International Archive of Applied Sciences and Technology
Int. Arch. App. Sci. Technol; Vol 10 [2] June 2019 : 25-32

[ISO9001: 2008 Certified Organization]
www.soeagra.com/iaast.html

IAAST
ONLINE ISSN 2277- 1565
PRINT ISSN 0976 - 4828

CODEN: IAASCA ORIGINAL ARTICLE

DOI: .10.15515/iaast.0976-4828.10.2.2532

Bioconversion of N-poor Recycled Paper Mill Sludge (RPMS) into value-added compost; Positive role of N-rich organic substrates supplementation on the enhancement of bioconversion processes under aerobic windrow system

Lalithvaradhan S*, Kanagaraj K, and Vignesh Kannan P*****
*Environmental Engineer, Sripathi Paper and Board, Pvt. Ltd., Sivakasi, Tamil nadu, India.
**Technical Advisor, Sripathi Paper and Board, Pvt. Ltd., Sivakasi, Tamil nadu, India.
***Deputy General Manager, Sripathi Paper and Board, Pvt. Ltd., Sivakasi, Tamil nadu, India.

ABSTRACT
The recycling and bioconversion of N-poor RPMS along with N-rich kitchen waste and Tephrosia purpurea into value added compost was studied under aerobic condition in windrow system.The composting of the RPMS was carried out for a period of 45 days into three treatments, namely, 1. RPMS + Inoculum source 2. RPMS + Kitchen waste + Inoculum source and 3. RPMS + Kitchen waste + Tephrosia purpurea + Inoculum source were tested. Among the three treatments, the treatment T_3 yielded high nutritive compost during 45 days of composting time when compared to other two treatments. The Physico-chemical analysis of the RPMS compost revealed a gradual decrease in EC and C:N ratio content and increase in pH level during the composting processes whereas the temperature of the composting pile reached the thermophilic stage on 15th day of decomposition and thereafter decreasing value in temperature was recorded. Among the three treatments, the treatment T_3 recorded a very narrow C:N ratio and quick stability during 45 days of composting period when compared to other two treatments. It was concluded that the N-poor RPMS can be successfully bio-converted into value added compost in a period of 45 days by the supplementation of N-rich organic materials like Kitchen waste and Tephrosia purpurea in the ratio of 3:1:0.5.
Keywords: *N-poor RPMS, Kitchen waste, Tephrosia purpurea, bio inoculum, value added compost.*

Received 14.02.2019 Revised 18.03.2019 Accepted 19.04.2019

CITATION OF THIS ARTICLE
Lalithvaradhan S, Kanagaraj K, and Vignesh Kannan P. Bioconversion of N-poor Recycled Paper Mill Sludge (RPMS) into value-added compost; Positive role of N-rich organic substrates supplementation on the enhancement of bioconversion processes under aerobic windrow system. Int. Arch. App. Sci. Technol; Vol 10 [2] June 2019: 25-32

INTRODUCTION

The pulp and paper industry plays an integral role in the global economy. Global production in the pulp and paper industries is expected to increase by 77% by the year of 2020 with over 66% of paper will be recycled at the same time [20]. There are about 500 Kraft mills and thousands of other forms of pulp and paper mills in the world. The paper recycling process produces a considerable amount of organic waste which is not suitable for the production of new paper. The waste paper sludge is a growing problem worldwide and subsequently sludge production upto 23.4% per unit of producing paper will continue to increase and environmental quality standards will become more stringent [25].

Sludge from a typical recycled pulp and paper effluent-treatment facility undergoes dewatering operations which increases the solids content of the liquid sludge from 3-5% to about 50% (wet weight basis). Chemical flocculation coupled with mechanical force is used to remove water from the mixture. The resultant sludge material is a tightly held wet mass of secondary wood fibre, inorganic clays and filler and contaminants.

The disposal of N-poor RPMS is an inevitable problem for these industries. The current practices of sludge disposal include land spreading [27, 4], land filling [30] and incineration. These practices are becoming increasingly unfavourable due to ecological and economic considerations. New sludge management approaches must be sought that utilize this material in a value-added manner. Innovative and initiatives have been considered by many, but have proved unrealistic due to the large quantities, high moisture content, unpleasant odour substantial variability and difficulties encountered in handling the sludge material [2, 12, 11]. To ensure the sustainability of the recycled paper industry economically viable and ecologically sound alternatives must be found for the re-use of this waste stream.

