Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

MONITORING AND RESEARCH DEPARTMENT

REPORT NO. 13-38

THE DEVELOPMENT OF BIOSOLIDS COMPOST IN CHICAGO

OCTOBER 2013

Metropolitan Water Reclamation District of Greater Chicago
100 East Erie Street Chicago, IL 60611-2803 (312) 751-5600

The Development of Biosolids Compost in Chicago

By

Guanglong Tian
Senior Soil Scientist

Olawale Oladeji
Associate Environmental Soil Scientist

Lakhwinder Hundal
Supervising Soil Scientist

Pauline Lindo
Associate Environmental Soil Scientist

Albert Cox
Environmental Monitor and Research Manager

John Gawrys
Associate Civil Engineer

Dan Collins
Supervising Civil Engineer

Heng Zhang
Assistant Director of Monitoring and Research

Thomas C. Granato
Director of Monitoring and Research

Monitoring and Research Department
Thomas C. Granato, Director

October 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENT

The authors acknowledge the staff of the Lawndale Avenue Solids Management Area of the Metropolitan Water Reclamation District of Greater Chicago's (District's) Maintenance and Operations Department for performing composting operations. The authors thank the staff of the Analytical Laboratories Division for conducting the analyses. We particularly acknowledge the significant contributions of the Biosolids Utilization and Soil Science Section staff, Minaxi Patel, Richard Adams, Tiffiany Tate, Ilyse Mackoff, and Beverly Horvath for the sampling and analysis of composted samples. We thank Christy Webber Landscapes for providing tree leaves, wood-chips, and landscape waste mix used in this study. Special thanks are also extended to Ms. Coleen Maurovich for formatting the report.

DISCLAIMER

Mention of proprietary equipment, chemicals, and materials in this report does not constitute endorsement by the District.

ABSTRACT

The process of producing Class A air-dried biosolids at the District includes lagoon-aging followed by air-drying to achieve greater than 60 percent solids content. When the air-dried product is stockpiled during storage, it has the potential to produce odor. The District has begun an initiative to produce a stable and odor-free final product that could be easily stockpiled by integrating the "composting concept" into biosolids stabilization. Biosolids composting often requires more bulking material than biosolids, and this could increase the biosolids management cost. This study was, therefore, focused on developing biosolids composting recipes using low rates of bulking materials.

The experiment included two types of centrifuge-dewatered biosolids: lagoon-aged (aged biosolids) and unaged biosolids, and three types of locally available bulking materials: tree leaves, wood chips, and yard waste mix. Each type of biosolids was mixed with a bulking material at the ratio of 2:1 (weight by weight) biosolids:bulking. There were two additional ratios for yard waste mix treatments at 4:1 and 1:1 biosolids:bulking. The biosolids and bulking materials were mixed with a mechanical auger and placed on a paved bed for ten days with additional mixing to increase the solids content to 40 percent. The mixtures were then piled as windrows. During the first 15 days (composting period), the windrows were turned every three days. After the composting period, the windrows were allowed to "cure" for 3.5 months and were turned every three weeks during that period. Samples of the composted biosolids were collected at the end of the curing period for chemical analyses and odor evaluation.

Without bulking materials, the biosolids windrow temperature increased slightly from 30 to 40°C, but it rapidly increased to 50 - 60°C with the addition of bulking materials. For the same bulking material and ratio, the windrow temperature was higher in the unaged than aged biosolids. For the same biosolids, it increased with the increase in plant bulking materials. The unaged biosolids:yard waste mix at the ratio of 1:1 (w/w) maintained the highest temperatures which met the composting temperature requirement of ≥55°C for 15 days. The odor of all the composted biosolids was lower than that of the District's typical lagoon-aged, air-dried biosolids, and the odor did not increase upon rewetting of the materials in the 1:1 biosolids:bulking mixture, which met compost temperature requirement. The total nitrogen (N) in biosolids compost was comparable to that in the air-dried biosolids, with relatively lower NH_4-N but higher organic N contents in the former than the latter.

Our results show that using the composting process, with minimal modifications to current biosolids drying operations, the District can produce stabilized, odor-free Class A biosolids in two ways: (1) Use 1:1 ratio of centrifuge-dewatered biosolids:bulking material to produce biosolids compost; (2) Continue using lagoon-aging to achieve Class A pathogen levels, then add bulking materials to increase the stabilization of the end-product.

