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Factors affecting waste generation: a study in a waste management program in Dhaka City, Bangladesh

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Abstract Information on waste generation, socioeconomic characteristics, and willingness of the households to separate waste was obtained from interviews with 402 respondents in Dhaka city. Ordinary least square regression was used to determine the dominant factors that might influence the waste generation of the households. The results showed that the waste generation of the households in Dhaka city was significantly affected by household size, income, concern about the environment, and willingness to separate the waste. These factors are necessary to effectively improve waste management, growth and performance, as well as to reduce the environmental degradation of the household waste.

Keywords Waste generation · Waste management program · Environmental degradation

Introduction

Urban solid waste management is considered to be one of the most serious environmental problems confronting urban areas in developing countries (Pfammatter and Schertenleib 1996; Sinha and Enayetullah 2000) and Dhaka city in Bangladesh is no exception. Dhaka city, with 9.3 million inhabitants and 6% population growth rate, is one of the fastest growing mega cities in the world (DCC 2010). Dhaka metropolitan area, also referred to as Dhaka mega city, occupies an area of about 1,530 km² in which 360 km² (6 million residents) are under the municipal administration of Dhaka City Corporation (DCC 2010). Solid waste generation under Dhaka City Corporation's (DCC) jurisdiction area is about 3,340 tons/day, of which 668 tons/day is recycled, 1,236 tons/day is illegally dumped, and 1,436 tons/day is finally disposed of at the landfill (AIT-UNEP RRC.AP 2005). It seems that DCC is able to collect about 43% of total solid waste generated. Irrespective of the municipal authorities' ability to collect solid wastes, both collected and uncollected solid wastes create problems for the residents. Finding adequate waste disposal sites for the future is

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very difficult with the increase in population and horizontal expansion of the city. Hence, there is a dire need to increase public awareness on solid waste minimization problem and to estimate factors that are responsible for increasing solid waste generation in this megacity.

Public participation in waste management and waste minimization in developing countries, including Dhaka, has received little attention. Examining from political and economical perspectives, previous researchers were interested in scavengers or junk buyers (the door to door collectors for recyclables) as a special group (Beukering 1997; DiGregorio 1994; Furedy 1992; Huysman 1994; Sicular 1992). Models are available to predict waste generation and waste minimization behavior in developed countries; however, very little research has been conducted in constructing models applicable to developing countries. Thus, data and models generated in developed countries might not be suitable in developing countries' situations without the respective countries' specific data gathering and analysis. This study aims to contribute to a better understanding of household waste management behavior by examining solid waste management practices and attitudes of Dhaka city's residents. More specifically, it analyzes the factors that promote households' waste generation and Dhaka city's residents' willingness to minimize the household waste. Results from this study will provide inputs to the environmental and waste management planners in their decision making, particularly on solid waste segregation and recycling activities in Dhaka city, Bangladesh.

Methodology

In developing an effective waste management strategy for a given region, it is important to know the amount of waste generated and the composition of the waste stream and these would have a direct effect on the socio-economic factors. Socio-economic factors directly affect solid waste generation. Early on, economists discussed the specific socio-economic factors that influence household waste generation. Viewed from an economic perspective, Wertz (1976) an-

alyzed the household behavior on waste generation in terms of changes in income, price of refuse service, frequency of service, site of refuse collection, and packaging. Household size, cultural patterns, education, and personal attitudes (Al-Momani 1994; Grossmann et al. 1974) are said to influence solid waste generation as well. Economists also compared the composition and quantity of waste in terms of income level, household size, and age structure of the household as these affect the quantity and composition of solid waste. For instance, Richardson and Havlicek's (1978) study shows that grass, yard wastes, and newspaper are positively correlated with the level of income. Various authors have shown that the amount of waste generated by a country is proportional to its population and the mean living standards of the people (Wertz 1976; Grossmann et al. 1974; Medina 1997) is related to the income levels of people hence individual household's waste generation is correlated. Thus, there is a positive relation between income and waste generation (Nilanthi et al. 2006).