Recycled paper mill sludge (RPMS) is an active organic material that has potential benefits as a source of nutrients for crop plants [7, 15]. According to Das *et al.* [10], composting paper sludge could be a promising technology in reducing waste problems by converting complex materials into useful soil amendments. According to Pe'rez-Piquarez *et al.* [26], compost amendment modify the microbial community composition and decrease plant pathogens activity by enhancing competition and antagonism among microbes and reducing mass and volume, which makes compost suitable for agricultural applications. Several studies on the feasibility and the advantage of composting pulp and paper mill sludge have been carried out mainly in the temperate countries, especially on the composting processes physical, chemical and microbial characteristics of the compost [1, 14, 22]. According to Marche *et al.* [22], composting paper mill sludge with hardwood sawdust (as bulking agent) could be successfully achieved with parameters such as aeration, moisture and close monitoring of C/N ratio. Moreover, the poor content of nitrogen (<0.3%) of the RPMS retards the anaerobic composting processes. Therefore, composting of N-poor RPMS along with kitchen waste and green manure plants (as nitrogen & bulking agent) could be an alternative method to reduce the composting time and increase the nutrient status of the compost under aerobic windrow system [6, 7].

Hence, the present research work has been undertaken with an aim to exploit the positive role of N-rich organic substrates supplementation on the enhancement of bioconversion processes of N-poor RPMS to value-added compost under aerobic windrow system.

MATERIAL AND METHODS

Experimental site and conditions

The study was conducted at the barren yard section of Sripathi paper mill, Sivakasi, Tamil nadu state, India in an open condition during the summer season (April to June, 2018). The mean minimum and maximum temperature of the area is 26˚C and 30˚C, respectively with 53% of relative humidity. The whole study was carried out on composted clay surface having low permeability (10^{-7} cm) and a two percent slope. The down slope boundary of the pad was surrounded by clay bund to ensure that leachate was diverted to leachate collection tank.

Collection of recycled paper mill sludge (RPMS):

The RPMS was collected from the filter press used for dewatering and used for dumping windrows (Plate 1). During the collection, the RPMS was in wet solid form (50% solid content) and transported to experimental site by using truck.

Physico-chemical characteristics of RPMS

Four samples (each 1 kg) of each windrow were collected from different layers of RPMS for the purpose of characterization. They were brought to the laboratory, air dried and ground to pass through a 2 mm sieve. After grinding the RPMS, all the four samples were pooled up and a representative sample (1 kg) was collected.

The representative sample is used to analyse the physico-chemical characteristics, namely, moisture content, pH, EC, organic carbon, C:N ratio and macro nutrients, namely, N, P and K.

Table 1: Physico-chemical analysis of Recycled Paper Mill Sludge

Parameter	RPMS
Moisture content %	60
pH	6.8
EC ms^{-1}	3.92
Organic carbon %	12.6
Total Nitrogen %	0.3
Total Phosphorus %	0.1
Total Potassium %	0.24
C:N ratio	42

Experimental setup:

The collected RPMS were dumped in windrow measuring 3 m (width) X 6 m (length) X 2m (height) and used for composting in aerobic environment. It has been documented that the windrow with the above measurements is enough to retain heat in composting mass to promote the desirable thermophilic activity [23]. The process of aerobic composting was carried out in three different treatments as detailed below.

1. RPMS + Inoculum source (The inoculum source was prepared as slurry containing cow dung, poultry waste and goat waste @ 3:1:1 ratio).
2. RPMS + Inoculum source + Kitchen waste (The kitchen waste was obtained from the industrial canteen of the Sripathi paper mill, Sivakasi and mixed with RPMS @ 3:1 ratio, respectively).
3. RPMS + Inoculum source + Kitchen waste + *Tephrosia purpurea* (The legume plant *Tephrosia purpurea* was collected from the gardenland site of the industry, shredded into 4mm pieces, transported to the experimental site and mixed with RPMS + Kitchen waste @ 3:1:0.5 ratio, respectively).