INTRODUCTION

The production of Class A biosolids at the District involves the process that is certified by the United States Environmental Protection Agency (USEPA) as equivalent to the Process to Further Reduce Pathogens. It consists of lagoon-aging of Class B biosolids for 18 months and subsequent agitation and air-drying of biosolids on paved beds for four to six weeks. This product has been used primarily as fertilizer or soil amendment for turf establishment and growth in the Chicago metropolitan area. However, the potential for odor development from the air-dried biosolids is a major factor limiting public acceptance and the economic value of our biosolids. Therefore, in the current operations, the air-dried biosolids are not stockpiled at either the solids management areas or the utilization sites because of the potential to develop odor. The odor potential appears to be due primarily to poor stabilization of the final product. Stabilization refers to the breakdown of readily decomposable organic matter in the substrate and the formation of slowly decomposable humus. Because of poor stabilization, the air-dried biosolids contain a high amount of degradable organic compounds, and further decomposition of these compounds in the stockpiled biosolids could result in anaerobic conditions and produce odor.

It has been previously shown that lagoon-aging for 18-months reduces the pathogens in biosolids to Class A pathogen levels (Tata et al., 2000). However, recent research indicates that the biosolids are not well stabilized after lagoon-aging due to the anaerobic conditions in the lagoon (Lukicheva et al., 2012). During the subsequent air-drying, the continuous decomposition of organic matter in the lagoon-aged biosolids for higher stability is limited by the decreasing moisture. Therefore, some of the decomposable organic matter remains in the final air-dried biosolids product, potentially generating odor upon rewetting or stockpiling.

We hypothesize that the maintenance of moisture suitable for microbial decomposition in biosolids on a drying bed for a short period of time before completion of drying (>60 percent solids content) may further stabilize the biosolids. To foster such decomposition, maintenance of aerobic conditions is also necessary, and this can be achieved by adding a bulking agent.

The plant materials that can be used as bulking materials in the Chicago area include tree leaves, woodchips, and yard waste mix (leaves, twigs, weed, etc.). These landscaping by-products are available primarily from April through November. Due to the high water content in biosolids, biosolids composting often requires proportionately more bulking materials than biosolids; thus, the cost involved in transportation and handling of the bulking materials has been a major limitation for biosolids composting. Therefore, the objective of the study was to compare the available landscaping by-products as a bulking material and determine the lowest ratio of the bulking material to biosolids for biosolids composting using current agitation equipment.

MATERIALS AND METHODS

Treatments and Operations

The lagoon-aged (>2 years) and unaged (fresh) centrifuge-dewatered biosolids at 20 percent solids content from the Stickney Water Reclamation Plant were prepared at the Lawndale Avenue Solids Management Area (LASMA) for the study. The analysis of biosolids used is presented in Table 1. The plant bulking materials were provided by Christy Webber Landscapes, the District landscape contractor, and they included tree leaves, woodchips, and yard waste mix. The plant materials were screened through a 5-cm screen, and the analysis of these materials is presented in Table 2.

The study included 12 treatments established at the same time, consisting of combinations of two types of biosolids and three types of bulking materials and various mixing ratios (by dry weight) of biosolids and bulking materials as follows:

1. Aged biosolids (AB)
2. AB + tree leaves (2:1)
3. AB + woodchips (2:1)
4. AB + yard waste mix(4:1)
5. AB + yard waste mix (2:1)
6. AB + yard waste mix (1:1)
7. Unaged biosolids (UAB)
8. UAB + tree leaves (2:1)
9. UAB + woodchips (2:1)
10. UAB + yard waste mix (4:1)
11. UAB + yard waste mix (2:1)
12. UAB + yard waste mix (1:1)

TABLE 1: ANALYSIS OF BIOSOLIDS[1] USED IN THE BIOSOLIDS COMPOSTING STUDY DURING YEAR 2011

Parameter	Unit	Aged biosolids	Unaged biosolids
pH		8.3	7.9
TS	%	19.7	20.5
TVS	%	46.3	51.8
Volatile acids	mg/kg	1,859	925
TKN	"	56,173	42,454
NH_4-N	"	16,935	7,444
NO_2+NO_3-N	"	345	204
Tot P	"	23,786	19,184
Al	"	17,156	14,287
As	"	<10	<10
B	"	37	36
Ca	"	36,554	37,583
Cd	"	3	3
Co	"	6	7
Cr	"	147	133
Cu	"	379	357
Fe	"	16,426	15,460
Hg	"	1.0	0.80
K	"	3,033	2,505
Mg	"	17,209	17,692
Mn	"	610	535
Mo	"	10	10
Na	"	1,625	850
Ni	"	39	37
Pb	"	111	88
Se	"	<5	<5
V	"	19	19
Zn	"	782	709

[1]Centrifuge-dewatered aged and unaged biosolids from Lagoons 27 and 30, respectively.

