ARCHIVES OF ENVIRONMENTAL PROTECTION

vol. 40 no. 1 pp. 33 - 40 2014

VERSITA

PL ISSN 2083-4772
DOI: 10.2478/aep-2014-0008

EFFECTS OF DIFFERENT AGRO-BASED MATERIALS ON COMPOSTING OF PULP/PAPER-MILL SLUDGE

NURDAN AYCAN, NURDAN GAMZE TURAN*

Ondokuz Mayıs University, Engineering Faculty, Dept. of Environmental Engineering,
55139 Kurupelit, Samsun, Turkey
*Corresponding author e-mail: gturan@omu.edu.tr

Keywords: Composting, agro-based materials, pulp/paper-mill sludge, compost.

Abstract: The effects of different volumetric ratios of bulking agents to pulp/paper-mill sludge on composting were studied. Rice husk and corncob were used as bulking agents. Volumetric ratios of bulking agents to pulp/paper-mill sludge were used as 10:100 and 25:100. To monitor the evolution of the composting systems, routine parameters such as temperature, moisture, pH, total N, NH_4^+-N, NO_3^--N, total C, and C/N ratio were analyzed. The results indicated that the agro-based materials significantly affected compost maturity parameters. Moreover, the quality of the product obtained in the composting process treated with the agro-based materials achieved satisfactory stabilization and sanitation for application to land.

INTRODUCTION

The pulp and paper-mill sludge is the residue produced in the wastewater treatment process from the pulp-paper industry [20]. While the yearly residue production has been and will continue to increase in the foreseeable future, the conventional management methods such as landfilling, incineration and beneficial uses have come under stronger public opposition and stricter regulatory pressure [10].

Composting is an acceptable and recommended means of recycling wastewater treatment sludge and is rapidly gaining acceptance in the world as a method for stabilizing/sanitizing organic wastes. Composting is biooxidative process involving the mineralization and partial humification of the organic matter; leading to a stabilised final product, free of phytotoxicity and pathogens and with certain humic properties [4].

Composting of wastewater treatment sludge has been traditionally carried out by using bulking agents. The use of bulking agents can enhance the stability of organic matter, inactive pathogens and parasites, and enable the production of a quality product that may be used as a soil conditioner or as an organic fertilizer [11, 13, 16, 17]. A large number of materials have been used as bulking agents, although the most widely used materials are wood chips and pruning waste [2, 9, 19].

The pulp and paper-mill sludge contains significant amounts of plant nutrients and are a widely available resource for composting, thereby curtailing environmental pollution such as direct land applications, reducing landfilling, and limiting greenhouse gas emissions. The compost so produced has the potential to sustain N-reserves and to improve the structural stability of the soil. It may also be used for horticultural and agricultural applications [5, 8].

The aim of the study is to investigate the effects of different agro-based materials such as rice husk and corncob on composting of pulp/paper mill sludge. Composting was performed in a laboratory scale in-vessel composting system. Various ratios of agro-based materials were added to pulp/paper-mill sludge as amendments and compared with the system of nonadded.

METHODOLOGY

The agro-based materials such as rice husk and corncob were used as bulking agents for pulp/paper-mill sludge composting. Rice husk was obtained from Toramanlar Rice Industry (Samsun, Turkey). Corncob was provided from the farm located in the Black Sea region (Samsun, Turkey). Agro-based materials were initially washed thoroughly with distilled water to remove any impurities, dried at 110°C for 6 h and then ground and sieved to a 5 mm particle size. The finer fraction was stored in desiccators for further use.

Pulp/paper-mill sludge was obtained from Omluksa Pulp/Paper Industry (Çorum, Turkey). The plant produces fluting and liner type paper from waste paper and straw. With annual production capacity of 21.000 tonnes, the plant produces approximately 100 tonnes/month wastewater treatment sludge. Primary and secondary sludges (70% primary and 30 secondary) are combined, conditioned with polymer and dewatered to approximately 20–25% solids. The sludge characteristics are given in Table 1.

Table 1. Characteristics of pulp/paper-mill sludge

Parameters	values
pH	7.02
Moisture Content, %	70.6
Total N, %	1.04
NH_4^+-N, mg L^{-1}	57.5
NO_3^--N, mg L^{-1}	26.4
Total C, %	44.4
C/N	42.7

To compost the poultry litter waste, five in vessel prototype composters were constructed. Each composter was made using a closed-ended glass tank (40 cm × 25 cm × 25 cm). Each tank had equipment to enable leachate collection, temperature measurement, aeration and gas release. The air flow rate was 0.8 m^3 min^{-1} m^{-3}. A temperature sensor was placed in the center of each reactor. During processing, the composts were mixed manually weekly throughout the trials. About 50 g of composite samples were taken from the composters after every complete mixing. All analyses were carried out in triplicate and the results were used to calculate mean values.

