Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2021, 8(3):58-66**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Composting and Co-Composting: Study on Recovery of Solid Waste Organics and Fecal Sludge Nutrients at Chattogram City, Bangladesh

Sabrin Ara[1]*, Mohammad Salah Uddin[2], Md. Majidul Ahad[3]

[1,2]Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh
[3]Department of Civil Environmental Engineering, Port City International University, Chattogram, Bangladesh.
*Corresponding author Email: sabrinara.sust@gmail.com; sabrin-cee@sust.edu
ORCID: 0000-0002-8767-4686

Abstract While urbanization is the forename of development of a country or a city, it brings reduction in natural resources and upsurge in waste stream. The volume of solid waste and fecal sludge is directly related to the increase in population which in turn is inspired by the attitude that urban areas have better opportunity to seize for betterment of life. To make the best consumption of the inadequate resources, recovery from waste is indispensable. Composting from solid waste and co-composting from both solid waste and fecal sludge (3:1) to reprocess the organic portion of solid waste and recover the nutrient of fecal sludge are inevitable in this combat. The study aims at investigating the quality of the output products from both this two processes of resource recovery to explore their potentials at Chattogram, Bangladesh. Co-composting, with enhancing compost products nutrients, assists correspondingly the solid waste management, sanitation and farming demands. In this research, both compost sample and co-compost sample were experimented to report the quality and to make recommendation. The result shows that both the samples meet the standard parameters guideline except for the moisture content and Potassium (K), which again can be made invariant by using sawdust (15%).

Keywords Co-compost, Compost, Fecal sludge, Organic waste, Urbanization

1. Introduction

Urbanization is one of the most obvious global changes in the present world which is in turn responsible for the challenges regarding production of wastes at a high and increasing rate. With the prompt increase in population and unplanned urbanization, many developing countries, are facing a vast challenge of managing solid waste [1] as the waste generation percentage is swelling even quicker than the frequency of urbanization [2]. Municipal services in most cities and towns are already over-burdened and hardly can meet the growing demand. Kaza *et al* [3] indicated the World Bank estimation of waste generation rate which is 0.74 kg/capita/day and will increase by 2050 by 70%. Afolabi and Sohail [4] said in their study that not more than 50% of the global population follows the waste disposal standard. Waste dumping in landfills is still the most common destination, but scarcity of land for landfills is a limitation. Urban expansion is causing the bare lands to be filled up leaving no suitable space for using as landfills [5]. Methane gas produced from degradation of organic solid waste causes global warming [6] which is a threat for the landfill area and can cause explosion. Again, landfilling process involves a quite good number of people which also requires to be salaried. Moreover, NIMBY (not in my back yard) and LULU (locally unacceptable land use) syndromes create hesitation in local people for newer landfill site acquisition [7].

Poor supervision of solid waste management results in intense urban, sanitary and environmental problems [8] and organic waste is even more important issue due to the harm it can cause to the public health and environment if not managed appropriately [9]. Municipal settlements mainly produce waste which is mostly organic in nature (raw or cooked food waste, garden waste) and rich in nutrient content. Altering the organic modules of the waste into valuable products is a good way to lessen landfilling related cost and impacts [10]. The port city of Bangladesh, Chattogram (previously called Chittagong) city accommodates about 5 million people [11]. But the present urban solid waste management scenario in Chattogram is not standard [12] which needs to be improved. In Chattogram city, 50% of the waste by weight, is recyclable in nature [13] while among all the household wastes, 66%- 73.6% of the waste is organic and compostable [14-15]. According to Masum *et al* [15] waste generation in Chattogram city is about 2289 ton per day having a rate of 0.31 to 0.51 kg/capita/day which again can have seasonal variation. The authors also made estimation of waste generation for the year 2051 which brings 4885 ton/day. Md. Tashfique, Nafisa and Safwan [16] conducted a survey research on management of solid waste in Chattogram City and concluded to a more efficient management to overcome the problems related the existing management system. Composting (hygienic alteration of organic wastes [17]) is one of the smartest, oldest and well-established approach of reprocessing the organic portion of the municipal solid waste which not only reduces landfilling related problems but also adds money by the output products meeting agricultural demand [18-19]. This biotechnological process [20] is comparatively modest, long-lasting and cheap alternative for reducing decomposable waste which also assists in avoiding Green House Gas (GHG) emissions through contributing towards carbon sequestration [21-23]. Increased demand of food by the increased inhabitants triggers at increasing crop production which again demands for enhancing soil quality. Composting has that testimony by more output and soil resilience through improving the soil structure and water retention capacity as well as diverting the tendency of land degradation [24-28]. According to Sadeghi *et al* [29] compost shields soil against wind, prevents soil erosion, upsurges soil porosity and decreases plant toxicity and waste volume.