Nine windrows were constructed in three rows in order to maintain three replications of each treatment. The oriented slope is used to permit leachate to flow towards the collection tank. The windrows were aerated by natural convection as hot air rises through the top of the pile, creating a partial vacuum that draws cooler air from the sides, thus, circulating air which provides enough oxygen and access for microbes to nutrients. Each windrow was initially turned on the same day. Windrows were turned throughout the study with a front loader for every 15 days. The samples were drawn at intervals of 15 days, dried and ground to pass through 2 mm sieve and used for Physico-chemical analysis.

Physico-chemical analysis of the composted RPMS

The pH and EC of the samples were determined by shaking 10 g of compost material in 100 ml of distilled water (1:10 w/v) for 3 minute and then measuring with digital pH and EC meters. Total nitrogen (N) in the compost was estimated by digestion and subsequent measurement with the Kjeldhal method [5]. Total carbon (C) content was determined by the dry ash procedure described by Jackson [17]. The C/N ratio was calculated by dividing the percentage of organic carbon by the percentage of total nitrogen [18]. Macronutrient contents (P and K) of compost were extracted by digestion with di-acid and estimated colorimetrically and by flame photometer, respectively [17].

Temperature of each windrow was measured daily with long stemmed thermometer. The thermometer sensor was inserted about 0.6 m below the pile surface and approximately half of the distance from the ground to the top of the pile in two locations of each windrow.

Statistical analysis

The experiment was conducted in completely randomized block design (CRD) with three replications.

0^{th} Day 45th day

Plate 1: Appearance of Recycled Paper Mill Sludge (RPMS)

RESULTS AND DISCUSSION

The physical and chemical properties of RPMS are presented in Table 1. The raw RPMS were wet, sticky, cake form with moisture content of about 60% and unpleasant odour. Generally, the RPMS was dewatered mechanically to increase the solid content, reduce the volume and weight and improve their handling properties. The composting of the RPMS is recognized as the best pre-treatment in order to obtain a material with reduced odour and better sanitization [3].

The mean pH value of the RPMS was 6.8 (Table – 1) so, the RPMS is suitable for land application because of its neutral pH and the cellulosic fibre content of the same can hold moisture in the soil system.

The Electrical conductivity (EC) of the RPMS was recorded as 3.92 ms cm^{-1} (Table-1). However, the EC level < 2 ms cm^{-1} in soil and irrigation water is generally considered as a safer level for agricultural crops. Generally, most of the agricultural crops were found to tolerate the EC level in a range of 3 – 4 ms cm^{-1} in soil.

The carbon content of the recycled paper mill sludge was recorded as 12.6 % whereas the N and P content of RPMS was found to be 0.3 % and 0.1%, respectively. The high organic matter content of RPMS improves the soil fertility and enhances the physical properties of agricultural soils (Table – 1).

Gulser *et al.* [8] and Rosazlin *et al.* [28] described the Physico-chemical characteristics of the RPMS in detail. In the present study also, the RPMS collected from Sriapathi paper mill had similar characteristics of the above reports except for the contents of nutrients and heavy metals.

Compost characteristics during composting processes

Changes in pH, EC and C:N ratio of the RPMS that occurred in the windrow during the decomposition of RPMS was studied. The pH values showed a variation among the three different treatments (T_1 – T_3). Among the three treatments, the treatment T_3 recorded a sharp increase in pH level when compared to other treatments. The initial pH value of the treatment T_3 was found to be 6.89 and the same increased to 7.41 after 45 days of decomposition of RPMS (Fig. 1). Kizilkaya *et al.* [19] reported that the increase in pH value during the decomposition of RPMS attributed to the production of ammonia. When ammonia reacts with water to form NH_4^+ and free OH^- groups and thus the pH value increases. Michel and Reddy [24] reported that the rise in pH level during the decomposition of RPMS might be attributed to the degradation of short chained fatty acids and ammonification of organic N in RPMS. Lakshmipriya *et al.* [21], Rosazlin *et al.* [28] and Gulser *et al.* [8] reported the increase in pH values during the decomposition of RPMS along with various bulking agents, namely, sawdust and empty fruit branches. In the present study also, the rise in pH level was recorded during the decomposition of RPMS along with *Tephrosia purpurea,* as bulking agent.