In order to observe the effect of agro-based bulking agents on composting of pulp/paper-mill sludge, the following samples were prepared:

S0: 100% pulp/paper-mill sludge
S1: 10% Rice husk + 90% pulp/paper-mill sludge
S2: 25% Rice husk + 75% pulp/paper-mill sludge
S3: 10% Corncob + 90% pulp/paper-mill sludge
S4: 25% Corncob + 75% pulp/paper-mill sludge

Representative compost samples were collected weekly from all composters and analyzed for pH, moisture content, total N, NH_4^+-N, NO_3^--N, total C, and C/N ratio. Moisture content and pH were also measured for the starting material in each composter. Samples were dried at 103–105°C before testing for total N, NH_4^+-N, NO_3^--N and total C. Moisture content was determined by drying at 105°C to constant weight [1]. NH_4^+-N and the NO_3^--N content of 2 N KCl (1:10 (w/v) soil extracts was determined by the steam distillation Kjeltec method [15]. The pH was measured using a digital pH-meter (Mettler Toledo-MP 220) in aqueous extract, which was obtained by mechanically shaking the samples with distilled water at a solid:water ratio of 1:10 (w/v) for 1 h [6].

RESULTS AND DISCUSSION

The characterization of pulp/paper-mill sludge compost treated with rice husk, corncob and without any bulking agent are presented in Table 2. The results obtained were used to measure the stability of the final compost.

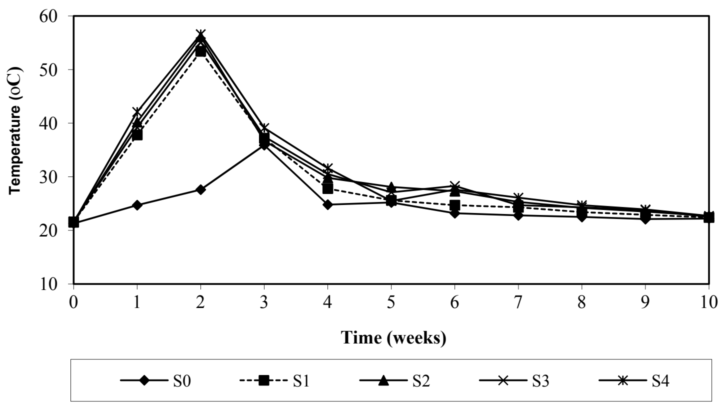

Fig. 1. Temperature profiles during the composting process

The profiles of average temperatures measured in composting piles are plotted in Fig. 1. As seen in Fig. 1, initially the temperature increased as a consequence of the rapid breakdown of the readily available organic matter by microorganisms. As the organic matter became more stabilised, the microbial activities and the organic matter decomposition rate decreased and the temperature gradually decreased to ambient

Table 2. Characteristics of pulp/paper-mill sludge composts

Parameters	S0	S1	S2	S3	S4
pH	8.89	7.01	6.94	6.91	6.84
Moisture Content, %	60.2	51.9	51.4	51.1	49.8
Total N, %	0.38	1.17	1.27	1.41	1.56
NH_4^+-N, mg L^{-1}	85.4	54.1	52.1	45.4	41.3
NO_3^--N, mg L^{-1}	18.4	60.4	64.2	77.7	80.9
Total C, %	12.4	17.7	18.4	15.4	15.8
C/N	32.7	15.1	14.5	10.9	10.1

levels, marking the end of the thermophilic phase [14]. The maximum temperatures higher than 55°C are necessary to destroy pathogen microorganisms, but temperatures of 45–55°C must be maintained for maximum biodegradation [12]. In the system without any agro-based material, the maximum temperature was 37°C, which may have been due to the high moisture content (above 65%) of the pulp/paper-mill sludge. However, all systems amended with agro-based materials reached thermophilic conditions. The maximum temperatures reached were 53°C and 56°C for the systems containing 10% and 25% rice husk, respectively. On the other hand, in the systems containing 10% and 25% corncob maximum temparatures were monitored as 55°C and 57°C, respectively. These temperatures, which were maintained for several days during the process, help ensure that organic matter is stabilised and that pathogenic microorganisms are suppressed.

The initial moisture content of pulp/paper-mill sludge was approximately 70%. The high moisture produced the lowest temperatures (Fig. 2). Agro-based bulking agents reduced moisture content of composts to optimum value. The compost without any bulking agent was not matured during the composting process. In the end of the composting, moisture content of untreated compost was higher than 50% which is not suitable for efficient screening.

