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A Pilot Study on the Potential for Household Composting in a Rural Community in Guyana

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ABSTRACT

Industrial and other activities along with increased population growth have given rise to incremental challenges in solid waste management within Guyana. The challenges are similar to other small island developing states (SIDS) with limited land space being a major concern. Therefore, the need for sustainable and environmentally friendly means of eliminating or reducing the waste produced becomes necessary. Composting, therefore, can do this while adding value to the agricultural sector. The use of self-administered questionnaires was employed to collect data on factors that influence the amount and types of waste produced and to evaluate the level of knowledge of persons on the practice of composting. Waste materials were collected, separated, weighted and composted. The results revealed that household size significantly influenced the amount of waste produced. Only 22% of the persons had very good knowledge of the practice of composting. The compost revealed high levels of Nitrogen, Phosphorous and Potassium. In conclusion, several methods of composting were recommended to persons to increase awareness. The nutrient quality of the compost produced can add great value to agricultural produce if applied correctly.

Keywords: Household composting, Solid waste management, Rural Community, Environmental Science, Environmental Management.

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INTRODUCTION

According to Hoornweg and Bhada-Tata (2012), more than 50% of the waste generated in Guyana is made up of organic material often without any subsequent treatment prior to disposal to the environment. The wastes in some cases are disposed of in a poor manner, which inevitably creates unpleasant dumpsites that impact our environment negatively. This places Guyana in a precarious situation since as organic material decays; it releases a wide array of toxic substances that may result in land, air and water pollution. Some of these substances are disintegrated by the environment in small quantities, however, in large amounts, they pose a serious threat to human life as it runs the risk of being exposed to our waterways and soils. For example, the leachate that is created in the decomposition process of organic material at unofficial dumpsites may infiltrate underground water resources. Once polluted, it inevitably threatens the health of persons in that area as well as surrounding areas and as such that water resource becomes of little use. If not, vast financial resources will have to be expended to treat the contaminated water. In addition, the methane gas that is emitted as these substances decay, adds to the already increasing amounts of greenhouse gases in the

atmosphere that is resulting in the global phenomena of climate change (Hoornweg and Bhada-Tata, 2012). There is no doubt that the municipal authorities of Guyana find it difficult to dispose of any type of waste material. The inability of any developing nation to adequately dispose of its waste material is bound to have serious environmental and social repercussions (Rootes, 2009). Therefore, we continue to seek out opportunities to help mitigate this increasing problem. The generation of solid waste is a consequence of everyday life (Tchobanoglous, et al., 1993). The unmanaged disposal and the accumulation of waste material have led to crucial health and environmental dilemmas, dating as far back as the medieval times. The situation has become increasingly worse since the advent of materials that take millions of years to disintegrate. For this particular reason, countries have developed and implemented several waste disposal methods that they deemed best to help mitigate the large amounts of waste generated, all of which have their merits and demerits (Tchobanoglous et al., 1993).

The main focus of this study was to determine the effectiveness of utilizing composting as an alternative method of dealing with organic waste in a rural community in Guyana. Therefore, determining the feasibility of composting to generate revenue for this community; with the added benefit of improving sustainable crop production as a result of the compost being used to improve the soil's farming capabilities. Furthermore, this study sought to act as an instrument of education and promotion in the wide-scale adoption of efficient and safe composting techniques while raising awareness on the need to protect the environment from degradation. According to Hiraoka et al. (2003) composting is the natural process of rotting or decomposition of organic matter by microorganisms under controlled conditions. All organic matter will eventually decompose; however, some materials are more suitable for composting than others. The raw materials that are most appropriate for composting include: vegetable and fruit waste; crop residue such as banana skin; yard waste such as leaves, grass and trimmings; kitchen waste; human excreta and animal manure. The absence of an adequate waste disposal facility throughout the years has made it very difficult to dispose of any type of waste material within this community. In the past, it was never a serious problem because of the small number of inhabitants living in the area. However, due to the increasing population as a result of the introduction of new housing schemes being opened, greater amounts of waste materials are now being generated on a daily basis. By encouraging locally based composting, policymakers will ultimately strengthen the public's commitment to all forms of recycling. Thus, reducing environmental pollution with the bonuses of improving the quality of compost produced, facilitating the growth of a compost market and injecting funds into safe environmentally friendly practices to boost future sustainable ventures.