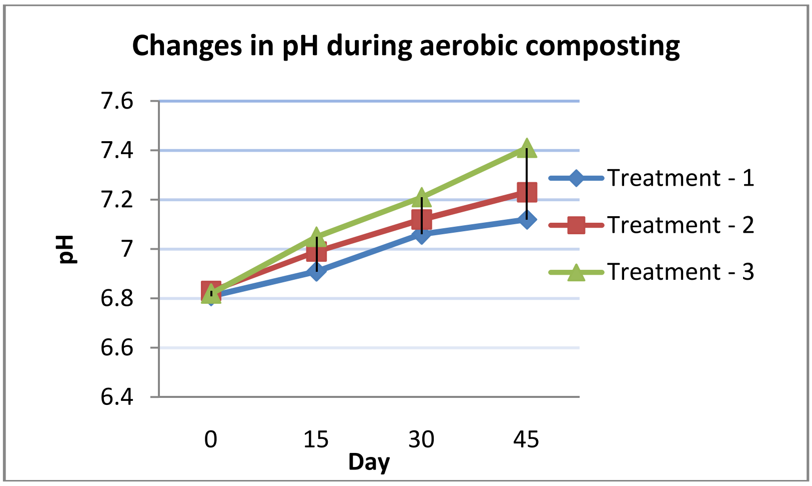

Fig 1: pH profile during composting

The decreasing pattern of EC was observed in all the treatments, namely, T_1 – T_3 during the decomposition of RPMS whereas the treatment T_3 recorded a sharp decrease in EC level compared to other treatments (Fig. 2). The decreasing profile of EC indicates that the compost is ideal for land application [29]. In the present study, the final EC of the RPMS compost occurred within the recommended values and the same can be used as soil amendment.

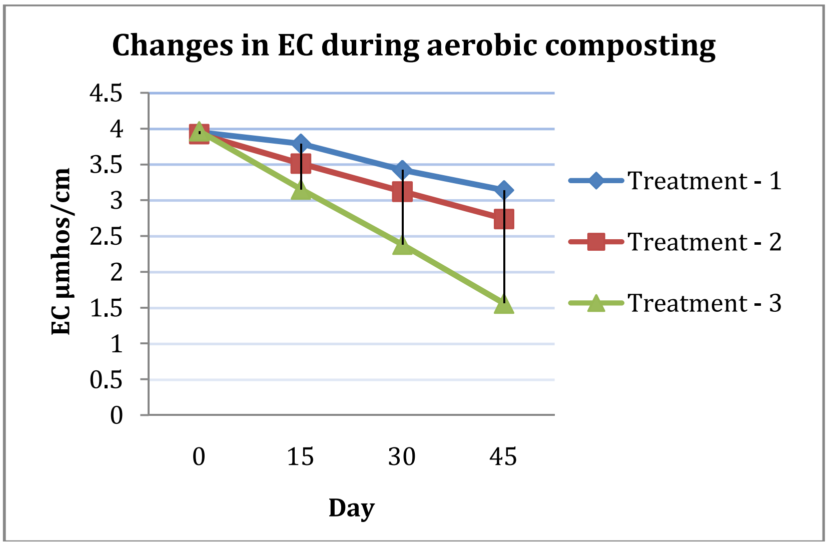

Fig. 2: EC profile during composting

In the present study, the C:N ratio of the RPMS compost was found to be 23.2, 18.46 and 11.8 in T_1, T_2 and T_3 treatments, respectively (Fig. 3). Among the three treatments, the treatment T_3 recorded a narrower C:N ratio when compared to other treatments. C:N ratio is an index for the maturity of the compost. The compost with narrow C:N ratio is highly suitable for land application [28]. The results of the present study clearly reported the positive role of enhanced microbial activity during the decomposition of RPMS and the same attributed to the addition of N – rich organic materials, namely, Kitchen waste and *Tephrosia purpurea* to the RPMS and thus the decomposition of RPMS reached the maturity stage of the compost at an earlier time, namely, 45 days.