On the other hand, fecal sludge generation is related with population which can be of both in liquid and semi-liquid forms and is considered one of the principal causes of pollution [30]. Disorganized throwing away of fecal sludge in the environment donates numerous diseases and infections [31-32]. Organic nutrients present in fecal sludge can intensify the water holding ability of soil, decrease erosion and offer a source of gradually released nutrients [33]. Through proper sanitation processes these valuable nutrients can be reclaimed as compost from fecal sludge [30] to lessen the declination of crop production due to loss in soil nutrients [34]. To increase the crop productions chemical or inorganic fertilizers are used which are not sufficient to hold the soil resources [21]. Using fecal sludge as a soil improving material has more benefits over applying chemical fertilizers alone [35].

From these two point of view, composting can with be done using the mixture of both the organic fraction of municipal solid waste and fecal sludge which is called co-composting [36]. As degradable solid waste contents high amount of organic carbon and fecal sludge has a high moisture and nitrogen content [37], output compost from these two will be rich in nutrient content to serve as soil conditioner as these two materials balance each other [38]. Since the output products from both the composting and co-composting processes comprise various substances like heavy metals that can be poisonous to plants, pass through the food chain, pollute water and affect human health, quality test of the output products is a must [39]. The potentials and execution of combined treatment of both fecal sludge (FS) and organic solid waste (SW) through co-composting was presented by Cofie *et al* [21].

In Chattogram city, the conservancy wing of the Chattogram City Corporation (CCC) has the responsibilities for solid waste management. Dustha Shasthya Kendra (DSK), a non-government organization, implemented a project for fecal sludge treatment at Anandobazar area of Halishahar, Chattogram aiming to rise hygiene coverage. Though there is a compost plant functioned under the CCC wing in Chattogram where only 0.44% of the collected waste is disposed for composting [40], co-composting is not practiced in large scale here. In this study efforts have been made to investigate the quality of the output products from both composting (organic solid waste) and co-composting (fecal sludge and organic solid waste) in order to recommend a more potential approach to the existing solid waste and fecal sludge management system in Chattogram, Bangladesh.

Additionally, this approach of resource recovery operation will also help solving the unemployment problem by involving the deprived people [5].

2. Study Area

The area has been chosen for this study is Chattogram city (Figure 1), the second largest city in Bangladesh as this area is a perfect match of the problem statement of this research. The area of Chattogram city is about 185 sq. km (60 sq. miles) having population of 25, 82401 [11]. The area is separated into 11 thanas, 41 plots and 211 mahallas, 5, 56,451 families [11] and furnished with 1350 dustbins, 95 metallic containers [41].

