseases, ignite wildfires, threaten area groundwater supplies, and generate other environmental problems, many governments in the Caribbean have recently begun initiatives to improve waste disposal practices through the construction of sanitary landfills and incinerators. Some governments have also enacted policies to improve household refuse disposal through recycling, composting, source reduction, and possibly green design (Cicin-Sain ed., 2005). Although traditional social norms that once supported household conservation could be revived, more likely legal or economic incentives are necessary to change current household disposal practices.

This paper makes several contributions to the existing literature on solid waste management in the Caribbean. First, it provides a concise summary of the evolution of solid waste management practices from agrarian to industrial economies – in evolution that has occurred throughout the Caribbean. The paper then summarizes the current state of waste management in the Caribbean. This summary includes estimates of the quantity

and composition of solid waste generated in several Caribbean countries. These early sections provide the proper context for further discussions of possible future directions for Caribbean waste management. First, existing empirical estimates from other parts of the world on the effect of income growth and other variables on solid waste generation rates are summarized and used to forecast future generation rates in the Caribbean. Such forecasts are necessary to adequate planning. Second, existing global practices available to manage solid waste, such as incineration, composting, and recycling, are considered for possible use in the Caribbean. Not all practices are found to be advisable. Third, the viability of methods to alter household disposal practices, from education and moral persuasion to behavioral mandates, are discussed for possible implementation in the Caribbean.

2. The Evolution of Solid Waste Management Practices

Although each country in the Caribbean has certainly experienced unique challenges with respect to the historical development of solid waste management practices, general patterns can be identified. First, virtually all Caribbean countries arose from traditional agricultural or maritime economies and were comprised largely of rural populations. These rural populations earned relatively low incomes and produced little refuse. Old clothing and household materials were repaired and reused, and household refuse consisted largely of bones, peels, and other by-products of consuming unprocessed meat, grains, fruits, and vegetables. This refuse was often composted and in some cases applied to fertilize the soil. Other forms of waste were likely organic and could be

burned for warmth or cooking. In these traditional economies, most refuse was thus managed by the household.[1]

As these populations grew and migrated towards urban areas, open dump sites often formed along the outskirts of newly constituted urban villages. The ideal dump site was located close enough for convenient disposal, but far enough to isolate the population from the odors and other problems associated with the open dump. These dump sites may have been located in a gully, deep valley, perhaps in the sea, or at a location downwind of the community. Most daily solid waste produced by households was still organic in nature, but many households began to produce occasional non-organic wastes such as construction materials, old appliances, automobile tires, and a wide assortment of other wastes ushered in by subsequent waves of global industrialization. Unlike many organic wastes, post-industrial wastes collect and trap rainwater and thus provide breeding grounds for insects, rodents, and pathogens that cause and transmit disease, such as malaria, dengue, schistosomiasis, South American trypanosomiasis, and Bancroftian filariasis. The World Bank estimates the burden to developing countries from these diseases alone is about two life-years per 1,000 persons (Beede and Bloom, 1995). These health problems can become magnified if urban expansion pushes outlying shanty neighborhoods within closer proximity to the open dumps. Scavengers might also work the dump to extract valuable materials for sale (Beede and Bloom, 1995).

The emergence of industrial economies not only altered the composition of refuse, but the accompanying availability of centralized industrial employment increased urbanization. Refuse management practices initially remained unchanged during these

[1] See Thomas-Hope ed. (1998) for a detailed discussion of many aspects of solid waste management in developing countries including the Caribbean.

transitions. Open dumps became larger, more remote from the urban centers, and increasingly hazardous to neighboring populations. As dumps became increasingly remote, households found transporting waste difficult and in some cases opted to dump refuse in nearby unauthorized neighborhood dumps or even neighborhood streets. Local governments often responded by initiating municipal collection systems where household refuse was collected from the household by the government at no added expense to the household.[2] Neighborhoods became clean, but refuse quantities increased at the remote dump site, and the associated environmental costs worsened. Refuse generating households became disassociated with the disposal of their own waste as the refuse was out of sight and therefore out of mind. The once important practice of conserving or reusing materials was largely forgotten.

