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Segregation of Biodegradable Solid Wastes of Chittagong Metropolitan Area Based on Specific Physical and Chemical Properties

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Abstract: The present study was conducted to identify the most potential source and composition of biodegradable solid waste generated in the Chittagong metropolitan area of Bangladesh, without which any energy recovery plan from solid waste tends to be trivial. The composition of the domestic source along with their sub sources (done by systematic sampling) and physical and chemical properties were studied. Pertinent domestic source was found the most potential (75.75%) source of biodegradable solid waste production. Vegetable matters and remaining of fruit matters was found the highest component (38.4%) of domestic solid waste along with the sub sources ranging from 50 to 25%. Average waste density, moisture content, organic matter, C: N was found 117 kg m^{-3} (ranging from 136.23-95.36 kg m^{-3} among the sub sources), 30 (34.13-25.38%), 39.57% (43.03-35.75%) and 17 (20.37-15.08), respectively. The study revealed the promising prospect of the capability of ostensible domestic solid waste to redeem the energy rather than pervert them to dump in the open low value lands.

Key words: Biodegradable, solid waste, domestic source, waste density

INTRODUCTION

Like other developed and developing countries, managing the solid waste, which comprise of domestic, commercial, industrial, agricultural and mining wastes, has become a matter of major concern in Bangladesh (Rao, 1998). Rapid population growth and uncontrolled urbanization are irreparably degrading the urban environment and placing serious strains on natural resources and consequently hindering back equitable and sustainable development. However many of these waste materials can be reused and thus, can become resources rather than wastes (Kumar and Bhowmick, 1998). The solid waste generation of the urban areas in Chittagong City is increasing proportionately with the growth of its population, which is posing serious threat to the management and disposal of solid wastes.

Chittagong is the gateway and the second largest city of Bangladesh with a substantial, self-sustaining economic base. It lies between latitude 22°14′ N and 22°24′ N and longitude 91°46′ E and 91°53′ E (GOB, 2003). Chittagong city was declared as municipal city in 1863. It is then up gradated as Municipal Corporation and finally as City Corporation in 1990 (Anonymous, 1992). The total production of solid waste from all sources is 1069 ton day^{-1} (Shahin, 2005). The amount of solid waste produced from industries and clinics in the city are much lesser in quantity than domestic wastes (Anonymous, 2000). A sound and effective solid waste management system is to be introduced through segregation of the solid waste on the basis of their specific physical and chemical properties. Therefore, this piece of research was conducted to identify the potential sources for production of biodegradable solid wastes and to examine the physical and chemical properties of wastes from these sources and their sub sources.

MATERIALS AND METHODS

The present research was conducted from September 2004 to June 2005. The selection of areas for collecting solid wastes was done on the basis of zonation of the city area viz: residential, commercial and industrial. Systematic sampling was carried out to select sub sources of the potential source of generating biodegradable wastes. There are 41 wards (administrative area) in Chittagong City Corporation of which 10 wards were selected (≅25% sampling intensity) randomly for collecting solid wastes to segregate into biodegradable and non-biodegradable solid wastes and to study their physical and chemical properties. Samples (5 kg) were collected from two local disposal points (dustbins), of each selected ward. The sample were then segregated (weight basis) into nine predetermined categories namely vegetables matters and remaining of fruits, newspaper, tree trimmings and straw, glass, stone ceramics and debris, plastic and

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polythene, cloths, rubber, clay to study the physical composition and to know the amount of ostensible biodegradable and not biodegradable solid waste.

Physical and chemical properties of the waste sample were determined by measuring waste density (weight method), moisture content (oven dry method), pH (using digital pH meter TOA, Japan), percentage of organic matter, organic carbon (percentage organic matter and organic carbon were determined using method described by Ball (1964) and nitrogen (using Micro-Kjeldahl digestion procedure).

RESULTS AND DISCUSSION

Out of the four selected sources of municipality wastes, domestic waste was found as the most potential source for using in the recycling process (Table 1). It has been depicted from the table that the commercial and industrial wastes possess more non-decomposable matter than the residential waste. Presence of rubber, cloths are also significantly more in case of commercial and industrial wastes than residential wastes. This may be due to the use of various plastic and rubber products and packing products in different offices, trade centers in case of commercial areas and due to the presence of large numbers of garments industries and various small automobile engineering shops in case of industrial areas. This result is in consistent with the findings of Ahmed (1994), who recorded 1.98% plastics, 8.18% paper, 12.11% metal, glass and construction wastes, 1.28% cloths and 46.45% food waste in commercial areas of Chittagong City. Residential areas thus proved to be the potential source for solid wastes rich in decomposable matter.