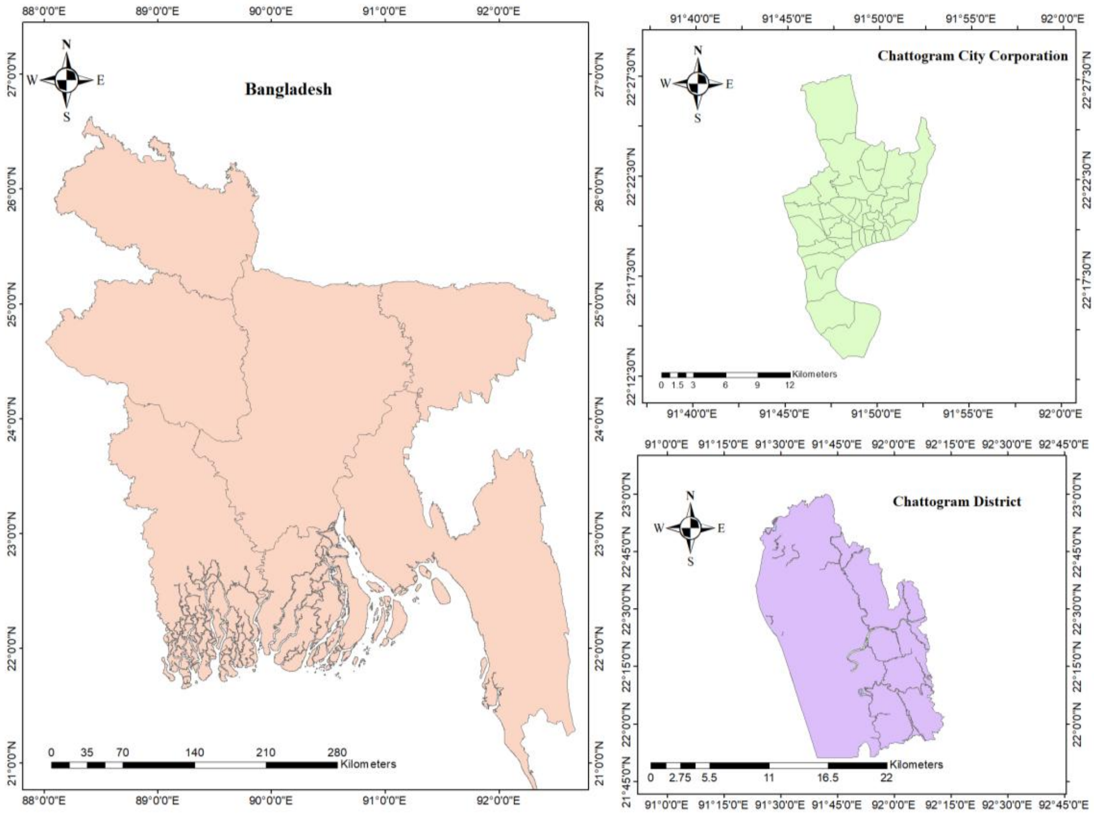

Figure 1: Study area of this research

3. Methodology

The overall work steps of this research started with gathering key information about the fecal sludge management (FSM) plant and compost plant situated in Anandobazar, Chattogram and ends at making recommendation.

Information of the existing fecal sludge management (FSM) plant functioned by Dustha Shasthya Kendra (DSK) and compost plant operated by CCC are presented in Table 1.

Table 1: Key information of FSM plant and compost plant

FSM plant				Compost plant
SL	**Description**	**Quantity**	**Capacity**	• Project Start : 2002
01	Total land area	1	8640 sft	• Total area : 250 decimal
02	Drying bed*	12	2 m^3 each time	• Manpower : 21+
03	Constructed wet land	4	25’x15’x4.5’	• Raw materials use : 100 ton/month
04	Polishing pond	5	25’x10’x4.5’	• Compost bed : 38
05	Dry sludge storage shed	1	45’x25’	• Volume of compost bed : 800 cubic meter

*Every drying bed is used 2 times per month. This plant capacity is 48000 liters per month.
Figure 2 shows the methodology of this research.

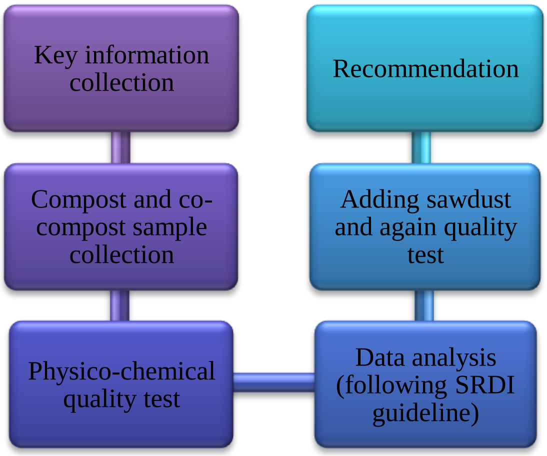

Figure 2: Work methodology of this research

Compost is the output products from the organic solid waste and co-compost is formed from both organic solid waste and fecal sludge in a mixing ratio of 3:1. Figure 3 shows the steps are taken by the plant for producing co-compost.