This section discusses the empirical analysis of the relationships between the quantity and composition of household solid waste and several selected social and economic variables. Various researchers have attempted building ideal models to predict solid waste characteristics as a reliable tool and parameters. They found that relationships obtained between various parameters vary among countries. This has been attributed to variations in consumer behavior and lifestyles. Normally, waste is a function of consumers' consumption. The relationship between waste and consumption activities may be expressed as (Richardson and Havlicek 1978):

$$W = \beta C,$$

Where

- W vector components of solid waste
- β vector of technical waste transformation coefficients relating to the types and quantities of solid waste with each consumption activity
- C vector of consumption activities selected by the household and it is related to the classical

utility maximization framework (Richardson and Havlicek 1974).

Any particular waste may be generated by the consumption of more than one commodity. Here no attempt is made to identify the technical waste transformation coefficients associated with the individual products. This study is comparing the relationship between total waste generation of households and socio-economic variables affecting the quantity of waste. A multiple regression model was performed to determine the factors that affect waste generation of the households. The ordinary least square method was used to estimate the parameters in multiple regression models. The significant relationships between dependent and independent variables were examined by the value of the correlation coefficient (*R*) in two variable cases. In the multivariate case, *t* values, *R*², adjusted *R*², and *F* values were estimated. As such, the model assesses the relationships between various factors and the waste generation of the households. In this regression analysis, the total solid waste generation of the households per month is regressed quantitatively, by several independent variables. The model is:

$$Y = \beta_0 + \beta_i X_i + e$$

Where

- Y* total waste generation per month
- X_i* independent variables
- β_0 constant term
- β_i coefficient of independent variables
- e* the error or disturbance term.

The independent variables of this model are household size, education, income, and extra land

within the compound of the household. Table 1 provides an overview of the independent variables used in the models of the study.

Empirical design and data collection

Target population

Dhaka, the capital city of Bangladesh, was chosen as the location of this study. Residents in Dhaka are the immediate beneficiaries of door to door waste collection systems provided by Dhaka City Corporation. The unit of analysis was household—either in an independent house, an apartment, a flat, a shanty, or a residence-cum office/business. The Bangladesh Bureau of Statistics’ (BBS) (1999) definition of household is a dwelling place where “person or persons related or unrelated [are] living together and taking food from the same kitchen” was adopted for this study. Those staying in barracks or orphanages and homeless individuals were excluded from the target population as they do not form a taxable household.

Unit of analysis

Another consideration needed to be addressed was whether the data on household waste management should be collected by households (Carson et al. 1992; McConnell 1995) or on an individual basis (Kealy et al. 1990; Imber et al. 1993). One of the options to select sample from the huge target population was to use voters’ list. Voters’ list containing individuals’ information has been used as a sampling frame in many other

Table 1 Variables included in the regression model

Variable	Definition	Mean (standard deviation)
Family member	Number	4.4 (1.4)
Education	Dummy to represent university “1” and others “0”	0.6 (0.5)
Income	Household monthly income (1,000 TKa/month)	11.7 (7.0)
Conscious about environment	Dummy to represent conscious about environment “1” and not conscious about environment “0”	0.7 (0.5)
Agree to separate	Dummy to represent agree “1” and not agree “0”	0.3 (0.5)
Extra land within the compound	In acre	0.1 (0.02)

studies. During the time of this survey, a new voters' list was being prepared to be used in the 2007 general election; however, it was considered as "confidential document." Besides being unavailable, voters' list was not reliable in this study. Bangladesh practices a joint-family culture system and incomes are joined together for the purpose of any expenditure decision. In most cases, the joint-family system still exists; therefore, "household" was chosen as the unit of analysis. Within each house, interviewed respondents were above 17 years old.

Household selection

Dhaka city comprises of 10 zones and within these zones there are 90 wards (subdivision) (BBS 2001). Each ward consists of one or more mohallas (blocks), each of which contains one or few streets and a varying number of households. In total, there are 659 mohallas and the number of households in Dhaka city is 643,016 (BBS 1999). This project utilizes stratification process and random sampling on the number of households. First, from each zone, we selected one ward with the highest level of waste generation. Then, two mohallas from each ward were chosen. This resulted in a total of 20 mohallas from the 10 wards. Next, from these 20 mohallas, 413 households were randomly chosen in proportion to each zone's population.