Local governments began to mitigate open burning and other externalities associated with refuse disposal by covering refuse with five to ten inches of soil. But covering waste reduces oxygen levels available for natural decomposition. Decomposition in an oxygen starved environment generates methane and leachate (the liquid byproduct of decomposing waste) (Kreith, 1994). Methane contributes to climate change and leachate is damaging to ground water supplies. Technologically advanced and economically costly disposal practices are necessary to manage these environmental problems associated with covered waste disposal.

3. The Current Status of Solid Waste Management in the Caribbean

[2] Large and condensed urban populations offer significant economies of scale in refuse collection. Stevens (1978) suggests returns to scale in collection exist up to service for 50,000 persons and then constant returns to scale.

Table 1 provides the average per-capita quantity of household refuse generated in selected countries in the Caribbean in the year 2000 (data for Jamaica and St. Vincent and the Grenadines are from 2002). The average generation rate in the Caribbean was 18.85 pounds of refuse per week per person. Per-capita generation rates varied from 8.08 pounds per week in Cuba to 43.21 pounds per week in the British Virgin Islands (BVI). Differences in per-capita income and collection practices (discussed in the next section below) could be responsible for this variation. Ten percent of daily refuse in the Eastern Caribbean is generated by tourism activities, including cruise ships and yacht traffic (Caribbean Recycling Foundation).

Table 1 also provides information on how selected countries in the Caribbean manage their waste. Landfill disposal was the predominant practice, and the Dominican Republic utilized some incineration (see Table 1 for sources). The alternate methods of disposal for the remaining portion of solid waste generated by each country were not reported; these could include composting, recycling, or possibly exporting refuse.

The composition of this waste is provided in Table 2. Food waste was the most common form of waste in the Caribbean, followed by paper/cardboard and plastic. BVI generated less food waste than other Caribbean countries, but generated more plastic, glass, and wood refuse. Perhaps surprisingly, the waste composition in the BVI resembled that of developed countries with higher levels of household incomes.

Why the difference in waste composition across developing and developed nations? Households in developing countries are more likely to consume unprocessed vegetables, fruits, and meats than households in developed countries. In addition, the lack of refrigeration and storage facilities make food preservation difficult. As incomes

rise and cultures change, the demands for prepared and packaged foods, office paper, newspapers, and magazines increase. The high wage rates that often accompany large incomes increase the opportunity cost of traditional meal preparation practices and the reuse of household waste materials. Therefore, instead of preparing meals at home, these households purchase processed and packaged food with the associated paper, plastic, and glass.

On the policy front, regional cooperation through the Organization of East Caribbean States (OECS) has been important to regional planning for solid waste management (Cicin-Sain, 2005). Many individual countries in the Caribbean have also engaged in long-term planning for household and ship-generated refuse disposal (Dragan, 2002). Roughly 62 percent of 16 countries in the Caribbean have developed a comprehensive national waste management plan. Barbados and Jamaica have been most successful implementing their plans, and St. Lucia most recently modernized its landfill. In addition, Jamaica has initiated biodigestors to reduce the need for landfill space and St. Kitts and Nevis has initiated an intensive recycling program.

4. Explaining Increases in Solid Waste Generation Rates

The quantity of household refuse disposed of in open dumps or sanitary landfills increases with (1) population growth, (2) per-capita incomes, and (3) improvements in the efficiency of municipal refuse collection systems. This section discusses each of these three factors. Meaningful planning is important to the proper management of household refuse, and understanding the magnitude of these sources of growth in waste could be beneficial to planners interested in preparing for future waste disposal needs.