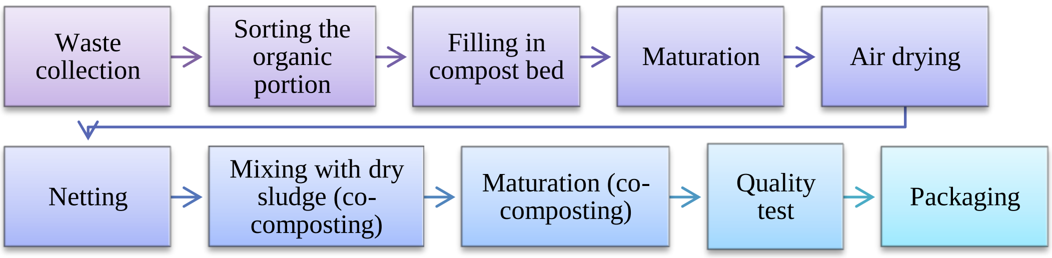

Figure 3: Work procedure followed by the compost plant for co-composting

3.1. Experimental program

It is essential to investigate the parameters value with a view to ensuring the use of the output products in soil will enrich the soil quality. The standard guideline for the compost indicates the value of parameters which will be helpful in enhancing the soil property. Deviation from the standard range will weaken organic activity and slow the desired composting process. Both the compost and co-compost samples were collected in 3 batches at an interval of 15 days to perform laboratory experiments of the physico-chemical parameters of those samples. Approximately 30 g sample was collected in each sampling through sampling holes. After that the parameters (depicted in Table 2) were compared with the standard compost quality guidelines by Soil Resource Development Institute (SRDI), a government organization of Bangladesh. All the tests were executed according to standard procedure prescribed in "Manual for Fertilizer Analysis", Ministry of Agriculture, Government of the People's Republic of Bangladesh. These tests were done in "Mrittika Gobeshona Institute", Bangladesh.

Table 2: Physico-chemical parameters to be tested

Property	Test performed	Standard value*
	Color	Dark grey to black
Physical parameters	Physical condition	Non-granular form
	Odor	Absence of foul odor
	Moisture content	15-20%
	Organic Carbon (C)	10-25%
	Total Nitrogen (N)	.5-4.0%
	C:N	Maximum 20:1

Chemical parameters	pH	6.0-8.5
	Phosphorus (P)	.5-3%
	Nickel (Ni)	Maximum 30 ppm
	Potassium (K)	.5-3%
	Sulfur (S)	.1-.5%
	Zinc (Zn)	Maximum .1%
	Copper (Cu)	Maximum .05%
	Chromium (Cr)	Maximum 50ppm
	Cadmium (Cd)	Maximum 5 ppm
	Lead (Pb)	Maximum 30.0 ppm
	Inert material	<1%

*Fertilizer (Management) Act 2006 and Compost Standards of Ministry of Agriculture, Government of Bangladesh for use in the agricultural purposes.

4. Result and Discussion

The experimental results from the tests are presented in tabular form. Table 3 represents the parameters for the compost sample. From the results it can be observed that, almost all the physico-chemical parameters mentioned earlier excluding moisture content meet the standard quality provided by SRDI.