MATERIALS AND METHODS

Sampling Location

The study took place in the mining town on Linden in the community of Christiansburg, more specifically, Section "C" Christiansburg (Figure 1), which is located to the extreme north. This community has approximately 94 households most of which practice some form of agriculture from small kitchen garden, which comprises of a small portion of several different plants to an integrated farm that involves the rearing of livestock and the planting of crops.

Number of Samples

Section 'C' Christianburg consists of a total of 94 households. Stratified random sampling was used in the distribution process, for the data to be representative. Hence, the study area was divided into 4 sections based on the geography of the community, 6 questionnaires were distributed along each street resulting in the distribution of a total of 24 questionnaires. The method of probability sampling was employed, where residents in the community were given an equal chance of being selected. The questionnaires were administered after every four households to produce representative data of the entire community.

Variables

Independent Variable: Type of waste, income level, size of household, types of crops, eating habits and Dependent Variables: Amount of waste.

Data Collection Technique

Questionnaire Method

Qualitative data was collected through the use of a survey, mainly to determine some of the factors that influence the amount and type of waste generated. The questionnaires were divided into three broad sections: basic information, knowledge and willingness to participate in the practice of composting. The knowledge of the respondents was assessed using a series of true and false questions. Upon which the scores were tallied and illustrated on a scale ranging from poor to excellent. Respondents who had at least 60% of the questions correct were deemed as having satisfactory knowledge of composting.

Solid Waste Measurement Method

Quantitative data was collected through the use of a scale, a compost tumbler and chemical analysis to determine the quality of compost produced as well as samples of the soil type from the study area. The measurement of the amount of waste generated by

Figure 1. Map showing study area.

households was done using a combination of two types of scales. A crane scale (Figure 2) was used to measure large quantities of waste, while a simple household scale (Figure 3) was used to measure smaller quantities.

Procedure

Waste materials were collected from a total of 23 households for 4 weeks, to establish the average amount of waste produced by each household. Upon collection, the materials were then separated, based on their characteristics, weighed respectively, and recorded. Sampling was also categorized based on household size and income level (Low, Middle and High income) (Table 1). A total of 5lbs (2.27 kg) of manure were introduced into each compartment of the compost tumbler as an activator along with the compostable household waste to encourage the decomposition process. Household

Figure 2. Picture showing crane scale.

Figure 3. Picture showing household scale.

Table 1. Categories of sampling.

Household Size	Income Level		
	Low Income ($0-50,000 GYD)	**Middle Income ($50,001-$125,000 GYD)**	**High Income ($125,001GYD and Over)**
1-3	Category One	Category Two	Category Three
4-6	Category Four	Category Five	Category Six
7 and over	Category Seven	Category Eight	Category Nine

compostable waste was then added weekly for four weeks from the various household samples. The process was allowed to run for a total of 14 weeks, while maturity tests commenced on the 12th week until the 14th week to measure the phytotoxicity levels in the compost. Temperature recordings of the compost, inside the greenhouse and the ambient environment, were made throughout the 14 weeks of decomposition, to determine the type of bacteria that was most dominant at the different temperatures.

After the 14 weeks of decomposition, the samples were subjected to a thermal treatment (heated) to remove the remaining moisture, then individually weighed and recorded for analysis. The samples of the compost were then further mixed and tested to determine an accurate value of the amount of micro and macronutrients present in the compost material produced. Additionally, a baseline analysis of the soil in the area was done to determine the suitability of the compost for application to the soil and crops cultivated in the area. Independent Variables: Animal manure, household waste. Dependent Variables: Nutrient Content of compost produced

Maturity Test

The purpose of this test is to determine the extent of completion of the decomposition process of the waste materials for compost formation. This was done through the measurement of the rate of germination in the compost extracts. Germination is the process by which

Table 2. Respondents' performance on the knowledge test.