The lack of planning can lead to the spontaneous development of unauthorized open dumps as households and businesses become frustrated with the lack of convenient disposal facilities. Countries as developed as Italy and Ireland have recently experienced this unfortunate phenomenon.

Using a cross-sectional data set of 36 nations compiled by the World Resource Institute (1993), Beede and Bloom (1995) estimated that a 1 percent increase in population is associated with a 1.04 percent increase in municipal solid waste. Comparing population statistics gathered for the eight Caribbean countries listed in Table 1 suggests solid waste increased an estimated 0.91 percent with a 1 percent increase in population, an estimate slightly less than the Beede and Bloom estimate.[3] Total refuse generation rates increase with population for fairly obvious reasons. Perhaps less obvious is the notion that per-capita generation rates decrease with increases in the average number of members in the household (Jenkins, 1993; Kinnaman, 1994; and Podolsky and Spiegel, 1998). Large families tend to share meals and other consumer waste-generating products. Thus, waste levels can increase unexpectedly if population rises are matched with reductions in average household size.

Beede and Bloom (1995) also estimated that, controlling for changes in population, a 1 percent increase in per capita income is associated with a 0.34 percent increase in solid waste. Individuals with average per-capita incomes of $8,000 (2006 US dollars) per year are estimated to each generate 11 pounds of refuse per week. Generation rates increase to nearly 19 pounds of refuse per week for households earning per-capita incomes of $18,500 per year. Waste generation increases by an estimated 0.46

[3] This estimate was obtained by regressing the waste quantities of the eight countries in Table 1 on population and income.

with a 1 percent increase in incomes in the eight Caribbean countries depicted in Table 1, a bit higher than the estimate provided by Beede and Bloom (1995). Several economic studies in the United States have also estimated a positive link between income and refuse generation rates (Kinnaman and Fullerton, 2000b; Hong, Adams and Love, 1993; Richardson and Havlicek, 1978).

Combining the estimated results for population and income implies a nation that experiences a 3 percent annual increase in population and a 3 percent annual increase in per capita income can be expected to experience roughly a 4 percent annual growth rate in refuse totals. If population and per-capita incomes rise at these rates in the long run, then garbage totals are estimated to double every 18 years over the levels reported in Table 1, unless steps discussed below are taken to deter garbage generation.

Such steps have been taken in some developed countries, and data from these developed countries suggest per-capita income and refuse generation rates become decoupled in high ranges of per-capita income. Despite large rates of income growth between 1990 and 2000, per-capita refuse generation increased from 21.49 pounds per week to just 22.82 pounds per week (a 6 percent increase) in Organization for Economic Co-operation and Development (OECD) countries (de Tilly, 2004). Per-capita generation rates increase by only 4 percent in the US over this same timeframe. Developed nations are more likely to engage in recycling, and households in these countries expend a larger portion of their incomes on services.

A third source for increases in refuse disposal quantities is the efficiency of the refuse collection and disposal system. Refuse quantities increase as government leaders and perhaps private waste industries make refuse collection more convenient to

households by, for example, regularizing collection frequencies or constructing landfills in areas more convenient to waste haulers. As described above, traditional households faced with the task of managing their own refuse might reuse waste around the household, bury waste, compost waste, or utilize local dumping areas. Convenient and free weekly collection services cause households to cease these practices and simply discard their waste materials. Local dump sites disappear, but the quantity of refuse collected for disposal increases, and planners should be aware of this.

Planners in Barbados experienced this issue when the Mangrove Pond Landfill was placed into operation in 1986. Planners expected 190 tons of refuse each day (the quantity at the retired landfill), but the convenient central location of the Mangrove Pond landfill made delivering waste easier, and waste totals to increase to 200 tons per day. The site filled one year earlier than planners anticipated. By the mid 1990's expansions to the Mangrove Pond Landfill received 400 to 425 tons of refuse per day (Headly, 1998). Frequent waste collection reduces improper household disposal, while increasing total waste collection.