Table 3: Physico-chemical analysis of the compost sample

Test performed	Test result			Standard value
	Sample A	Sample B	Sample C	
Color	Dark grey	Grey	Dark grey	Dark grey to black
Physical condition	Non-granular form	Non-granular form	Non-granular form	Non-granular form
Odor	Absence of foul odor	Absence of foul odor	Absence of foul odor	Absence of foul odor
Moisture content	12.44%	11.97%	13.23%	15-20%
Organic Carbon (C)	22.6%	19.5%	21.3%	10-25%
Total Nitrogen (N)	3.10%	3.00%	2.93%	0.5-4.0%
C:N	7.29:1	6.5:1	7.27:1	Maximum 20:1
pH	6.6	6.6	6.8	6.0-8.5
Phosphorus (P)	0.92%	0.93%	0.91%	0.5-3%
Nickel (Ni)	11.59 ppm	10.55 ppm	10.78 ppm	Maximum 30 ppm
Potassium (K)	0.87%	0.90%	0.93%	0.5-3%
Sulfur (S)	0.23%	0.25%	0.27%	0.1-0.5%
Zinc (Zn)	0.064%	0.080%	0.072%	Maximum 0.1%
Copper (Cu)	0.02%	0.010%	0.015%	Maximum 0.05%
Chromium (Cr)	19.39 ppm	16.89 ppm	18.53 ppm	Maximum 50 ppm
Cadmium (Cd)	1.78 ppm	1.29 ppm	1.29 ppm	Maximum 5 ppm
Lead (Pb)	29.5 ppm	30.0 ppm	30.0 ppm	Maximum 30.0 ppm
Inert material	0.95%	0.98%	0.96%	<1%

Experimental results of co-compost sample are shown in Table 4. It is clear from the result that, moisture content and Potassium (K) go lower than the standard quality provided by SRDI which need to be adjusted to maintain the output products quality.

Table 4: Physico-chemical analysis of the co-compost sample

Test performed	Test result			Standard value
	Sample A	Sample B	Sample C	
Color	Dark grey	Dark grey	Dark grey	Dark grey to black
Physical condition	Non-granular form	Non-granular form	Non-granular form	Non-granular form

Odor	Absence of foul odor	Absence of foul odor	Absence of foul odor	Absence of foul odor
Moisture content	10.3%	9.93%	12.01%	15-20%
Organic Carbon (C)	19.5%	17.5%	17.7%	10-25%
Total Nitrogen (N)	3.20%	3.50%	3.90%	0.5-4.0%
C:N	6.09:1	5:1	4.54:1	Maximum 20:1
pH	7.2	6.98	7.00	6.0-8.5
Phosphorus (P)	1.91%	1.23%	1.35%	0.5-3%
Nickel (Ni)	18.07 ppm	17.97 ppm	17.5 ppm	Maximum 30 ppm
Potassium (K)	0.35%	0.21%	0.23%	0.5-3%
Sulphur (S)	0.49%	0.38%	0.32%	0.1-0.5%
Zinc (Zn)	0.98%	0.95%	0.97%	Maximum 0.1%
Copper (Cu)	0.0018%	0.002%	0.003%	Maximum 0.05%
Chromium (Cr)	12.06 ppm	9.23 ppm	9.65 ppm	Maximum 50ppm
Cadmium (Cd)	3.19 ppm	2.68 ppm	2.91 ppm	Maximum 5 ppm
Lead (Pb)	22.12 ppm	25.56 ppm	20.32 ppm	Maximum 30.0 ppm
Internal material	0.86%	0.87%	0.87%	<1%

In order to solve this problem, 15% sawdust (by dry weight) has been used with the co-compost samples as it is an appropriate source of high carbon content which has the capability of preservation of moisture and high water holding capacity [42]. Sawdust also improves the compost quality [43].

After adding 15% sawdust, the moisture content and Potassium content have been increased together with the increase in C/N ratio. Table 5 shows the updated value of the compost and co-compost samples.