Among the three treatments, the treatment T_3 recorded a narrow C:N ratio (11.8:1) when compared to other two treatments after at 45 days of RPMS decomposition. The C:N ratio was found be higher on the first day of decomposition, but it decreases subsequently with time. This might be attributed to the decomposition of organic matter into CO_2 and H_2O due to the enhanced microbial activity in windrow. The result of the present study is complying with standards recommended by the Central Public Health and Environmental Engineering

Organization (CPHEEO, 2000), India[9]. The C:N ratio below 20 is an acceptable maturity in final product. However, a C:N ratio of 15 or less being preferable [16].

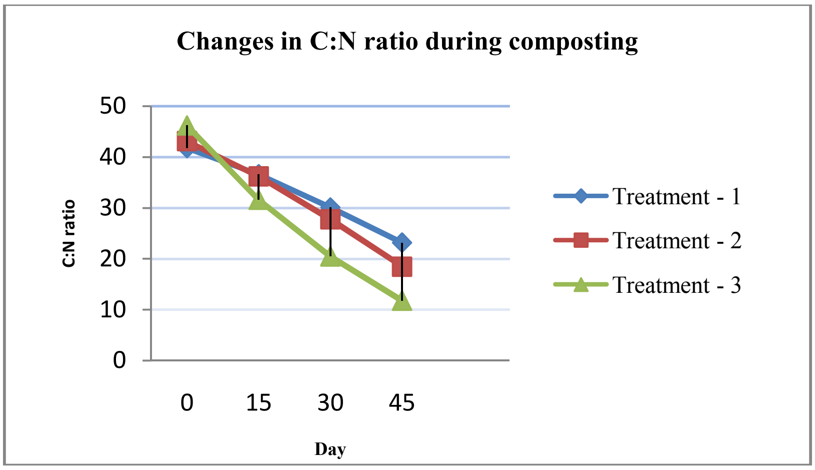

Fig. 3: Changes in C:N ratio during composting

All the treatments namely, T_1 – T_3 showed a variation in temperature pattern. Among the three treatments, the initial temperature of the treatment T_3 was found to be 27˚C and the same increased to 65˚C after 15 days of composting period. The temperature of the compost pile is either a consequence or determinant of microbial activity (Vallini *et al*., 2002)[31].

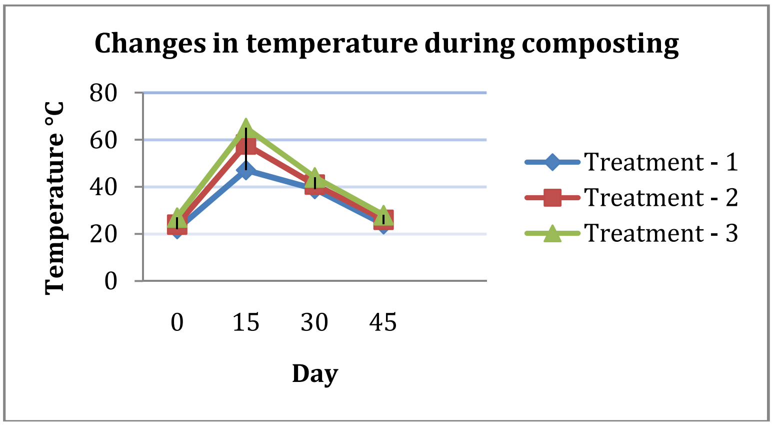

Fig. 4: Temperature pattern during composting

The results of the present study clearly indicated the intense activity of the microorganisms so that the composting processes was at higher rate when compared to other treatments. The temperature gradually decreases to mesophilic range by the end of the composting period as indicated in fig. 4. The heat generated in this process also helps in the destruction of pathogens [13].