The current study revealed that the domestic solid waste contains only 19.95% inorganic matters in the study area. The presence of lower inorganic matters may be due to the presence of fewer amounts of industries, lower consumption capacity of the inhabitants of the city. This result is in consistent with the findings of research on solid waste in three districts of Bangladesh (Bhide, 1990). However in developed countries inorganic waste comprise 26.5% of domestic solid waste (Saxena, 1999). This may be due to the use of inorganic chemicals, non-biodegradable components in higher quantities by the inhabitants of developed countries. Nature of segregation of domestic solid wastes collected from ten sub sources are shown in Table 2.

It is also revealed from the study that 81.05% of the solid wastes are biodegradable matter and the rest 18.95% are non-biodegradable. The small amount of plastic and polythene were found in the domestic solid waste, which may be due to the ban on the use of polythene in general. The reason for absence of glass (0%) (Table 2) may be due to the collection of the broken and unused glass by the school dropout children and unemployed people as the unused glass pieces have a reselling value to the recyclers.

Table 1: Composition of solid wastes from different sources in Chittagong City area

Sources	Readily Biodegradable					Not readily Biodegradable					
	Vegetable matters and fruit remaining (%)	Newspaper (%)	Tree trimmings and straw (%)	Clayey matters (%)	Total*	Glass (%)	Stone ceramics and debris (%)	Plastic and polythene (%)	Cloths (%)	Rubber (%)	Total*
Domestic	41.4	4.2	22.6	7.55	75.75ᵃ	-	7.85	9.1	6.3	1	24.25ᵈ
Commercial	15	5	10	-	30ᵇ	-	5	15	40	10	70ᶜ
Textile industrial	5	5	-	-	10ᵈ	-	5	5	70	10	90ᵃ
Mechanized industrial	-	15	10	-	25ᶜ	-	5	10	60	-	75ᵇ

*Same letter (s) in the same column did not vary according to Duncan's Multiple Range Test at $p<0.05$

Table 2: Composition of solid wastes from domestic source in Chittagong City area

Sub sources	Vegetable matters and fruit remaining (%)*	Newspaper (%)*	Tree trimmings and straw (%)*	Clayey matters (%)*	Stone and debris (%)*	Plastic and polythene (%)*	Cloths (%)*	Rubber (%)*	Glass (%)*
Chawlkbazar	50^{a}	5^{bc}	15^{d}	-	10^{c}	10^{b}	5^{c}	5^{a}	-
Alkaran	40^{c}	10^{a}	30^{a}	-	10^{c}	10^{b}	-	-	-
Jamalkhan	35^{d}	-	30^{a}	25^{a}	5^{d}	5^{c}	-	-	-
Bagmoniram	50^{a}	3^{c}	20^{c}	-	-	12^{a}	15^{a}	-	-
Sholakbahar	33^{d}	3^{c}	29^{a}	5.5^{d}	3.5^{d}	11^{a}	15^{a}	-	-
Anderkilla	25^{f}	5^{bc}	25^{b}	-	25^{a}	10^{b}	5^{c}	5^{a}	-
East madarbari	46^{b}	6^{b}	25^{b}	-	5^{d}	10^{b}	8^{b}	-	-
Enayetbazar	30^{e}	5^{bc}	22^{bc}	-	20^{b}	8^{b}	15^{a}	-	-
West madarbari	40^{c}	5^{bc}	15^{d}	20^{b}	5^{d}	10^{b}	5^{c}	-	-
Pathantooly	35d	-	25^{b}	15^{c}	5^{d}	5^{c}	5^{c}	-	-
Average	38.4	4.2	23.6	6.55	8.85	9.1	7.3	1	0
F-value	78.32	14.37	34.62	-	71.03	7.38	78.45	-	-

* Same letter (s) in the same column did not vary according to Duncan's Multiple Range Test at $p<0.05$

Table 3: Different physical and chemical properties of domestic wastes of sub sources