Table 5: Physico-chemical analysis of both compost and co-compost samples after adding 15% sawdust

Compost sample				
Test performed	**Test result**			**Standard value**
	Sample A	**Sample B**	**Sample C**	
Moisture content	17.21%	16.01%	18.23%	15-20%
Organic Carbon (C)	24.35%	21.54%	22.95%	10-25%
Total Nitrogen (N)	3.00%	3.00%	2.98%	0.5-4.0%
C:N	8.12:1	7.18:1	7.7:1	Maximum 20:1
Co-compost sample				
Test performed	**Test result**			**Standard value**
	Sample A	**Sample B**	**Sample C**	
Moisture content	16.3%	15.09%	15.6%	15-20%
Organic Carbon (C)	24.65%	24.59%	24.73%	10-25%
Total Nitrogen (N)	3.10%	3.50%	3.67%	0.5-4.0%
C:N	7.95:1	7.02:1	6.74:1	Maximum 20:1
Potassium (K)	1.23%	1.88%	2.01%	0.5-3%

5. Conclusion

Population explosion, rapid and undeliberate urbanization lead to continuous increase in waste of various types and fecal sludge generation. Although composting and co-composting have the evidence of being cheap and smart techniques to not only reduce the waste stream to be disposed by demanding lands and treatment, but also to add revenue through resource recovery from waste, these are not practiced in a large scale in Chattogram, Bangladesh. The FSM plant capacity is not enough to treat all the fecal sludge generated in this city. Also, the composting rate is too low here to achieve the desired resources. If the capacity can be increased in a wide scale, it would bring much more revenue and will engage a portion of the unemployed folk in this area. Based on the experimental programs set for this study, it can be concluded that both the compost and co-compost products have the potentials to be used as soil amendment. This study intends to recommend that, as both the compost and co-compost products meet the standard quality of fertilizers by SRDI, these should be practiced and proper training on this issue should be provided by the city Governor. Market value of the output products should be set and the local people should be inspired to use those organic fertilizers. It can be dreamt that, co-composting will help in reducing waste stream to the dumping site together with adding revenue.

Acknowledgments
Authors would like to thank "Mrittika Gobeshona Institute" for their laboratory support and also DSK and CCC for their material supply.

Reference

[1]. Damghani AM, Savarypour G, Z and E, Deihimfard R. Municipal solid waste management in Tehran: Current practices, opportunities and challenges. *Waste manage.* 2008 Jan 1; 28(5):929-34.
[2]. Hoornweg D, Bhada-Tata P. What a waste: a global review of solid waste management. World Bank 15, 2012.
[3]. Kaza S , Yao L, Bhada-Tata P, Van Woerden F. What a waste 2.0: a global snapshot of solid waste management to 2050. World Bank Publications; 2018 Dec 6.
[4]. Afolabi OO, Sohail M. Microwaving human faecal sludge as a viable sanitation technology option for treatment and value recovery–a critical review. *J. Environ. Manage.* 2017 Feb 1;187: 401-15.
[5]. Sabrin A, Rabea K, Mohammad SU. Urbanization challenge: Solid waste management in Sylhet city, Bangladesh. *Int. J. Eng. Appl. Sci. Tech*. 2021. (Accepted).
[6]. Mor S , De Visscher A , Ravindra K , Dahiya RP , Chandra A, Van Cleemput O. Induction of enhanced methane oxidation in compost: Temperature and moisture response. *Waste Manage*. 2006 Jan 1; 26(4):381-8.
[7]. Morrissey AJ, Browne J. Waste management models and their application to sustainable waste management. *Waste Manage.* 2004 Jan 1; 24(3):297-308.
[8]. Pokhrel D, Viraraghavan T. Municipal solid waste management in Nepal: practices and challenges. *Waste Manage.* 2005 Jan 1; 25(5):555-62.
[9]. Hettiarachchi H, Meegoda JN, Ryu S. Organic waste buyback as a viable method to enhance sustainable municipal solid waste management in developing countries. *Int. J. Environ. Res. Public Health.* 2018 Nov; 15(11):2483. https://doi.org/10.3390/ijerph15112483
[10]. Fathi H, Zangane A, Fathi H, Moradi H, Lahiji AA. Municipal solid waste characterization and it is assessment for potential compost production: A case study in Zanjan city, Iran. *Am. J. Agr. Forestry.* 2014 Jan 1;2(2):39-44.
[11]. BBS (Bangladesh Bureau of Statistics). Population & Housing Census. 2011. Ministry of Planning., Bangladesh.
[12]. Chowdhury RB, Sujauddin M, Murakami S, Chakraborty P, Alam MS.. Current status of municipal solid waste management system in Chittagong, Bangladesh. *Int. J. Environ. Waste Manage.* 2013 Jan 1;12(2):167-88.
[13]. Hossain ML, Das SR, Rubaiyat A, Salam MA, Uddin MK, Hossain MK.. Characteristics and Management of Institutional Solid Waste of Jamalkhan Ward, Chittagong, Bangladesh. *Int. J. Res. Manage.* 2013 Mar;2(3):155-62.
[14]. Sujauddin M, Huda SM, Hoque AR Household solid waste characteristics and management in Chittagong, Bangladesh. *Waste Manage.* 2008 Jan 1;28(9):1688-95.
[15]. Mehedi M, Shardul R, Riazur RR. Solid waste management in Chattogram City Corporation area. Proceedings of 4th International Conference on Advances in Civil Engineering- 2018 at Chittagong University of Engineering & Technology, Chittagong, Bangladesh, 2018.
[16]. Chowdhury Md. TU, Haque NS, Kabir S. Solid Waste Management in Chittagong City. ISBN 978-93-84422-57-8 .Proceedings of 2015 International Conference on Disaster Management in Civil Engineering (ICDMCE'2015). Phuket, Thailand, October 1-3, 2015;87-92.
[17]. Azim K, Soudi B, Boukhari S, Perissol C, Roussos S, Alami IT Composting parameters and compost quality: a literature review. *Org. Agr.* 2018 Jun;8(2):141-58.