A potential fourth determinant of refuse generation rates is the educational status attained by adult members of the household. Educated households might be aware of recycling opportunities and understand the environmental impacts of their refuse. Studies linking recycling behavior and education are unavailable in the Caribbean. Economic studies in the United States such as Hong, Adams, and Love (1993), Callan and Thomas (1997), Judge and Becker (1993), Reschovsky and Stone (1994), and Duggal, Saltzman, and Williams (1991) estimate recycling levels increase with education. Waste is thus reduced to the extent that education increases recycling.

5. Current Options for Solid Waste Management in the Caribbean

Once serious planning for solid management in the Caribbean is initiated, the options facing each nation are outlined below.

A. Green Design

Household refuse generation rates could decrease if products consumed in the economy generated less waste. The idea behind green design is to manufacture goods that either generate less waste or are less costly to recycle. For example, the cardboard boxes used to package many goods could be produced without the waxy surface that makes recycling the cardboard problematic. Small economies in the Caribbean that import a substantial portion of their goods may be unable to influence the design and manufacture of products made in different parts of the world, but the concept of green design is gaining momentum in many parts of the developed world, and Caribbean countries that import these goods could benefit as a result.

B. Composting

Roughly 50 percent of disposed household refuse in the Caribbean is organic in nature and is therefore available for composting (Richards, 2002). The organic matter component of solid waste can simply decompose naturally. This decomposition process can be accelerated by manipulating the moisture content, temperature, and oxygen levels within the composting materials. The oxygen allows the decomposition to occur without

creating methane. The decomposed waste can then be used to enrich the nutrient content of farm lands and thus improve agriculture.

Composting is not new to inhabitants of the Caribbean, as it was once common for residents in rural parts of many countries to dispose of organic waste in gardens or around fruit trees before weekly door-to-door waste collection became popular. Such practices are less likely today, but centralized composting facilities can be constructed on lands adjacent to landfills to increase efficiency. Households could be expected to separate organic material for separate collection. This process is quite common for garden waste in countries such as Barbados, Jamaica, and Cuba among other Caribbean nations, but it has not been initiated for other organic materials including household food waste.

C. Recycling

Many forms of refuse generated by households in the Caribbean are recyclable. Paper, cardboard, plastic, glass, and metal can be removed from the waste stream, processed, and taken to manufacturers that specialize in converting these materials into materials useful to the economy.

One drawback of recycling in both developed and developing countries is its cost. In the United States, for example, the per ton cost to collect, process, and transport recyclable materials roughly double the cost of disposing the same waste in a sanitary landfill (Kinnaman, 2006). The costs of recycling might be quite different in the Caribbean. The unskilled labor supply is relatively abundant in many Caribbean nations, and labor-intensive recycling practices might therefore be less costly. However,

recycling firms are often located within close proximity to manufacturing regions. Because few centralized manufacturing regions exist in the Caribbean, the costs of shipping recycled materials could be substantially higher in the Caribbean than in the United States. Despite this second obstacle, several countries in the Caribbean, most notably Barbados, have established a recycling infrastructure for glass, aluminum, and plastic drink containers. Consumers in these countries pay a deposit with the purchase of beverages, and receive a refund when the containers are returned to designated collection areas. These programs not only reduce household refuse designated for landfill disposal, but also reduce the likelihood of littered beverage containers.

As Caribbean countries continue to develop, they could consider less labor intensive recycling process that utilizes compartmentalized trucks to collect refuse directly from households. Households would then separate all recyclable materials into a single recycling bin, and refuse collectors would deposit the materials into separate compartments of a truck for transport to a transfer station for additional processing and eventual transfer to recycling markets.