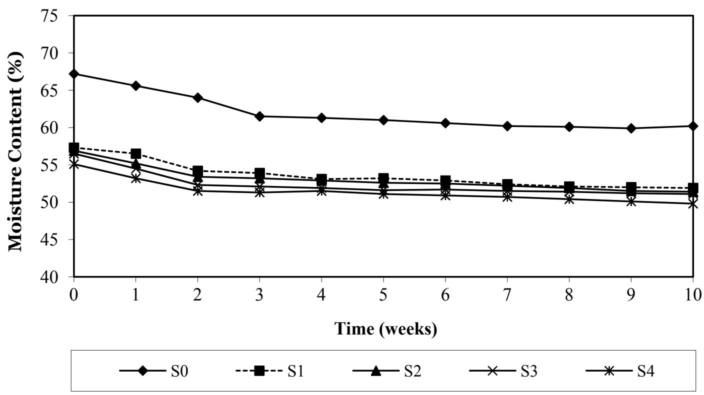

Fig. 2. Evolution of moisture content during the composting process

The trends for pH during the composting of pulp/paper-mill sludge are shown in Fig. 3. During the initial phase of composting, reduced pH can occur due to the production of organic acids. Consumption of organic acids produced can cause a rise in pH [3], and if the pH level approaches 8, ammonia and other odors may become a problem. In this study, the pH values decreased for up to two weeks in composts with added bulking agents that were in a thermophilic phase, but then their pH increased again as the decomposition progessed. After 10 weeks of composting, the pH values of the composts containing rice husk ranged from 6.9 to 7.1 for 10% and 25% rates, respectively. The final values of pH were 6.9 and 6.8 for the systems containing 10% and 25% corncob, respectively. However, in the system without any bulking agent pH values increased during the composting process and reached to 8.9 at the end of the process.

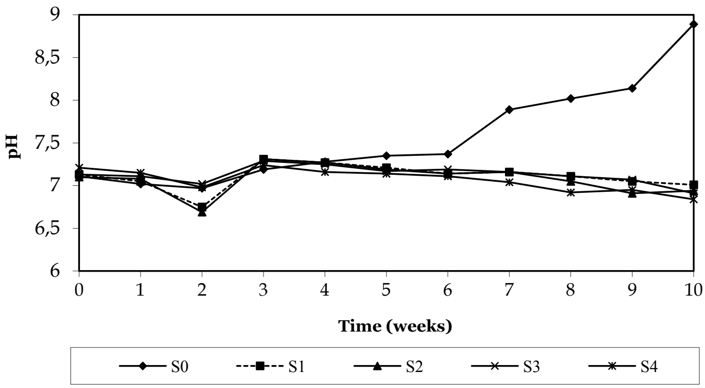

Fig. 3. Evolution of pH during the composting process

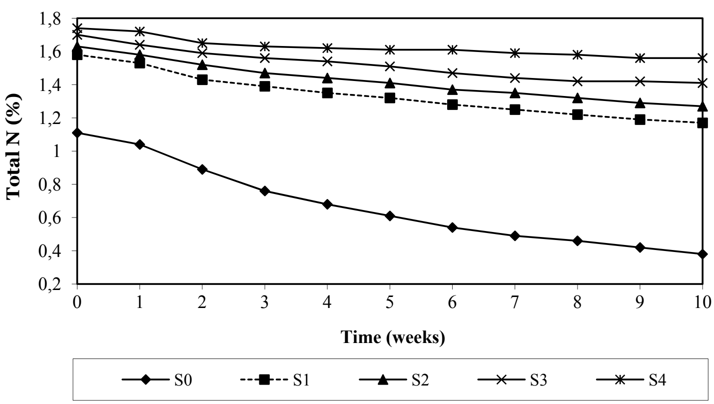

Fig. 4. Evolution of total nitrogen during the composting process

Total nitrogen evolution during the composting of pulp/paper-mill sludge is shown in Fig. 4. As it can be observed, bulking agents have a significant influence on total nitrogen. Initially, total nitrogen concentration of pulp/paper-mill sludge was 1.04%.