Research instrument

In developing countries like Bangladesh, telephone or mail surveys are impractical and not common. Many people do not have telephones (more than 80% in Dhaka city) as telephones normally belong to the population's richer class (BBS 1999). Moreover, mailing addresses' list or street directory is nonexistent and the mailing system is not reliable. Bangladesh's literacy rate is 47.9% (CIA 2010); many people are not able to read information printed on the mailed survey. The direct face-to-face interview is the most commonly used approach and was employed in this study.

The questions in the interview were grouped into three sections: A, B, and C. Section A asked the respondents about their knowledge and concern towards the environment, knowledge and

attitude towards waste management, and recycling activity. "Knowledge" here refers to respondents' awareness on recycling issues, information on what are recyclable and non-recyclable wastes, who can collect wastes and where solid waste can be disposed of (as advertised by the Bangladesh Government in the mass media). Respondents' concern for the environment was evaluated based on responses to a set of five questions in the questionnaire. A respondent was only classified as being environmentally conscious if, in response to these questions, he/she satisfied all the following criteria: perceived a clean environment as a personal responsibility, not the responsibility of other parties; participated in any clean environment campaign or project; disposed of waste responsibly during outings when no waste bins were available; was involved in some environmental protection activity; and rated him/herself as being environmentally conscious. Section B enquired the respondents about their recycling activity and waste disposal practices. Section C queried the respondents about their socio-economic information.

Before the final data gathering, two pre-tests were conducted in April 2006. The first pre-test involved 10 participants, to test on their understanding and clarity of the questions. One week later, 50 individuals were interviewed based on the modified questions from the first pre-test. In August 2006, the final data gathering was conducted in Dhaka city.

Results

Socio-economic characteristics of the respondents

Interview forms with missing information and inconsistent answers were censored and 402 (97%) responses were valid for further investigation. Table 2 shows the socio-economic characteristics of the respondents. The study found that 67.1% of the respondents were male and 32.9% female. The highest percentage of the respondents had university degree (61%) followed by diploma (13.4%), higher secondary certificate (11.8%), secondary school certificate (5.7%), primary level (4.8%), and 3.3% had no formal education. Concurring

Table 2 Descriptive statistics of socio-economic characteristics of the respondents

Item	Number of respondents	Percentage
Sex		
Male	270	67.1
Female	132	32.9
Education		
No formal education	13	3.3
Primary education	19	4.8
Secondary school certificate (S.S.C.)	23	5.7
Higher school certificate (H.S.C.)	47	11.8
Diploma	54	13.4
University	246	61.0
Employment		
Service holder	216	53.7
Business man	90	22.4
Housewife	78	19.5
Retired	18	4.4
Average		
Household monthly income	Taka (USD)	12,000 (172)
Age in years	402	39
Family members (number of persons)	402	4
Extra land with the compound	402	0.5 acre

with Dhaka’s literacy rate of 63.2% (DCC 2010), it seems that 96.7% of the respondents received formal education. Most of the respondents had tertiary education and this proportion was quite high for a developing country like Bangladesh. It could be that many of those who had tertiary education decide to reside in Dhaka city. Most of the respondents (53.7%) were service providers (paid employment), 22.4% were business people, 19.5% housewives, and 4.4% retirees. In Dhaka, unemployment remains high at 23%, half the workforce is employed in household and unorganized labor, while about 800,000 work in the textile industry (DCC 2010). On average, the monthly household income of the respondents is USD 176.1 (1 US dollar = 70.1 BD Taka). Despite many respondents having tertiary education, the total income per household is low as the annual per capita income of Dhaka is estimated at \$550 (DCC 2010).

Waste generation in the households

The respondents were asked on who normally collects and places solid waste generated in the households. Servants/maids were in charge of waste discharge among 64% and 23% was wife or mother, 10% children, and 3% husband or father

(Fig. 1). It seems that household waste disposal was likely to be done by the weaker members, for instance, children or dependent women such as a widows, daughters-in-law, or housemaids. Irrespective of education attained, many women in Bangladesh stay at home and become full time caretaker. The respondents were asked on how many containers of waste each household produce in 3 to 4 days. Most respondents (55.2%) produced three to four waste containers (Fig. 2).