Table 2. Macronutrient content of RPMS composed after 45th day of composting in aerobic windrow system

Parameter	T_1	T_2	T_3
Total Nitrogen %	0.5	0.78	0.95
Total Phosphorus %	0.2	0.34	0.42
Total Potassium %	0.32	0.47	0.72

In the present study, the treatment T_3 recorded a higher level of nutrient concentrations, namely N, P, K in the final product when compared to other two treatments after 45 days of composting period (Table – 2). The results of the present study are also in concomitant with an earlier findings of Zucconi and De Bertoldi [32].

CONCLUSION

The results of the present study clearly revealed the recycled paper mill sludge (RPMS) which is rich in carbon and poor in nitrogen content can be recycled together with nitrogenous rich organic materials like Kitchen waste and *Tephrosia purpurea* (Bulking agent) by mixing in a ratio of 3:1:0.5 with suitable inoculum source (cow dung slurry, Poultry waste and Goat waste) in a period of 45 days under aerobic windrow composting system. The treatment, namely, RPMS + Kitchen waste + *Tephrosia purpurea* + inoculum source recorded a decreasing composting time with high nutrient content (NPK) due to the enhanced microbial activity. Therefore, the addition of nitrogenous rich organic materials and effective inoculum source play a vital role in the recycling and bioconversion of N-poor RPMS into value added compost. However, the biochemical and physiological mechanism of bioconversion of RPMS into compost needs further exploitation.

ACKNOWLEDGEMENT

The authors are gratefully acknowledged the moral support and financial assistance rendered by Mr. R. Krishnaswamy, Chairman, Mr. K. Ravichandran, Managing Director, Mr. A. Ragupathy, Director. Mr. K. Rajkumar, Vice President, Mr. G. Srinivasan, General Manager of Administration, Mr. B. Ragunathan, General Manager – Production/Technical and other Staff members of Sripathi paper mills, Sivakasi, Tamil nadu, India for carrying out the research work successfully.

REFERENCES

1. Atkinson C.F., D.D. Jones and J.J. Gauthier. (1997). Microbial activities during composting of pulp and paper mill primary solids. *World Journal of Microbiology and Biotechnology.* 13(5): 519-525.
2. Badar, T.A. (1994). Environmental Impact of Recycling in the Paper Industry. Ed. M. DOSHI. *Recycled paper Technology: An Anthology of Published Papers.* Atlanta, GA: TAPPI Press, 235-245
3. Barkey, A.V. (1997). Composition and uses of compost. In *Agricultural Uses of By-Products and Wastes;* ACS Symposium Series 668; Rechcig, J.E., MacKinnon, H.C., Eds.; ACS: Washington, DC, USA; pp. 539-544.
4. Bellamy, K.L., N. deLint, N. F. Pridham and R. A. Cline. (1990). Agricultural utilization of paper mill sludge in the Niagara area. *Proceedings of the 12th International Symposium on Wastewater Treatment and 2nd Workshop on Drinking Water*, Montreal. pp. 65 – 81.
5. Bremner, J.M. (1960). Determination of nitrogen by Kjeldhal method. *J. Agric. Sci.,* 55: 11-33.
6. Chong, C. and R.A. cline. (1991). Composts from paper mill wastes. *Landscape Trades*, 13(9): 8-11.
7. Cline, R.A. and C. Chong. (1991). Putting paper mill waste to use in agriculture. *Highlights Research*, Ontario, 14(1): 16-19.
8. Coskun Gulser, Ridvan Kizilkaya, Muleyka Nur Karadayt, Nazhean Kuren, Murat Durmus. (2010). composting potential of paper mill waste with town waste. http://www.researchgate.net/publication/295859025.
9. CPHEEO, (2000). Manual on Municipal Solid Waste Management, Central Public Health and Environmental Engineering Organization, New Delhi, India.
10. Das, K.C., E. W. Tollner and T.G. Tornabene. (2002). Windrow composting of paper mill by-products: scale-up and seasonal effects. *Compost Science and Utilization* 10(4): pp. 6-12.
11. Engel, P. and B. Moore. (1998). Recycled Mills Seek Options to Turn Deinking Residuals into Resources. *Pulp and Paper,* 72 (4): 83-84.
12. Glowacki, J.J. (1994). Land filling of Sludge remains most viable, but new options on horizon. *Pulp & Paper,* 68(9): 95-97.
13. Golueke, C.G. (1977). Biological Reclamation of Organic Wastes, Rodales Press, Emmans. PA. USA.
14. Graydon A.R., Hackett, Charles A. Easton and Sheldon J.B. Duff. (1999). Composting of pulp and paper mill fly ash wastewater treatment sludge. *Bioresource Technology.* 70(3): 217-224.
15. Henry, C.L. (1991). Nitrogen dynamics of pulp and paper mill sludge amendment to forest soils. *Water Science Technology,* 24:417-425.
16. Inbar, Y., Y. Chen, Y. Hadar and H.A.J. Hoitink. (1990). New approaches to compost maturity. Biocycle, 31: 64-69.
17. Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