At the end of the process, total nitrogen value of compost without any bulking agent was reduced 0.38% and approximately 63.46% nitrogen was lost or mineralized. The loss of nitrogen reduces the value of compost as a fertilizer. In the experiments, nitrogen losses were reduced by using bulking agents. Increasing amendment ratio from 10% to 25% greatly reduced total nitrogen. A higher amendment ratio resulted in better aerobic conditions due to greater porosity. In the systems containing 10% and 25% rice husk, total nitrogen losses were obtained as about 23.52 and 19.62%, respectively. Also, in the systems containing 10% and 25% corncob, total nitrogen losses were determined as about 14.02 and 9.30%, respectively. As seen, corncob supplied the little losses than rice husk. Both NH_4^+-N and NO_3^--N initially increased and then decreased because of the result of an increased in N-fixing bacteria. The anaerobic and partially aerobic conditions can result in ammonia release to the atmosphere. It also appears that the ammonia nitrogen content in the final product decreased when the amount of bulking agent used was increased. NH_4-N/NO_3^--N ratio and total NH_3-N concentration are good indicators for compost maturity [18]. According to the Compost Maturity Index, if NH_4^+-N/NO_3^--N ratios are higher than 3 and NH_3-N concentrations are higher than 500 mg L^{-1}, the final composts are accepted as "immature". As observed in Table 1, the parameters of NH_4^+-N/ NO_3^--N ratios and NH_3-N concentrations were lower than the values for composts where bulking agent is added. Therefore, the composts without any bulking agents were immature, the other composts were mature.

The initial organic carbon in different treatments with bulking agents varied from 50% to 55%. As expected, the organic carbon content in the composts decreased as the decomposition progressed. At the end of the process, the lowest organic carbon was observed in the treatment with corncob, which was also the treatment that showed the highest degree of decomposition. The highest final organic carbon concentrations were measured in the litter amended with rice husk. During the composting of pulp/paper-mill sludge, the C/N ratios of each runs are shown in Fig. 5. As the decomposition progressed due to losses of carbon mainly as carbon dioxide, the carbon content of the compostable material decreased with time while the N content per unit material increased, resulting in a decrease of C/N ratio [7]. After 10 weeks of composting, the pulp/paper-mill sludge

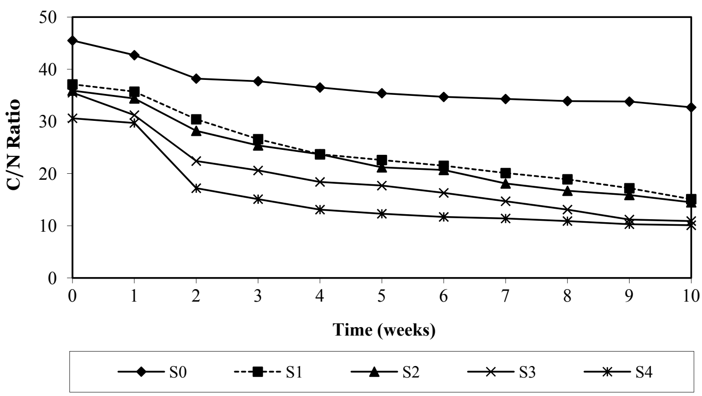

Fig. 5. Evolution of C/N ratio during the composting process

compost had final C/N ratios of 15.1 and 14.5 for 10% and 25% rice husk, respectively. The lowest ratio was measured in composts with corncob. The final values of C/N ratios were found as 10.9 and 10.1 for the systems containing 10% and 25% corncob, respectively. The C/N ratios of composts containing corncob and rice husk were below 20 which is indicative of an acceptable compost maturity [7]. However, the pulp/paper-mill sludge compost without any bulking agent was above 20.

CONCLUSIONS

Composting, a biological oxidative process, is widely accepted and practiced as a fast, simple and safe approach to disposal of agricultural, industrial and municipal organic wastes, leading to product that may contribute to soil conditioning and fertility. Although composting has been used for a long time, many aspects of composting are still discussed. A major limitation of composting process is an immature compost. The results clearly showed that the compost derived from the pulp/paper-mill sludge without any bulking agent did not provide any compost maturity criteria. Based on the experimental data obtained, it can be concluded that rice husk and corncob have good potentialities as bulking agents on composting of pulp/paper-mill sludge.

REFERENCES

[1] APHA. (1995). Standard Methods for the Examination of Water and Wastewater. 19th Edition, Eds. Eaton, A.D., Clesceri, L.S. and Greenberg, A.E., American Public Health Association, American Water Works Association, Water Environment Federation, Washington, D.C 1995.

[2] Atkinson, C.F., Jones, D.D. & Gauthier, J.J. (1996). Biodegradabilities and microbial activities during composting of oxidation and ditch sludge, *Compost Science & Utilization*, 4, 84–96.