Poor	Satisfactory	Good	Very Good	Excellent
(0-50%)	(51-65%)	(66-75%)	(75 to 85%)	(86-100%)
10	8	0	5	0
43%	35%	0%	22%	0%

an organism grows from a seed (evidenced by sprouting). Immature compost may contain phytotoxins that will often kill seed embryos. Seeds grown in immature composts would not sprout or may die immediately after sprouting. There was also testing for major nutrients such as Total Phosphorous, Total Potassium and Total Nitrogen.

Data Analysis

Microsoft Excel was used to illustrate the results such as correlations on graphs to establish relationships and disparities between the different variables contributing to the quantity and quality of the waste generated.

Limitations

On some occasions, the collection of waste was hindered due to garbage receptacles being disturbed by stray animals.
Some persons accidentally disposed of their garbage into inaccessible sites (as is customary), despite continued encouragement not to do the same, thus preventing the collection of waste on a few occasions.
The weight of the materials in the compost tumbler made it immobile hence mixing had to be done manually.
Odor was detected which may be an indication of ammonia gas being produced.

Ethical Consideration

Persons were informed of the purpose of the research and the intended use of their household waste. Respondents and researchers were made to sign a confidentiality clause.

RESULTS AND DISCUSSION

The questionnaires were completed by 23 households, which represented a participation rate of 95.83% of the targeted households. Only 22% of respondents showed very good knowledge of composting while 43% showed poor knowledge as shown in Table 2. The results also showed that only 30% of persons were willing to practice composting and only 74% were willing to attend any educational session on composting. The survey results reflect that persons within this community did not have sufficient knowledge of composting. This means that health promotion and health education along with awareness campaigns should be done to sensitize the populace in an attempt to prepare and introduce policies that are aimed at waste separation for the utilization of compostable materials. Long term environmental education in developed countries are considered to be an effective method for increasing environmental awareness in reducing, recycling and reusing waste, beginning with children in schools and emanating into the community. A practical example of this approach is the implementation of extensive programs of education and engagement by the Mindarie Regional Council (MRC), Australia.
The council recognizes how critical it is for residents to understand how their actions in waste reduction and separation can assist their region locally and the environment globally (Atkinson, 2008). As mentioned by Atkinson (2008) the program targets a wide audience of all age groups ranging from kinder garden to senior citizens. It comprises of elements that are comprehensively educational, engaging, entertaining, motivating and fun while remaining seriously strict with regards to waste reduction. Over the years the program has seen remarkable results. Community groups have continually forwarded information on their activities and detail changes they have made in workplaces, schools and communities. Many Residents have supported a local community garden activity to utilize compost and provided building materials. All in all, the members of the Mindarie Council have reported increases in the recycling rates from their respective constituencies (Atkinson, 2008). Currently, there is no overall program for educating the public about the importance of waste separation and solid waste management in Guyana. Formal coverage in the school curriculum is quite limited. There is, however, a degree program offered in Environmental Studies and a Master's in Public Health conducted by the University of Guyana. Clearly, it shows that work needs to be done to educate persons about the importance of reducing and reusing waste. This community where 70% of the respondents indicated that they are not willing to participate in the practice of composting, simply because of the lack of knowledge on the subject is a cause for serious concern and should be addressed effectively by the competent authorities. However, on the contrary, 74% of the respondents pointed out that they would attend an educational session on composting should it be available, while 26% indicated that they would not.
These numbers can improve significantly with occasional talks and seminars within the community through the

Table 3. The result of Solid waste measurement.

Sample	(Avg. Solid Waste/Week)	(Avg. Compostable Solid Waste/Week)	(Avg. non-Compostable Solid Waste/Week)
1	7.71kg	5.91kg	1.81kg
2	4.42kg	3.18kg	1.27kg
3	4.76kg	3.40kg	1.36kg
4	4.76kg	3.86kg	0.91kg
5	16.78kg	9.98kg	6.80kg
6	6.8kg	4.08kg	2.72kg
7	3.63kg	1.81kg	1.81kg
8	4.88kg	2.72kg	2.15kg
9	6.92kg	4.54kg	2.38kg
10	6.58kg	4.65kg	1.93kg
11	5.10kg	4.08kg	1.02kg
12	3.48kg	2.27kg	1.21kg