[18]. Tognetti C, Mazzarino MJ, Laos F.. Comprehensive quality assessment of municipal organic waste composts produced by different preparation methods. *Waste Manage.* 2011 Jun 1;31(6):1146-52.
[19]. Martínez-Blanco J, Lazcano C, Christensen TH, Muñoz P, Rieradevall J, Møller J, Antón A, Boldrin A. Compost benefits for agriculture evaluated by life cycle assessment. A review. *Agron. Sustain.* Dev. 2013 Oct 1;33(4):721-32.
[20]. Anwar Z, Irshad M, Fareed I, Saleem A. Characterization and recycling of organic waste after co-composting-a review. *J. Agr. Sci.* 2015 Apr 1;7(4):68.
[21]. Cofie O, Nikiema J, Impraim R, Adamtey N, Paul J, Koné D. Co-composting of solid waste and fecal sludge for nutrient and organic matter recovery. (Vol. 3). *IWMI.* 2016 Dec 5.
[22]. Onwosi CO, Igbokwe VC, Odimba JN, Eke IE, Nwankwoala MO, Iroh IN, Ezeogu LI. Composting technology in waste stabilization: On the methods, challenges and future prospects. *J. Environ. Manage.* 2017 Apr 1;190:140-57.
[23]. Lou XF, Nair J. The impact of landfilling and composting on greenhouse gas emissions–a review. *Bioresource Technol*. 2009 Aug 1;100(16):3792-8.
[24]. Giagnoni L, Martellini T, Scodellini R, Cincinelli A, Renella G. Co-composting: An Opportunity to Produce Compost with Designated Tailor-Made Properties. In Organic Waste Composting through Nexus Thinking 2020;185-211. Springer, Cham.
[25]. Wei Y, Li J, Shi D, Liu G, Zhao Y, Shimaoka T. Environmental challenges impeding the composting of biodegradable municipal solid waste: A critical review. *Resour. Conserv. Recy*. 2017 Jul 1;122:51-65.
[26]. Brändli RC, Kupper T, Bucheli TD, Zennegg M, Huber S, Ortelli D, Müller J, Schaffner C, Iozza S, Schmid P, Berger U. Organic pollutants in compost and digestate. Part 2. Polychlorinated dibenzo-p-dioxins, and-furans, dioxin-like polychlorinated biphenyls, brominated flame retardants, perfluorinated alkyl substances, pesticides, and other compounds. *J. Environ. Monitoring.* 2007;9(5):465-72.
[27]. Furlong C, Rajapaksha NS, Butt KR, Gibson WT.Is composting worm availability the main barrier to large-scale adoption of worm-based organic waste processing technologies?. *J. Clean. Prod.* 2017 Oct 15;164:1026-33.
[28]. Sullivan DM, Bary AI, Miller RO, Brewer LJ. Interpreting compost analyses. Oregon State University Extension Service; 2018 Oct.
[29]. Sadeghi S, Dehvari M, Bahmani P, Teymouri P, Fattahi A, Sadeghnia M, Fallahzadeh, R.A. Physical-Chemical Analysis and Comparison with Standards of the Compost Produced in Sanandaj, Iran. *Open Access Library J.* 2015. 2: e1855. http://dx.doi.org/10.4236/oalib.1101855
[30]. Werner C, Panesar A, Rüd SB, Olt CU. Ecological sanitation: Principles, technologies and project examples for sustainable wastewater and excreta management. *Desalination.* 2009 Nov 15;248(1-3):392-401.
[31]. Gonzaga MI, Mackowiak CL, Comerford NB, da Veiga Moline EF, Shirley JP, Guimaraes DV. Pyrolysis methods impact biosolids-derived biochar composition, maize growth and nutrition. *Soil. Till. Res.* 2017 Jan 1;165:59-65.
[32]. Kofoworola OF. Recovery and recycling practices in municipal solid waste management in Lagos, Nigeria. *Waste manage.* 2007 Jan 1;27(9):1139-43.
[33]. Debnath T. Study on Bioconversion of Household Waste and Faecal Sludge through Various Composting Process (Doctoral dissertation, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh). 2018.
[34]. Odey EA, Li Z, Zhou X, Kalakodio L. Fecal sludge management in developing urban centers: a review on the collection, treatment, and composting. *Environ. Sci. Pollut. Res.* 2017 Oct;24(30):23441-52.
[35]. Strauss M, Heinss U, Montangero A. On-site sanitation: when the pits are full--planning for resource protection in faecal sludge management. *Schriftenreihe des Vereins fur Wasser-, Boden-und Lufthygiene.* 2000 Jan 1;105:353-60.
[36]. Alamin M, Bari QH, Alamgir AA. Seasonal Variation on Extent of Stabilization of Faecal Sludge Co-Composting in Khulna city of Bangladesh, Proceedings Sardinia 2017 / Sixteenth International Waste