The current experience of developing countries today could provide a glimpse of recycling practices in the future Caribbean once incomes rise. Despite the high cost, there is a broad trend towards recycling in OECD countries where 80 percent of metals, 35-40 percent of glass, and 40-55 percent of paper and cardboard are recycled (de Tilly, 2004). As a total of all solid waste generated, the United States recycles 30 percent of its waste, and OECD countries recycle 16 percent (de Tilly, 2004). Recycling in some developed countries can be capital intensive. Rather than requiring households to separate materials for recycling, all refuse is delivered to a facility that uses highly

automated systems with magnets to extract ferrous metals. Air classifiers with blowers separate light materials (plastics), and eddy-current separators with magnets above a conveyor belt repel aluminum to special bins (Beede and Bloom, 1995). A less capital intensive recycling process involves the use of conveyor belts that slowly transport refuse as workers pick and sort through the materials.

D. Incineration

Incineration involves the burning of generated household and commercial refuse at very high temperatures. The heat produced by the burn can be useful for the generation of energy. Incineration is an expensive waste disposal option. Incineration represents an economical solution to high refuse generation rates where land is scarce, as is the case in many Caribbean countries. There is a broad and growing trend towards incineration in OECD countries, especially in parts of Europe, Japan, and the northeastern of the United States.

But incineration may not currently be appropriate for many Caribbean countries for several reasons. First, the content of household refuse in developing countries is comprised of large proportions of organic food waste. Such waste contains a lower level of energy content and a higher level of moisture content than other forms of waste such as paper and plastic. Refuse in developing countries is therefore not as combustible, and fossil fuel must be added to keep burning temperatures sufficiently high.

Second, there are economies of scale in incineration. Kreith (1994) examined the costs of several incineration plants, and estimated the per-ton cost of operating an incinerator decreases with waste quantities for plants that take up to 1,100 metric tons of

waste per day. Per-ton costs are constant for plants that burn an excess of 1,100 tons per day. One reason for the scale economies in incineration is the reduction in the per-ton cost of emission control, which declines sharply as daily capacity increases from 500 to 1,000 metric tons (Kreith, 1994). Thus, average costs of incineration are minimized for populations of 700,000, assuming again that individuals generate an average of roughly 20 pounds per week. Trinidad and Tobago has a sufficient population to capture these scale economies, but Barbados falls short.

Pollution control is quite necessary with incineration. Incinerators generate particulate matter and incomplete-combustion products such as CO, NOx, chlorinated hydrocarbons, acid gases, mercury, and lead (US Congress, 1989). To remove these wastes from the final air stream, the heat of the burn must reach 1,800 degrees Fahrenheit for complete combustion. The plant also needs electrostatic precipitators or fabric filters to remove particulates and metals and scrubbers to remove acid gases. Highly efficient technologies for incinerator emission were developed in the 1990s. The incinerator in Tortola, BVI, for example, includes a ceilcote-designed scrubber packed with polypropylene to control air pollution. This scrubber removes 98 percent of all hydrogen chloride, 80 percent of all sulphur dioxide and 98 percent of all particles greater than ten microns. Although the BVI government does not have its own air quality standards, the emissions from the incinerator fall well within acceptable limits of most air pollution standards in the developed world (Lettsome, 1998).

E. A Highly Capitalized Sanitary Disposal Facility

A sanitary landfill may seem a bit of an oxymoron to any individual not acquainted with advances in the technology of garbage disposal experienced over the past 40 years. Sanitary disposal facilities are constructed over thick and impermeable clay or plastic bases. Plumbing systems are imbedded to collect methane gas and leachate (the liquid byproduct of decomposing garbage). Reverse-osmosis systems are constructed to treat the collected leachate, and the treated leachate can be returned to the area water supply. Wells are dug on all sides of the facility to monitor the quality of area ground water, and disposed solid waste is covered continuously with several feet of clean fill to virtually eliminate odor and the spread of disease. Captured methane can be burned to generate electricity. A moderately sized sanitary disposal facility can generate methane sufficient to provide energy to 3,200 homes (U.S. EPA).