Sub source	Waste density (kg m^{-3})	Moisture content (%)	pH	Organic matter (%)	Organic carbon (C) (%)	Nitrogen (N) (%)	C: N
Chawlkbazar	115.13	30.78	7.2	39.46	29.02	1.57	18
Alkaran	129.81	33.69	6.8	43.03	30.11	1.74	16
Jamalkhan	136.23	34.13	7.1	42.53	29.41	1.6	15
Bagmoniram	114.22	28.13	7.2	37.69	27.35	1.81	17
Sholakbahar	109.87	30.48	7.2	36.87	28.22	1.75	19
Anderkilla	121.03	25.38	6.6	39.64	25.9	1.59	17
East Madarbari	102.58	30.02	6.2	35.75	27.47	1.91	16
Enayetbazar	95.36	28.12	6.6	38.41	29.64	1.82	18
West Madarbari	132.56	27.46	6.7	40.15	24.89	1.65	15
Pathantooly	111.82	28.47	6.8	42.18	29.13	1.43	17
Average	116.86	29.67	6.8	39.57	28.11	1.69	16.8

The domestic solid waste from the study area has only 18% of non-combustible matters (Table 2) in comparison of developed countries where non-combustible matters is 24% (Saxena, 1999). This result indicates that domestic waste of the study area is more potential for biological decomposition. The major portion of the waste consists of vegetable matters and remaining of fruits (38.4%) followed by tree trimmings and straw and (23.6%) (Table 2) thus may be considered for composting.

Vegetable matters and remaining of fruits contains the major portion of the domestic solid waste of study area, this may be due to the presence of large number of squatters or slum dwellers living in and around the study area. Secondly, in case of the sub sources, the areas, which contain the large daily vegetable markets, like sub source Chawkbazar (W. No. 16) and Bagmoniram (W. No. 15) contain 50% of their waste along with vegetable matters and remaining of fruits. These sub sources also contains more plastic and polythene matters (Table 2) than others, may be due to their use during trading. However, the sub source Jamalkhan (W. No. 21), which is the cleanest ward in the City Corporation, contains maximum biodegradable matters than others. These may be due to the collection and pre-dumping segregation of solid wastes by small-scale waste processing enterprises.

Density of domestic solid waste varies widely. However, the average density of domestic solid waste found was 116.86 kg m^{-3} (Table 3). The highest density was found in case of sub source Jamalkhan (W. No. 21) followed by sub source West Madarbari (W. No .29) and the least was found in sub source Enayetbazar (W. No. 22) (Table 3). This may be due to the large amount of vegetable and fruit matter and presence of clayey matters. The waste of the sub sources located near or within the slums tends to be denser than the sub sources mainly inhabited by middle or upper income group of people. This may be due to the higher density of lower income group of people in these areas and also due to the presence of improper drainage and sanitation condition which increase the moisture content of the solid waste and ultimately the waste density.

Waste tends to have a lower density in industrialized countries than in Asia, due to the predominance of non-putrescible components (Alter, 1983). The high-density values of municipal and residential wastes indicate refuse rich in decomposable matter and can be economically used for composting or energy recovery. But the main problem with these bulky products in case of developing countries lies with its huge cost of transportation to the final disposal point (Gupta, 2002).

Moisture content also indicates decomposability of domestic solid waste. The average moisture content was 29.66% (Table 3). The moisture content was found highest in sub source 3 followed by sub source 2 and least in the sub source 6. Deposition of higher amount of vegetable and fruit remaining, tree trimmings and straw and clayey substances possibly contribute the higher moisture content of the wastes. At the same time, the cleaners in some sub sources also deposit the solid waste in the local disposal points straightway from the drains, which contribute much of the moisture content.

The rich decomposable matters like food and vegetables contribute higher moisture to residential wastes (Park and Bhargava, 1992). Aerobic decomposition precedes best between 40 and 70% moisture with good aeration (Anonymous, 2004). If the moisture content falls much below 40%, many of the organism will cease to function, moisture content above 70% may cause the waste to go anaerobic and thus producing foul odors. On the other hand the higher moisture content tends to increase the bulk of the waste and increase the cost of transportation. Thus, the domestic waste of Chittagong City provides a good source for aerobic decomposition

The range of pH lies between 6-7 among all the sub sources (average 6.84) (Table 3). However, in case of sub source Anderkilla (W. No. 32) the pH level was found much lower than the average value. Materials that contain large amounts of ash will have a high pH and may be expected to lose more nitrogen (Trivedi and Gurudeepraj, 1992). Generally, the decomposition rate is enhanced in pH range 6 to 7 (neutral). Since the industrial wastes tends to be acidic in nature (pH 3 to 6) may not easily