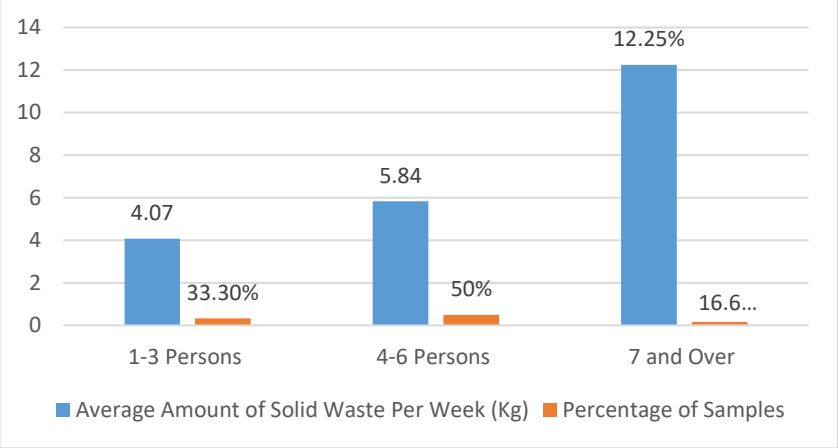

Figure 4. Graph of waste generated by the different household sizes.

Table 4. Table showing types of waste to income level.

Household Waste	Income Level		
	Low income $0-50,000 GYD	Middle income $50,001-125,000 GYD	High income $125,001 GYD and Over
Plastics	0.61kg	0.84kg	1.16kg
Glass	0.45kg	0.25kg	0.57kg
Paper and Cardboards	0.91kg	0.63kg	0.57kg
Metals	0kg	0.25kg	0.62kg
Textiles	0kg	0.11kg	0.38kg
Organic Material	4.08kg	4.06kg	4.31kg

Municipality and other government agencies. This would allow persons to become more informed of how useful and simple it is to get rid of their biodegradable waste. In addition, the introduction of environmental education into the school curriculum beginning at the lowest level would provide long-term benefits to the country at large. Through fun and engaging activities, students can learn simple ways to minimize waste in schools, which can then be transferred into homes and communities. Such programs that are aimed at reducing, reusing and recycling waste will promote the sustainable use of natural resources and minimize our collective environmental footprint. Moreover, the Ministry of Education (MoE) along with Environmental Protection Agency (EPA) will have major roles to play in developing and implementing sustained and comprehensive public outreach programs with adequate resources to change social behaviour towards the environment (Bynoe, 2010). The amount and type of waste produced by these households are imperative in determining the best possible method that can be implemented to reduce or eliminate most of the waste generated as much as possible. It is also important in assessing the feasibility and design of any energy and resource recovery system within the area (Grover and Singh, 2014). Table 3 and Figure 4 illustrate the amount of waste for each household. In addition, Table 4 illustrates the waste collected in comparison to household income. As

Table 5. Table showing average waste generated in relation to size of household.

Size of Household (Person/s)	Number of Samples (# of Samples)	Average Amount Waste per Week (Avg. Solid Waste/Week)
1 to 3	4	4.07kg
4 to 6	6	5.84kg
7 and Over	2	12.25kg

Table 6. How the level of income influenced the amount of waste produced.

Household Income (GYD Dollar)	Number of Samples (% of Samples)	Average Amount of Waste (Avg. Solid Waste/Week)
$0 - $50,000	16.66%	5.61kg
$50,001-$125,000	41.66%	6.46kg
$125,001 and Over	41.66%	5.56kg

indicated by the Table 5, 4 samples qualified for the category of 1 to 3 persons which recorded an average amount of waste of 4.07 kg within the 4 to 6 persons category an average of 5.84 kg waste was recorded while 2 samples within the category of 7 and over recorded an average amount of waste of 12.25 kg. There is a very strong correlation (R^2= 0.903) between the size of the household and the mass of waste generated. Residential waste consists of more compostable waste than non-compostable waste. For this particular reason, a small kitchen garden or a farm becomes very useful, since the compostable materials can be added to a compost pile and when finished used as organic fertilizers. This simple method would eliminate more than half the amount of waste generated by households and reduce the number of unofficial dumpsites within the community.