TABLE 2: ANALYSIS OF PLANT BULKING MATERIALS USED IN THE BIOSOLIDS COMPOSTING STUDY

Type of Bulking Materials	Dry Matter	Total N	C:N[1]	TP
	(%)			
Tree leaves	41.4	1.33	35	0.13
Woodchips	59.0	0.50	90	0.07
Yard waste mix	62.2	0.94	50	0.10

[1]Assume 46.5 percent C in plant materials.

For each treatment, three truckloads of biosolids and the corresponding dry weight of bulking materials were spread on the drying bed, then mixed by augering to form small (0.5 m high) windrows. The windrows were augered again for 3 - 5 times during the period of ten days to achieve 40 percent solids content. Then, the mixture was piled into a larger windrow, about 1.5 m high x 2 m wide. The windrows were turned every three days during the first 15 days (composting period) according to the USEPA's composting guidelines, then weekly during the "curing" period of 105 days. The experiment was conducted from June to December 2011.

Monitoring and Compost Analysis

The temperature at the center of the windrows was monitored daily using a probe for the first 15 days and with longer intervals thereafter. The USEPA's temperature requirement for compost is $\geq$ 55°C for 15 days with five turnings.

Samples of composted biosolids at the end of curing were taken for analysis. The samples were air-dried and sieved to pass a 2 mm screen. The samples were analyzed by the Biosolids Unitization and Soil Science Laboratory and the Analytical Laboratories Division using standard methods.

For odor testing, the samples collected in 1 L polyethylene bottles were "sniffed" by an odor panel made up of at least six members. Odor intensity was ranked on a scale from 0 to 10 that was established based on three reference materials: Kankakee County sandy soil (0), the District's typical Class A air-dried biosolids (5), and fresh centrifuge cake biosolids (10). The moisture contents of composted biosolids sampled for odor testing ranged from 55 percent to 68 percent. To evaluate the effect of rewetting on the odor of the composted biosolids, the moisture content of the original sample was adjusted to 50 percent solids content, and the rewetted materials were left to incubate in the laboratory for two weeks. Odor emissions from the wetted samples were assessed by the odor panel.

RESULTS AND DISCUSSION

Windrow Temperature

Temperature of biosolids windrow without any bulking material rose slightly from 30 to 40°C but rapidly increased to 50 to 60°C with the addition of bulking materials during composting (Figure 1). The magnitude of temperature increase in windrows depended on the type of biosolids, bulking material, and mixing ratio. For the same bulking material and ratio, the windrow temperature was higher in the unaged biosolids than the aged biosolids. The temperature increased with the increasing bulking material ratio. For the same biosolids, the temperature was higher during composting in the treatments with yard waste mix than in leaves and wood chips. The unaged biosolids composted with yard waste mixture at the ratio of 1:1 (w/w) had the highest temperatures, which met the composting temperature requirement of ≥ 55°C for 15 days. This better composting performance is probably due to the higher extractable protein in unaged biosolids (Lukicheva et al., 2012).

Quality of Composted Biosolids

Chemical Composition. Ammonium (NH_4-N) in the composted biosolids was lower than in the lagoon-aged, air-dried biosolids (Table 3). This could be due to greater ammonia volatilization under high temperature during the composting and the incorporation of NH_4-N into microbial biomass during the composting and curing process. The NO_3-N concentration was slightly lower in the composted biosolids than in the air-dried biosolids. The organic N in the composted biosolids ranged from 2.01 to 2.75 percent as compared to 1.91 percent in the air-dried biosolids. The results suggest that while more NH_4-N could be lost during the composting than air-drying, the composting retained relatively more organic N than the air-drying, leading to the comparable total N in the composted biosolids and air-dried biosolids.

The biosolids composted with plant bulking had a C:N ratio ranging from 8 to 10 (Table 3). The potential for N immobilization resulting from application of organic materials increases with the C:N ratio of materials, with the critical level of 12 - 25 (Iglesias-Jimenez and Alvarez,1993; Gutser et al., 2005; Sims, 1990). Thus, net immobilization from all composted biosolids may not be expected when these composted materials are applied to land.