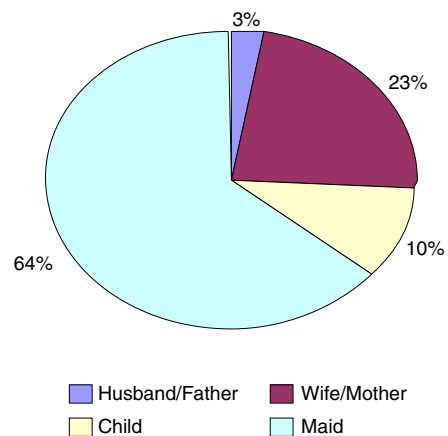
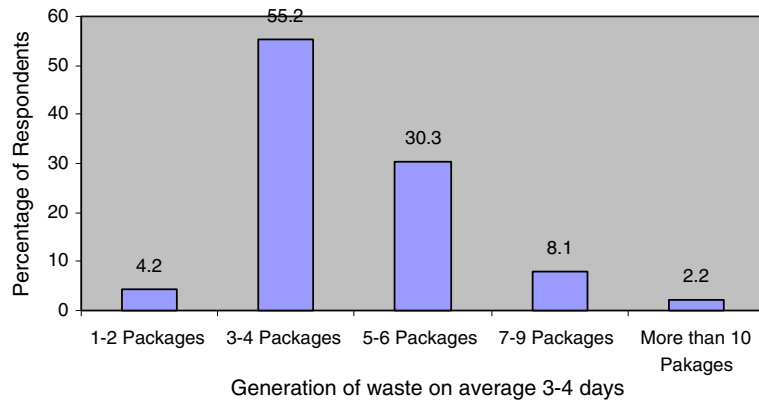


Fig. 1 Person in charge of collecting and placing of wastes for disposal

Fig. 2 Packages of wastes on average 3–4 days

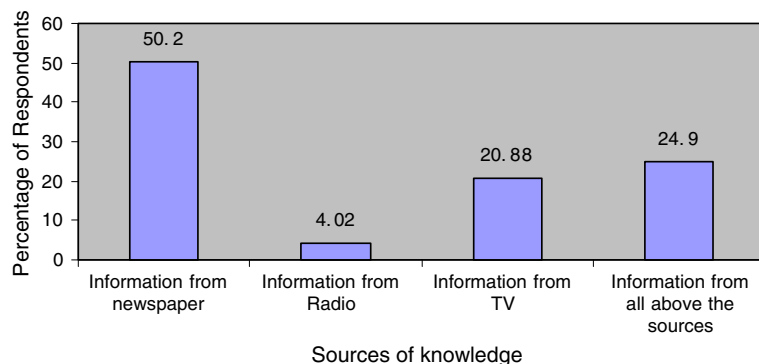


A typical waste container contained about 1 kg of waste. Waste generation in the study area averaged 38 kg/month for each household. As the household average number was 4, the waste generation averaged was 0.3 kg/day per capita, which was similar to the previous findings (AIT-UNEP RRC.AP 2005).

Knowledge about solid waste minimization

The respondents were asked about their knowledge of solid waste minimization. A majority of the respondents (61.94%) stated that they had knowledge about solid waste minimization. Figure 3 shows that the majority obtained their sources of knowledge from the newspapers (50.2%), television (20.9%), and radio (4%). In this case, the newspapers and television had been most influential in promoting environmental issues.

Fig. 3 Sources of knowledge about recycling



Waste recycling practices

In solid waste minimization aspect, the respondents were asked how often they recycle their solid waste. For recycling practice, only 25.6% regularly recycled (Table 3), 18.2% seldom recycled, and 56.2% never practiced recycling. It must be pointed out that most people in Dhaka were not and are still not served by any convenient recycling network. This high figure of those who seldom and never recycled (74.4%) agrees with the study conducted by DCC (2005) showing a high level of solid waste in Dhaka city. Of those who regularly recycled (25.6%), a majority separated recyclable materials from solid waste and sold it (74.4%), followed by those who separated the waste and gave it to waste collectors (20.9%) and separated the waste, sold recyclable materials, and composted organic materials (4.7%). The reasons given by those who