Table 4: Correlations between different parameters

		Waste density (kg m^{-3})	Moisture content (%)	pH	Organic matter (%)	Organic carbon (C) (%)	Nitrogen (N) (%)	C: N
Waste density	Pearson Correlation	1.000	0.360	0.297	0.692*	-0.188	-0.427	-0.680*
(kg m^{-3})	Sig. (2-tailed)	-	0.307	0.405	0.027	0.603	0.218	0.030
Moisture content	Pearson Correlation	0.360	1.000	0.324	0.386	0.687*	0.066	-0.237
(%)	Sig. (2-tailed)	0.307	-	0.361	0.271	0.028	0.856	0.510
pH	Pearson Correlation	0.297	0.324	1.000	0.198	0.260	-0.313	0.323
	Sig. (2-tailed)	0.405	0.361	-	0.584	0.467	0.378	0.362
Organic matter	Pearson Correlation	0.692*	0.386	0.198	1.000	0.347	-0.677*	-0.458
(%)	Sig. (2-tailed)	0.027	0.271	0.584	-	0.326	0.031	0.183
Organic carbon	Pearson Correlation	-0.188	0.687*	0.260	0.347	1.000	-0.031	0.255
(C) (%)	Sig. (2-tailed)	0.603	0.028	0.467	0.326	-	0.933	0.477
Nitrogen	Pearson Correlation	-0.427	0.066	-0.313	-0.677*	-0.031	1.000	0.067
(N) (%)	Sig. (2-tailed)	0.218	0.856	0.378	0.031	0.933	-	0.855
C: N	Pearson Correlation	-0.680*	-0.237	0.323	-0.458	0.255	0.067	1.000
	Sig. (2-tailed)	0.030	0.510	0.362	0.183	0.477	0.855	-

* Correlation is significant at the 0.05 level (2-tailed)

decomposable and thus not suitable for converting into good compost (Richard, 1992).

In the current study the average organic matter, organic carbon, nitrogen found was 39.57, 28.11 and 1.69%, respectively (Table 3). In the sub sources having more biodegradable matters generally, contribute more organic matter in waste and hence contain higher organic carbon contents. The reason for the decrease of nitrogen content of some sub sources may be the late collection of sample, which allows escaping nitrogen in the form of ammonia (Anonymous, 2004). However, the subsequent sub sources having higher C: N ratio is due to the presence of higher nitrogenous materials in the wastes, which implies a good possibility for composting or energy recovery.

The proportion of carbon and nitrogen to each other is of great importance in all phases of organic matter (Anonymous, 2004). Carbon and Nitrogen content of the collected samples reveal that they are good for composting. Optimum C: N either in the preliminary stage i.e. before composting is very crucial. The average C: N was 17 (Table 3), which shows good potentiality of composting. A ratio of available carbon to available nitrogen of about 30 or more permits minimum loss of nitrogen in case of garden debris (Anonymous, 2004). Though no study had yet been carried out to find out the appropriate C: N of the solid waste of the studied area, the sub sources Chawkbazar (W. No. 16) to Bagmoniram (W. No. 15) and Pathantooly (W. No. 28) of the present study were identified of having good potentialities for composting.

Composting is a process of biological process influenced by a variety of environmental factors waste density, moisture content, pH level, organic carbon, organic matter, nitrogen, presence of micro-organism, oxygen levels, temperature etc. (Storm, 1985). In the current study Karl Pearson's coefficients of correlation among different physical and chemical properties of samples were calculated and the results are shown in Table 4. The result showed negative correlation of Organic carbon (C), Nitrogen (N) and C: N and a positive correlation of Organic matter with waste density, a negative correlation of C: N and a positive correlation of Organic carbon with moisture content. At the same time there exists a negative correlation of Nitrogen with pH while a negative correlation of C: N and Nitrogen whereas a negative correlation of Nitrogen with Organic carbon. However, this interrelation showed a good potentiality for accelerating recycling process. Eventually it is recommended to use domestic solid waste for recycling (composting) not in mere land filling.

It has been predicted from the present study that domestic source of solid waste production of a third world country city like the present one is the most potential for bio decomposition. Among the domestic sources sub sources Jamalkhan (W. No. 21), Alkaran (W. No. 31) were found the most effective for any sort of energy recovery plant. The study also emphasis on the in-situ segregation of domestic solid waste from industrial and commercial source to save our environment from havoc due to the raw dumping of solid waste from all sources together in low value lands. It has also emphasized on the possibilities of converting the wastes as a useful matters.

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