Management and Landfill Symposium/ 2 - 6 October 2017 S. Margherita di Pula, Cagliari, Italy /© 2017 by CISA Publisher, Italy

[37]. Eawag and ENPHO. Co-composting: Large scale. Sustainable Sanitation and Water Management (SSWM). 2014. Switzerland.

[38]. Enayetullah I. Co-composting of Municipal Solid Waste and Faecal Sludge in Kushtia Bangladesh. ESCAP Session: Designing Effective Partnership for Waste to Resource Initiative. Waste Concern. Bangladesh. 2015.

[39]. Rahman MM, Bhuiyan MS, Rouf MA, Sarker RR, Rashid MH.. Quality Assessment of Municipal Solid Waste Compost. *Acta. Chem. Malays.* 2020 Jun 1;4(1):33-9.

[40]. Miah MD, Siddik MA. Greenhouse Gas Emissions from Municipal Solid Waste Management of the Chittagong City Corporation. *The Chittagong Uni. J. Sci.* 2018 Jun 28;40(1):21-46.

[41]. CCC (Chattagram City Corporation).Retrieved June 9, 2018, from http://www.ccc.org.bd/

[42]. Imbeah M. Composting piggery waste: a review. *Bioresource Technol.* 1998 Mar 1;63(3):197-203.

[43]. Yousefi J, Younesi H, Ghasempoury SM. Co-composting of Municipal Solid Waste with Sawdust: Improving Compost Quality. *Clean–Soil, Air, Water.* 2013 Feb;41(2):185-94.