Table 3 Waste management activities

Particulars	Number of respondents	Percentage
Recycling practice		
Never practiced recycling	226	56.2
Seldom recycle	73	18.2
Recycle regularly	103	25.6
Total	402	100
Method of recycling		
Separate the recyclable materials from the waste and sell it	77	74.4
Separate the waste and give it to waste collectors	22	20.9
Separate the waste, sell the recyclable materials and compost the organic materials	4	4.7
Total	103	100
Reasons for practicing recycle regularly		
Good for environment	70	68.0
Allows for composting	11	10.7
Earn for extra income	22	21.4
Total	103	100
Reasons for seldom or never practice recycling		
There was no facility for recycling	9	3.1
Lack of time	115	38.5
No economic incentive	12	3.9
No space at home	111	37.2
No reason	16	5.4
Expensive to recycle	36	12.0
Total	226	100

practiced waste separation at the source were: good for the environment (68.0%), earn extra income (21.4%), and allows for waste composting (10.7%). On why respondents seldom and never recycled their wastes (74.4%), reasons given were: lack of time (38.49%), no space at home (37.2%), recycling is expensive (12.0%), no economic incentives (3.9%), no recycling facilities (3.1%), and no reason (5.4%). The group of households who seldom and never practiced recycling were also presented with another scenario in which the government will provide them with a container to keep and separate their household waste. Interestingly, 30.1% of these respondents were willing to separate their waste if facilities are provided.

Estimation results of waste generation and socio-economic model

The estimation result of waste generation and socio-economic model is shown in Table 4. This study found that income and household size had a highly significant positive relationship. The positive coefficient on income variable (5% significant level) indicates that, holding all other variables constant, higher income people generate more waste than the lower income people. The positive relationship between these two variables is supported by previous literatures (Jenkins et al. 2003; Jenkins 1993; Hong et al. 1993). This result seems reasonable since increases in income are expected to increase the demand for commodity products.

Table 4 Factors affecting the solid waste generation

Variables	Estimation	Standard error	t statistics
Household size	0.221	0.0082	27.01 ^a
Education	0.263	0.1413	1.23
Income	0.832	0.2659	3.15 ^b
Concern about the environment	1.90	0.78	4.32 ^a
Willingness to separate	0.56	0.12	2.33 ^a
Extra land within the compound	0.08	1.58	0.05

^aSignificant at $p \leq 0.01$

^bSignificant at $p \leq 0.05$

The positive coefficient on households' size (5% significant level) indicates that, holding all other variables constant, large families generate more waste than the smaller families. This result was expected to be positive since a larger household size was presumed to generate higher quantity of waste since more individuals are included in the household unit. Similar to previous studies (Hong and Adams 1999; Fullerton and Kinnaman 1996), the coefficient of education variable was positive but not significant. As expected, coefficient on the attitudinal variable for concern about environment was positive and statistically significant (1% significant level), which supports the hypothesis that the respondents who are more concerned about the environment in Dhaka city would have generated less solid waste and willing to improve the solid waste management program. The positive sign for concern about the environment was supported by Jin et al.'s (2006) study. The positive coefficient for willingness to separate wastes was also significant (1% significant level). This means that the respondents who agreed to separate the waste at their house are willing to recycle more and generate less waste. Extra land area had positive but insignificant effect. In the study area, there were very few households with extra land area; the result will not be useful in the analysis.

The goodness of fit model was tested in this study with some diagnostic tests which fulfilled the following criteria of good results. Firstly, the adjusted R^2 value (which is a measure of goodness of fit for the estimated regression model) of 0.51 depicts a good fitting of the model, which defines that 51% variation in charge of the waste generation of the households could be explained by the independent variables in the model. In this model, the observed R value of 0.73, R^2 value of 0.55, and the F test show that the estimated regression was quite meaningful in the sense that the dependent variable was related to each of the specified explanatory variables. The linear relation of the model was highly significant (p value for F test was less than 0.0001). Secondly, the signs for the estimated coefficients were consistent with the theoretical or prior expectations. Thirdly, most of the estimated coefficients were statistically significant (0.01 and 0.05 significant level), which was substantially different from zero.

Correlation matrix of the explanatory variables was studied to identify the occurrence of multicollinearity. The results of this multiple regression model showed no multicollinearity issues, ensuring no two independent variables have a correlation in excess of 0.70. This means that the independent variables were not too highly related to each other. The study also employed the technique of collinearity diagnostics to eliminate the problem of multicollinearity. The eigenvalues of the explanatory variables were also studied by factoring the scaled, uncentered cross products matrix of the explanatory variables. Eigenvalue provides an indication of how many distinct dimensions are among the explanatory variables. In this model, several eigenvalues of the explanatory variables were not close to 0, thus the variables were not intercorrelated and the matrix was efficiently conditioned.