One drawback of this solid waste management option is the economic cost. A large site must be selected; the ground needs to be prepared; the clay or plastic base must be laid; and the plumbing systems must be installed. A new facility resembles a massive construction site where engineers are on the site and land-moving machinery is fully employed. Depending upon the cost of the land and local economic conditions, the per-ton tipping fees levied on the disposal of solid waste could exceed $30US to recover the construction and operation cost (Stevens, 1978). Individuals would then pay about $0.30US per week on average to pay for such proper disposal. Thus, a household of four individuals would pay an average of $1.20US per week.

But per-household disposal costs are this low only for sufficiently large populations. Because the fixed costs associated with the initial construction of the facility are substantial, economies of scale are of great importance. According to

DeLong (1994), the average per-ton cost of operating a sanitary landfill declines by a minimum of 70 percent as their capacity increases from 227 to 2700 metric tons per day. Thus, for a country whose residents generate an average of 20 pounds of refuse per week, average disposal costs are minimized with a population of nearly 2 million people. Among nations of the Caribbean only Cuba, Dominican Republic, Haiti, Puerto Rico, and Jamaica have populations in excess of this threshold. Many smaller nations do not generate sufficient quantities of solid waste to spread the high fixed costs of initial landfill construction. Each resident of Barbados, for example, where the population is only 280,000, could pay almost $2.00US per week (or $8.00US per family of four). Countries with populations smaller than those of Barbados would face even higher, potentially prohibitive, per-capita costs of disposal. Perhaps neighboring countries in the Caribbean can cooperate and share solid waste disposal sites. This strategy would of course involve shipping solid waste to countries in order to help spread the costs to larger populations, which could have both political and ethical ramifications.

Two environmental problems remain with sanitary disposal facilities. First, because such facilities are often large in order to capture the economies of scale, the facility needs to be centrally located, and the number of waste hauling trucks visiting the site each day could be large. These trucks damage local access roads, produce congestion, increase the threat of roadway accidents, and produce a disamenity to those living along access roads. To minimize these problems, disposal facilities are best developed on sites along major roadways engineered to handle high truck traffic.

Second, even sanitary disposal facilities release greenhouse gasses. The decomposition of organic waste in an environment void of oxygen generates methane and

other gasses. The release of these climate gasses can be minimized with the collection of methane for power generation, but currently 6 percent (U.S. Department of Energy, 1993) to 16 percent (Gandy, 1994) of estimated global annual methane emissions are emitted by the decomposition of organic waste at landfills.

F. The Status Quo

Many developing countries, including many in the Caribbean, rely upon open and controlled dumps to manage solid waste. Refuse may be covered on a daily basis to minimize pests, disease, and the threat of open fires, but only minimal effort is extended to ensure water supplies are protected. The clear advantage of this management option is the low economic costs involved, especially in comparison to the costs of other options described below. The obvious disadvantage of continued reliance upon the open dump is the threat to the area environment and to human health. Not only can open and controlled dumps foster the spread of disease, but dumps also threaten area groundwater supplies. This problem is particularly worrisome in areas where untreated groundwater is consumed by urban and rural populations. The rainwater runoff from open dumps can also impact surface water supplies and the ecosystems that rely upon clean water. Finally, the open and controlled dumps can affect the local tourism industry as many vacationers may seek a safe and environmentally friendly destination.

6. Strategies to Change Household Disposal Practices

If a reduction in solid waste disposal through recycling, composting, or other related practices is desirable to any particular government, then all but the most capital

intensive separation processes will then require some effort on the part of households. Households might be expected to separate waste by categories for separate recycling collections; households might also be required to transport certain forms of waste materials to collection centers, and in some cases households might engage in composting or possibly reducing the quantity of waste they generate. To encourage these behaviours, solid waste managers can consider changing the moral, legal, and/or economic incentives of households. Education can also play an important role. Most countries in the Caribbean have only attempted the first two of the five options described below.