Also, with regards to remaining non-compostable waste or materials that are resistant to degradation such as plastic materials, metal containers, textiles, paper and cardboard, these can be sent to the local waste collection services to be disposed of. This will certainly help the authorities with the management of solid waste and even improve the system since most of the waste would be eliminated at the source where it is created. There is a clear difference in the amount of waste produced by these households and it is not difficult to determine why. The trend shows that as household size increases waste with a strong correlation to support such (R^2= 0.903). As mentioned by Grover and Singh (2014), there is a similar case in India where the annual amount of waste generated has increased, in proportion to the rise in population, which has become challenging as more land is needed for the ultimate disposal of waste. Waste is expected to increase as income increases. However, this trend was not seen. The data showed a poor correlation between the amount of waste generated and average income. Generally, the pattern of consumption decides the amount of goods each person uses, hence the consumption of goods rises as income rises and so do waste generation (Bogoro et al., 2014). One possible explanation for the low disparity in the amount of waste produced by the different income brackets is the fact that Guyana is a Lower Middle-Income Country (Hoorneg et al., 1999). In respect to rural communities like the one under study the average amount of waste produced by households within the proposed income brackets is relatively uniform. Additionally, it is fitting to note that even though persons may fall within a specific income category officially, it is quite common for low-income earners in this community to have multiple sources of income in the form of small businesses, which is quite a characteristic trait of the community. As such, no significant difference may be detected in the amount of waste generated by this category. According to Table 6, there was no particular trend among the different income categories and the amount of waste they produced. This was peculiar since it is expected that increase income would correlate with increase waste. As indicated by the Table 6, households who registered an income level between $0 to $50,000 produced an average of 5.61kg of waste, households within the income bracket of $50,001 to $125,000 recorded an average of 6.46 kg of waste, while household within the category $125,001 and over recorded an average of 5.56 kg per week. There was a poor correlation (R^2= 0.0367) between the amount of waste and average income.

The temperature of the community for the period under study ranged from 26 to 33°C throughout the entire period. The temperature of the greenhouse during this same period ranged from 29 to 35°C. While the temperature of the compost ranged from 25 to 38°C. The dried compost recorded an average moisture content of 0.5%. There is an obvious trend in the temperature fluctuations that were recorded. Within the first 7 weeks of composting the pile was most active, temperature reached its highest and ranged from 34 to 38°C. This was as a result of the availability of organic material to be decomposed by mesophilic bacteria since materials were added weekly for four weeks. In the last 7 weeks of the compost process, the temperature ranged from 25 to 33°C. During this period, the compost recorded its lowest

Table 7. Chemical analysis of the compost.

Compost Analysis Report			
Parameter	**mg/kg**	**Percentage**	**Average Nutrient of Compost mg/kg**
Nitrogen (N)	19025	1.9025	3000-15000
Phosphorous (P)	1164	0.1164	1000-10,000
Potassium (K)	14300	1.43	3000-10,000
Copper (Cu)	2.19	0.000219	
Manganese (Mn)	59.3	0.00593	
Iron (Fe)	4.7	0.00047	
Boron (B)	21	0.0021	
Sulphur (S)	438	0.0438	
Calcium (Ca)	2839	0.2839	
Magnesium (Mg)	1772	0.1772	
Cadmium (Cd)	ND	ND	
Chromium (Cr)	0.09	0.000009	
Nickel (Ni)	ND	ND	
Lead (Pb)	ND	ND	
Zinc (Zn)	148	0.0148	

ND- Not Detected

The Table illustrates the nutrient analysis report of the compost produced. According to the table above, of the primary macronutrients tested in the compost, the total nitrogen content was 1.9025%, the total phosphorous content was 0.1164% while potassium had a recording of 1.43%.