The electrical conductivity in the biosolids was, in most cases, reduced by the composting, with the lowest value in the 1:1 biosolids:bulking mixture, which met the composting temperature requirement (Table 3). The volatile acids were also lower in the composted biosolids than the air-dried biosolids, especially for compost product produced from unaged biosolids.

Odor Potential. The odor rating of the composted biosolids is shown in Figure 2. Without plant bulking materials, the odor rating of composted biosolids was close to that of the District's typical lagoon-aged, air-dried biosolids. However, with the addition of bulking materials, all composted biosolids demonstrated a considerably lower odor rating than the air-dried biosolids. Following the rewetting of the composted biosolids and being incubated in a closed jar for

FIGURE 1: TEMPERATURE IN THE WINDROWS DURING COMPOSTING OF BIOSOLIDS WITH VARIOUS TYPES AND MIXING RATIOS OF PLANT BULKING MATERIALS

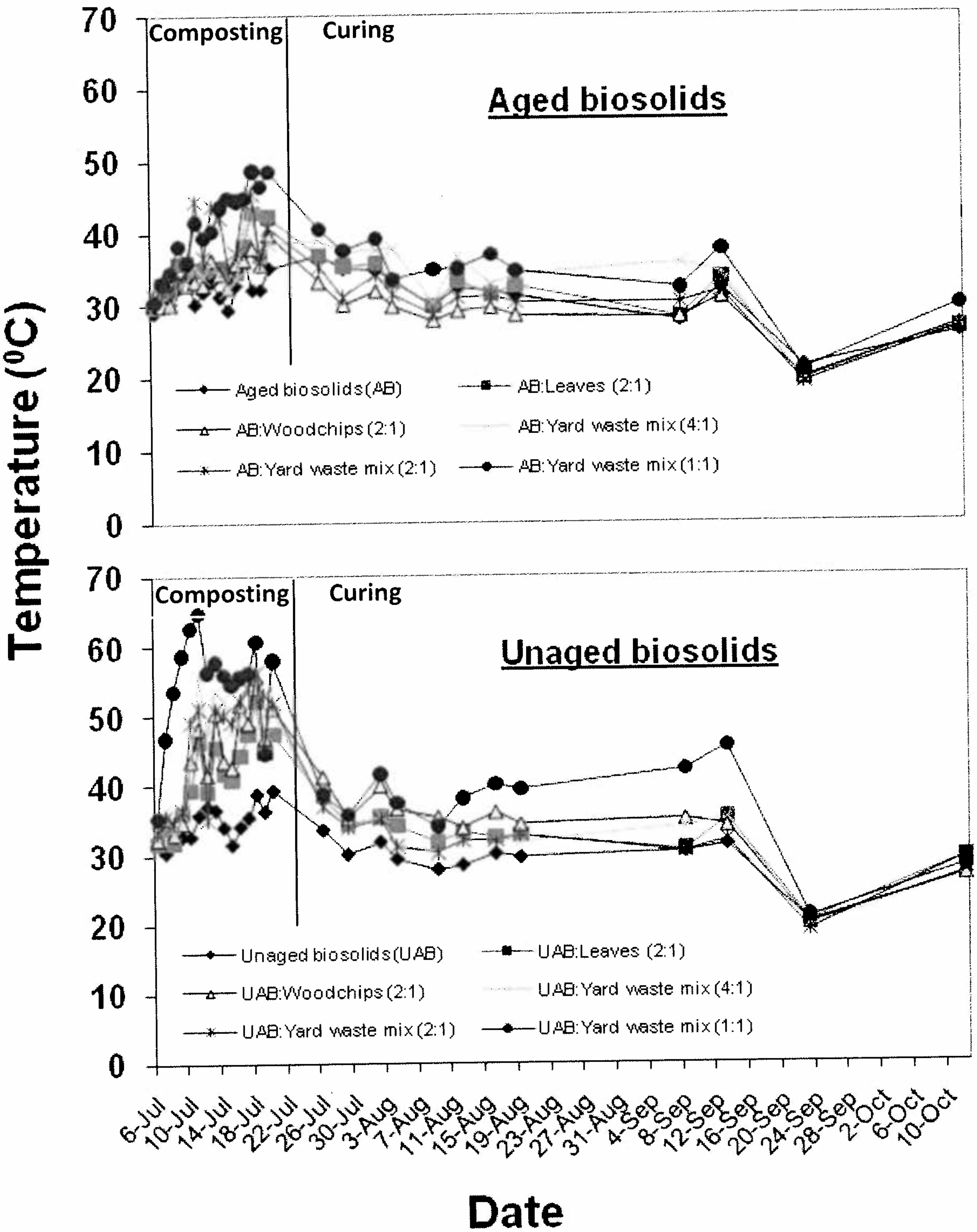
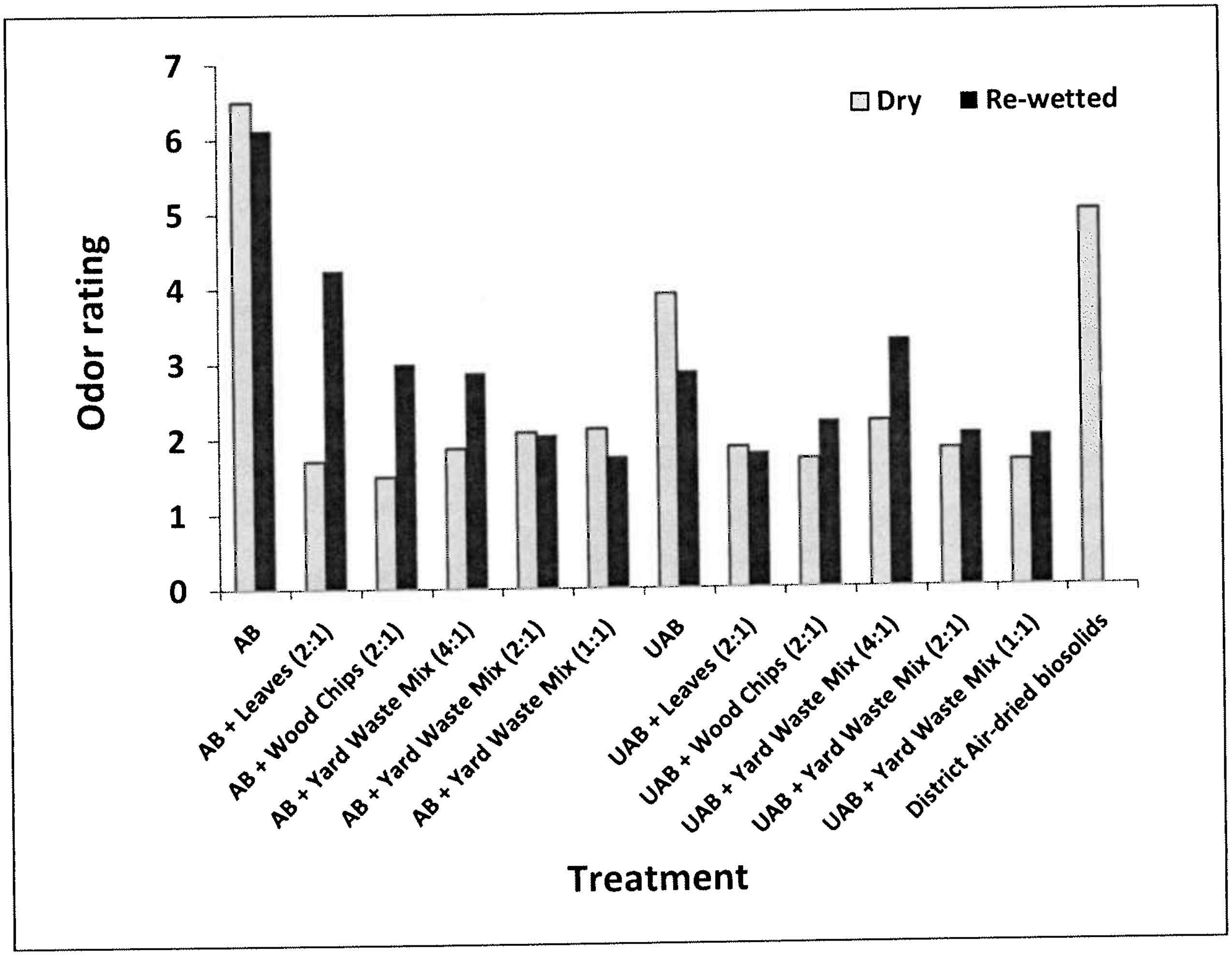


TABLE 3: QUALITY OF COMPOSTED BIOSOLIDS PRODUCED FROM LAGOON-AGED AND UNAGED BIOSOLIDS WITH VARIOUS TYPES AND MIXING RATIOS OF PLANT BULKING MATERIALS