A. Moral Persuasion

Reestablishing old social norms that once supported the traditional practices of reusing, recycling, and composting behavior might prove difficult in those countries with relatively high per-capita incomes and therefore high opportunity costs of time. But these households could be persuaded to, for example, separate recyclable materials for curbside collection. The resource cost to separate recycled materials is relatively low to many households, and social norms have been established in many developed countries that make such recycling efforts common. Callan and Thomas (1997) find that an extra dollar spent per household to encourage recycling increases the recycling rate by 2.55 percent in the United States. But Judge and Becker (1993) find no impact from publicity efforts in the United States to increase awareness of municipal recycling opportunities.

B. Education

Roughly 56 percent of countries in the Caribbean have implemented educational programs to raise the issue of the environment and waste management in school systems (Cicin-Sain, 2005). Environmental education has been integrated into the general curriculum at all levels of schooling in Jamaica. A survey of 12 waste management professionals in Jamaica determined that 15 concepts related to waste management should be included in the school curriculum at both the primary and secondary levels. But only four of these concepts were addressed at the primary level and nine at the secondary level. These disappointing results suggest much room for improvement (Collins-Figueroa, 1998).

Ideally, education would go beyond providing students with the simple awareness of issues and testing their recollection of concepts to incorporate environmental responsibility, action, and citizenship. To link knowledge with action, Jamaica has initiated the Issue Investigation and Action project in the late primary or lower secondary schools state (Collins-Figueroa, 1998). This project expects students to identify and investigate an environmental issue and then take effective action. A study of a seventh grade life science unit on waste management showed statistically significant gains in the understanding of content and actions taken for students who participated in this project relative to students taking a traditional course. Unfortunately, the lack of educational resources, the time demands of the traditional curriculum, and poor horizontal links across subjects have impeded the success of this program in other countries (Collins-Figueroa, 1998). But, with inspirational administrators and encouraging teachers, the Issue Investigation and Action strategy could help students in the Caribbean become responsible, knowledgeable, and active citizens.

C. Legal Mandates

Household disposal behavior can be mandated by law. Households could for example be required to remove certain recyclable materials from their refuse and either place them in special recycling containers for separate collection, or households could be required to transport those materials to collection centers. Households ignoring the legal mandate could be fined or potentially imprisoned if offenses are repeated. The legal mandates also help to define new social norms; blatant throw-away behavior will be no longer acceptable by the community. To prevent social backlash from what could be perceived by households as a heavy-handed legal requirement, officers could initially issue written reminders and warnings to those households that blatantly disregard the new legal expectations.

Effort should be expended to enforce such recycling laws. Experience in the United States suggests such legal measures without enforcement do little to alter household disposal behavior (Kinnaman and Fullerton, 2000b).

D. Pay As You Throw

Economic incentives can be developed to encourage households to change disposal practices. Pay as you throw programs require households to affix a special tag or sticker on each bag of refuse they generate for collection. The special tags or stickers can be obtained at local grocers or gas stations for a designated price, maybe $1-$2US each. Households facing such fees can economize on their own disposal costs by recycling, composting, or otherwise reducing the quantity of waste they generate.

Such programs have been implemented in many developed countries. Over 2,000 municipalities in the United States charged households a fee for each bag of refuse collected, and the nation of South Korea required this pricing scheme for all of its cities. Economists have studied the success of these programs at reducing refuse quantities. Results suggest households facing a fee of $1US reduce refuse generation by 12 pounds per week, roughly a 30 percent reduction in waste generation (Kinnaman, 2006).

A problem associated with these economic incentive programs is the unfortunate increase in the likelihood of illegal or illicit waste disposal. This threat should be weighed carefully by leaders of developing countries especially Caribbean states. Memories of old dump sites such as nearby gullies that existed prior to organized collection may still persist, and some households may return to undesirable disposal habits to save the costs of purchasing the special tags or stickers.