temperatures, indicating a less active compost pile. This was as a result of the lack of fresh organic material for the microorganisms to decompose. The temperature of the compost did not drop dramatically; instead, it remained almost consistent with the temperature within the greenhouse. This is entirely due to the tropical climate of Linden, Guyana, which is generally warm throughout the year. According to the US Composting Council (2017), the optimum moisture percentage of finished compost ranges between 40 to 50%. However, the dried compost recorded average moisture content of 0.5%. This result indicates that the compost is dusty and maybe irritating to work with, but it can be adjusted by the simple application of water. When the chemical composition of the compost was compared to the Food and Agriculture Organization (FAO) average range of nitrogen, phosphorous and potassium content that can be found in household compost, Nitrogen amounts were above the average range, phosphorous amounts were within the average range, while potassium amounts were above the average range. The tested heavy metals in the compost such as nickel, lead and cadmium were not detected, while zinc and chromium were well below standards posited by the German Compost Quality Standards. The low level of heavy metals in the compost indicates that the materials were adequately separated hence reducing the chances of trace metal contamination. Although this compost contains fertilizing elements for plants in an organic form, it has a smaller amount than synthetic mineral fertilizers. It is recommended that before applying the compost to specific plants as well as fertilizers, a soil test must be performed to control the nutrient levels and adjust the fertilization based on the release mechanism and crop needs (Martinez and Pantoja, 2015).

The results of the maturity test would indicate that the compost was immature after its 14 weeks decomposition period and that there were high levels of phytotoxicity present. Compost that contains high phytotoxic levels, which may stunt or kill plants and should not be used as a growth medium or should be incorporated into soils in which crops are already planted. It was found that the compost contains 19025 mg/kg of total nitrogen, of this amount it is estimated that 2165 mg/kg is available for plant absorption as mineralized nitrogen. Cucumber that is one of the major crops that is cultivated in the study requires 200 mg/L of mineralized nitrogen for 1 fully developed plant. This would mean that there is enough mineralized nitrogen in the compost to support the growth of a total of 10.8 cucumber plants. Secondly, Pak Choi is another major crop that is cultivated in the area, requires a total dose of 116 mg/L of mineralized nitrogen for one fully developed plant. Since the total amount of mineralized nitrogen that is available for the plant in the compost is 2165 mg/kg, it would mean that there is enough available nitrogen found in the compost for the development of 18.6 fully developed Pak Choi plants. Based on the chemical analysis done on the compost (Table 7), it was found that there are sufficient concentrations of mineralized macronutrients like nitrogen, phosphorous and potassium to facilitate the growth of the major crops found in the study area. This approach is not without its faults as waste separation, awareness building and implementation of such a system among households are very challenging and expensive for private enterprises (Ali et al., 2004).

CONCLUSION

Composting remains one of the simplest and most effective means of waste reduction around the world

today, yet its practice is often overlooked. Its ability to eliminate more than half of the waste material generated by households at little to no cost is remarkable. It has greater potential on a larger scale to generate a significant amount of revenue, not only for enthusiastic communities but nationally. The majority of persons in the study area possessed poor knowledge of composting however, the willingness to be educated more on the topic of composting is encouraging. The compost possessed an adequate amount of N, P and K that were above the typical values detected in composts from household wastes, and as such is very suitable for leafy crops. The feasibility of a composting management program will depend on the policies norms and regulations that the government can put in place to initiate and grow this sector as a part of a national waste management program. However, education and awareness will play a part in the quest for waste reduction through the practice of composting because as reflected by the results, most persons lack basic knowledge of what it entails. Only then person will develop a moral responsibility for the environment, leading to an increase in the number of persons separating their waste material. It will have the most impact on our society if introduced in the school's curriculum so that children from a young age will develop a moral responsibility for the environment and this will emanate into our growing society. The government will play a major role if the total amount of waste is to be significantly reduced. First, the provision of an adequate waste disposal facility to dispose of waste material will be a priority. The creation of a business environment to encourage the sale of compost can be another way to foster the practice. Lastly, through the development and implementation of standards to safeguard the quality of compost produced and the health of the nation.

RECOMMENDATION

An investigation should be done on the extent to which the greenhouse increases the rate of the decomposition of organic material based on its design.
An investigation should be done on the identification of the most lucrative market segments for composting in Guyana and what strategies can be implemented to add to its salability.
An investigation into the effects of household compost on the growth rate of the different types of crops.

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