[3] Beck-Friis. B., Smars, S., Jönsson, H., Eklind, Y. & Kircman, H. (2003). Composting of Source-Separated Household Organics at Different Oxygen Levels: Gaining an Undertandaing of the Emission Dynamics, *Compost Science & Utilization*, 11, 41–50.

[4] Bernal, M.P., Alburquerque, J.A. & Moral, R. (2009). Composting of animal manures and chemical criteria for compost maturity asessment: A review, Bioresource Technology, 100, 5444-5453, DOI: 10.1016/j biortech.2008.11.027.

[5] Campbell, A., Folk, R. & Tripepi, R. (1997). Wood ash as an amendment in municipal sludge and yard waste composting processes, *Compost Science & Utilization*, 5 (1), 62–73.

[6] FCQAO. (1994). Methods Book for Analysis of Compost. Federal Compost Quality Assurance Organisation, Stuttgart 1994.

[7] Goyal, S., Dhull, S.K. & Kapoor, K.K. (2005). Chemical and biological changes during composting of different organic wastes and assessment of compost maturity, *Bioresource Technology*, 96, 1584–1591, DOI:10.1016/j.biortech.2004.12.012.

[8] Hackett, G.A.R., Easton, C.A. & Duff, S.J.B. (1999). Composting of pulp and paper mill fly ash with wastewater treatment sludge, *Bioresource Technology*, 70, 217–224, DOI:10.1016/S0960-8524(99)00048-6.

[9] Larsen, K.L. & McCartney, D. (2000). Effect of C:N ratio on microbial activity and N-retention: bench-scale study using pulp and paper biosolids, *Compost Science & Utilization*, 8, 147–159.

[10] Mahmood, T. & Elliott, A. (2006). A review of secondary sludge reduction technologies for the pulp and paper industry, *Water Research,* 40, 2093–2112, DOI:10.1016/j.watres.2006.04.001.

[11] Ponsá, S., Pagans, E. & Sánchez, A. (2009). Composting of dewatered wastewater sludge with various ratios of pruning waste used as a bulking agent and monitored by respirometer, *Biosystem Engineering*, 102, 433–443, DOI: 10.1016/j.biosystemseng.2009.01.002.

[12] Stentiford, E.I., Mara, D.D. & Taylor, P.L. (1998). Forced aeration co-composting of domestic refuse and sewage in static piles. In: Composting of Agricultural and other Wastes, Gasser, J.K.R. (ed.), Elsevier Applied Science Publishers (pp. 42–55), London 1998.

[13] Tremier, A., Guardia, A., Massiani, C., Paul, E. & Martel, J.L. (2005). A respirometric method for characterising the organic composition and biodegradation kinetics and the temperature influence on the biodegradation kinetics, for a mixture of sludge and bulking agent to be co-composted*, Bioresource Technology*, 96, 169–180, DOI:10.1016/j.biortech.2004.05.005.

[14] Turan, N.G., Akdemir, A. & Ergun O.N. (2007). Emission of Volatile Organic Compounds during Composting of Poultry Litter, Water Air Soil Pollution, 184, 177–182, DOI: 10.1007/s11270-007-9406-0.

[15] Vandenabeele, J., Verhaegen, K., Sudradjat, R., Avnimelech, Y., Van Cleemput, O. & Verstraete, W. (1990). Interferences in simple N-determination methods: I. Reference compounds, *Environmental Technology*, 11, 859–862, DOI: 10.1080/09593339009384934.

[16] Wang, J.Y., Stabnikova, O., Ivanov, V., Tiong-Lee, S. & Tay, J.H. (2003). Intensive aerobic bioconversion of sewage sludge and food waste into fertiliser, Waste Management and Research, 21, 405–415, DOI: 10.1177/0734242X0302100503.

[17] Wei, Y.S., Fan, Y.B. & Wang, M.J. (2001). A cost analysis of sewage sludge composting for small and mid-scale municipal wastewater treatment plants, Resources Conservation and Recycling, 33, 203–216, DOI:10.1016/S0921-3449(01)00087-8.

[18] WERL. (2000). Compost Quality in America. Technical Document. Woods End Research Laboratory, Inc. (pp. 30–42), USA 2000.

[19] Wong, W.J., Fang, M., Li, G.X. & Wong, M.H. (1997). Feasibility of using coal ash residues as co-composting materials for sewage sludge, *Environmental Technology*, 18, 563–568, DOI: 10.1080/09593331808616574.

[20] Zhang, L, Xu, C.C. & Champagne, P. (2010). Energy recovery from secondary pulp/paper-mill sludge and sewage sludge with supercritical water treatment. Bioresource Technology, 101, 2713–2721, DOI: 10.1016/j.biortech.2009.11.106.