E. Deposit-Refund Programs

Economists that studied solid waste and recycling subsidy from a theoretical perspective are almost universally united in support of deposit-refund programs to generate economic incentives to promote recycling (Kinnaman and Fullerton, 2000a). The refund encourages the practice of recycling without simultaneously encouraging illicit disposal behavior. The deposit, essentially a tax on consumption, prevents the disposal subsidy from unintentionally subsidizing consumption. This policy option could be applied to specific products such as drink containers as in Barbados and other countries, or more broadly to all forms of physical consumption.

This latter option has several advantages. First, a sales tax on all forms of physical consumption might be easier to implement and administer than a specific deposit on each material. Second, the subsidy need not take the form of a return of payment to a household that carts materials back to the appropriate collection facility, but can instead take the form of free collection of all recycled materials. In other words, the revenue from the added sales tax can be applied to finance separate collections of recycled materials from households. The collection represents a real subsidy to the household, especially those households with high opportunity costs of time, in that the household is saved the effort of transporting the material to a recycling collection point.

7. Conclusion

This article has summarized the present state of solid waste management in the Caribbean, has provided crude estimates of future refuse amounts, and sketched out some policy options to both manage collected waste and encourage households to change their disposal practices. Planners in the Caribbean might find this information useful to prepare for future waste management needs.

Investing in long-term strategies for managing solid waste will likely become common in many countries in the Caribbean over the next few decades. Sanitary landfills, incinerators, large-scale composting facilities, efficient recycling facilities, and perhaps green design require the investment of significant resources. Investing in such strategies offers economic dividends as well. Countries that manage and plan for waste disposal responsibly enjoy a cleaner environment, which can improve international investment, tourism, and economic growth.

Finally, the substantial economies of scale that arise with the construction of sanitary landfills, incinerators, and recycling facilities could justify shipping waste within low-populated nations of the Caribbean. Political, environmental, and ethical question will surely abound, but environmental and economic savings could be significant. Future research could estimate the savings from centralized waste facilities as functions of incomes, populations, and transportation costs within the Caribbean.

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TABLE 1: Per-Capita Generation of Refuse in Selected Caribbean Countries (2000)

Country	Generation (pounds/week)	Percentage Landfilled	Percentage Incinerated
Caribbean[1]	**18.85**	**83**	**2**
Bahamas[1]	**36.54**	**70**	
Barbados[2]	**13.89**		
BVI[2]	**43.21**		
Cuba[1]	**8.08**	**90**	
Dominican Republic[1]	**9.62**	**90**	**6**
Jamaica[2*]	**15.43**		
St. Lucia[1]	**21.15**	**83**	
St. Vincent and the Grenadines[2*]	**11.27**		

Sources: 1: IPCC (2006); **2:** Treasure (2004)
*Data from 2002.

TABLE 2: Composition of Household Refuse in Selected Caribbean Countries

Material	Caribbean[1**]	St. Vincent and the Grenadines[2***]	Jamaica[2***]	Barbados[2**]	BVI[2**]	Trinidad[2*]
Food Waste	46.9%	49.6%	53.96%	59%	6.5%	46%
Paper /Cardboard	17.0%	22.1%	17.34%	20%	33.5%	13%
Wood	2.4%	1.34%			22.2%	
Textiles	5.1%	4.0%	2.88%		4.8%	4%
Rubber /Leather	1.9%					
Plastic	9.9%	8.4%	11.77%	9%	6.3%	12%
Metal	5.0%	3.8%	5.29%		8.6%	7%
Glass	5.7%	5.6%	4.27%		18.1%	6%
C&D Materials		5.8%				7%
Other	3.5%	0.3%	3.15%	12%		5%
Total	100%	100%	100%	100%	100%	100%

Sources: 1: IPCC (2006); **2:** Treasure (2004)
*Data from 1999.
**Data from 2000.
***Data from 2002.