Treatments	Initial C:N Ratio Mixture	EC	Vol. acids	NO_3-N	NH_4-N	Org. N	Org. C	C:N
		mS cm^{-1}	-------------(mg kg^{-1})----------			---------- % -------		
AB[1]	5.8	4.55	371	552	637	2.75	20.9	7.5
AB + Leaves (2:1)[2]	15.5	2.99	346	207	70.8	2.68	23.0	8.6
AB + Woodchips (2:1)	33.9	2.46	217	71	56.0	2.53	25.1	9.9
AB + Yard waste mix (4:1)	14.6	3.92	451	467	91.8	2.54	23.0	9.0
AB + Yard waste mix (2:1)	20.5	3.52	296	243	13.3	2.40	19.2	8.0
AB + Yard waste mix (1:1)	27.9	4.14	130	411	28.5	2.48	22.1	8.9
UAB[3]	7.1	3.31	182	327	32.3	2.65	20.2	7.6
UAB + Leaves (2:1)	16.4	3.07	161	336	22.5	2.45	22.2	9.0
UAB + Woodchips (2:1)	34.7	3.01	144	318	4.3	2.24	20.9	9.3
UAB + Yard waste mix (4:1)	15.7	3.16	256	323	39.8	2.36	19.1	8.1
UAB + Yard waste mix (2:1)	21.4	2.63	95	214	29.8	2.08	20.2	9.7
UAB + Yard waste mix (1:1)	28.6	2.36	122	226	14.5	2.01	18.7	9.3
Lagoon-aged, air-dried biosolids	ND[4]	ND	364	405	2807	1.91	21.2	9.7

[1]Aged biosolids.
[2]Mixing ratio of biosolids:bulking material (dry-weight basis).
[3]Unaged biosolids.
[4]Not determined.

FIGURE 2: ODOR RATING OF BIOSOLIDS COMPOSTED WITH VARIOUS TYPES AND MIXING RATIOS OF PLANT BULKING MATERIALS



AB = aged biosolids.
UAB = unaged biosoldis.

two weeks, the odor rating of the composted biosolids remained unchanged for treatments with higher bulking material (1:1 ratio) and increased for the treatments with lower bulking material (2:1 and 4:1 ratios). The 1:1 biosolids:bulking mixture, which met the composting temperature requirements, demonstrated a very low odor rating even after rewetting.

For most of the aged biosolids treatments, the addition of plant bulking materials increased the organic carbon content in the composted biosolids (Table 3). However, for most of the unaged biosolids treatments, the addition of plant bulking materials did not increase organic C in the end-product. The higher degradation of plant bulking C in unaged biosolids treatment suggests the unaged biosolids are of higher compostability, which could be due to their high extractable protein (Lukicheva et al., 2012). Therefore, the unaged biosolids are preferred as feed stock for making compost.

CONCLUSIONS

The study demonstrated that the 1:1 (biosolids:plant bulking material) ratio by dry weight is the minimum bulking requirement for achieving the composting temperature requirement. Composted biosolids produced with a 1:1 (biosolids:bulking) ratio had lower odor potential than the lagoon-aged, air-dried biosolids. Even after rewetting, the odor potential of this product remained low. The total N in the composted biosolids was equivalent to or higher than that in the lagoon-aged, air-dried biosolids.

REFERENCES

Gutser, R., T. Ebertseder, A. Weber, M. Schraml, and U. Schmidhalter, 2005. "Short-Term and Residual Availability of Nitrogen After Long-Term Application of Organic Fertilizers on Arable Land." *Journal of Plant Nutrition and Soil Science* 168: 439-446.

Iglesias-Jimenez, E., and C. E. Alvarez, 1993. "Apparent Availability of Nitrogen in Composted Municipal Refuse." *Biology and Fertility of Soils* 16: 313-318.

Lukicheva, I., G. Tian, A. Cox, T. C. Granato, and K. Pagilla, 2012. "Anaerobic and Aerobic Transformations Affecting Stability of Dewatered Sludge During Long-Term Storage in a Lagoon." *Water Environment Research* 84: 17-24.

Sims, J. T., 1990. "Nitrogen Mineralization and Elemental Availability in Soils Amended With Cocomposted Sewage Sludge." *Journal of Environmental Quality* 19: 669-675.

Tata, P., C. Lue-Hing, J. J. Bertucci, S. J. Sedita, and G. J. Knafl, 2000. "Class A Biosolids Production by a Low-Cost Conventional Technology." *Water Environment Research* 72: 413-422.