Policy implication

A number of the findings in this study, if confirmed by subsequent testing, might be useful in developing public policies concerning household waste. It is evident that environmental consciousness is significant positive predictors of waste management. So, in this study it is suggested that concerted efforts to raise environmental consciousness through education and more publicity regarding waste reducing and recycling could affect the households waste generation. In recent years, reducing and recycling of households waste has become increasingly imperative because waste generation has been increasing with increase in population and economic development and resources has been becoming scarce, making recycling not only sensible practice but essential. Although there is widespread public support for reducing and recycling of households waste this is not reflected in participation levels in Bangladesh. For example this study has found that only 30.1% of the households are willing to separate their household waste if the facilities will be provided. The study has also found that only 25.6% of the households are doing recycling regularly. So, the reasons for this disparity need to be

investigated. It is suggested in this study that we should investigate what motivates people to reduce and recycle their waste and what discourages them from participating. It is essential now because the government is also attempting to reduce waste and increase recycling rates which will improve the quality of waste management system. A study by Tam and Tam (2008) showed that reward schemes and incentive systems contribute to the employee awareness and motivation regarding waste reduction, reducing waste up to 23%. As such, policies should be formulated to focus on raising awareness, promoting knowledge, and motivating households with regard to environment and waste management practices. Thus, these policy implications should be helpful to environmental and waste management planners as well as to policy makers as they manage household waste in order to reduce environmental pollution and hopefully improve performance within the household. For the waste management program to be successful, the attitudes of the residents of Dhaka towards waste reducing and recycling should be taken into consideration as should the results of this study, which are important indicators of positive attitudes of the residents towards waste reducing and recycling.

Conclusion

The population of Dhaka city is increasing tremendously every year and so does its waste generation. This study was to analyze the factors that promote household's waste generation and Dhaka city's residents' willingness to minimize household waste. Data were gathered by interviewing the residents and 402 responses were further examined. Findings show that the majority of the respondents were male, a majority had tertiary education, many worked as service providers, and the monthly household income was USD 176.1. The majority of individuals who normally collected and placed solid waste generated in the households were servants/maids and most households produced around three to four waste containers that weight about 1 kg per waste bag. Thus, the waste generation averaged was 0.3 kg/day

per capita. This study has found that majority of the respondents stated that they have knowledge about recycling of solid wastes. With regard to the source of knowledge, the majority obtained their knowledge about recycling from newspaper and television. Regarding recycling, although it is conducted mostly by informal sector, the government in Bangladesh is trying to promote the households through television and newspaper to separate their households waste and to recycle the recyclable materials. So, newspaper and television have been most influential in promoting environmental issues. The response for radio was low considering it is a developing city. But the reason is due to the sampling problem because we choose the sample from high-income area and they eventually do not use radio. This study has also found that 25.6% of the respondents are doing recycling regularly. It must be pointed out that most people in Dhaka were not and still are not served by any convenient recycling network. But in this case, 25.6% of the respondents did at least sometimes separate household waste for recycling. This was quite encouraging. This study employed regression model to determine the dominant factors that might influence the waste generation of the households. It is evident from the findings of the study that income has a positive significant effect on waste generation of the households. This result seems reasonable since increase in income is expected to increase the demand for convenience factors and services embodied in commodities. Another variable is also expectedly positively related with household waste generation. A larger household size is expected to generate higher quantity of waste since more households are included in the unit; thus, the sign is also expected to be positive. As might be expected, the coefficient for the attitudinal variable for concern about environment is positive and statistically significant. Environmentally concerned food buyers were hypothesized to be less likely to buy foods with a high level of processing and packaging. This preference would lead to a negative relationship between favorable environmental attitude and the amount of food packaging. Furthermore, environmental awareness may lead to recycling or conservation, which would reduce the solid waste. The positive coefficient

for willingness to separate wastes was also significant. This result indicates that Dhaka residents have a positive willingness to pay for the new solid waste management program, which includes a waste minimization and recycling option. This is a welcome development in the progress towards a sustainable solid waste management program.

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