18. Jones, J. B. (2001). Laboratory guide for conducting soil tests and plant analysis. Washington; CRC Press.
19. Kizilkaya, R., N. Sahin, D. Tatar, A. Veyisoglu, T. Askin, S.N. Sushkova and T.M. Minkina. (2017). Isolation and Identification of Bacterial Strains from Decomposting Hazelnul Husk, *Compost Science & Utilization.* 23(3): 174-184.
20. Lacour, P. (2005). Pulp and paper markets in Europe Prepared for the United Nations Economic Commission for Europe and the food and Agriculture Organization of the United Nations. USA.
21. Lakshmi Priya Thyagarajan, T., T. Meenambal, L., Mangaleshwaran, N. Lakshminarasimaiah and N. Ramesh. (2010). Recycling of Pulp and Paper Industry Sludge with Saw Dust by Aerobic Composting Method. *Nature Environment and Pollution Technology: An International Quarterly Scientific Journal,* 9(1): 149-154.
22. Marche, T., M. Schnitzer, H. Dinel, T. Pare, P. Champagne, H-R. Schulten and G. Facey. (2003). Chemical changes during composting of a paper mill sludge hardwood sawdust mixture. *Geoderma.* 116: 345-356.
23. Mathur, S.P. and R.S. Fernham,(1985). In: Humic Beulah Gnana Anathu substances in Soil, Sediment and Water. Eds. G.R. Aiken, D.M. Menights, R.L. Warshaw and P. Mac Carthy, John wiley, New York. P. 53.
24. Michel J.R., F.C., and C. A. Reddy. (1998). Effect of oxygenation level on yard trimmings composting rate, odour production and composting quality in bench-scale reactors. *Compost Sci. util.,* (6)4: 6-14.
25. Miner, R. (1991). *Environmental Considerations and Information Needs Associated with an Increase Reliance on Recycled Fiber.* pp: 343-362, in Focus 95' Proceedings, TAPPI PRESS, Atlanta.
26. Pe'rez-Piquere, A., V. Edel-Hermann, C. Alabouvette and C. Seinberg. (2006). Response of soil microbial communities to compost amendments. *Soil Biology Biochemistry.* 38: 460-470.
27. Pridham, N.F. and R. A. Cline. (1988). Sludge disposal: Completing the ecological cycled Pulp and Paper Canada, 89(2): 173-175.
28. Rosazlin Abdullah, Che Fauzhiah Ishak, Wan Rasidah Kadir and Rosenanai Abu Bakar. (2015). Characterization and Feasibility Assessment of Recycled Paper Mill Sludges for Land Application in Relation to the Envrionment. *International Journal of Environmental Research and Public Health,* 12: 9314-9329.
29. Rynk, T. (1992). On Farm composting Handbook, NRAES-54.
30. Scott, G.M. and Smith, A. (1995). Sludge characteristics and disposal alternatives for the pulp and paper industry. *In: Proceedings of the 1995 International environmental conference;* Atlanta, GA: TAPPI PRESS: 269-279.
31. Vallini, G.D., S. Gregario, A. Cristina and F. Cunha Queda. (2002). Exploitation of composting management for either reclamation of organic wastes of solid-phase. *Treatment Environment Review,* 10: 195-207.
32. Zucconi and de Bertoldi (1987). Compost specification for the production and characterization of compost from municipal solid waste. In: De Bertoldi, M., Ferranti, M.P., L'Hermite, P. and Zucconi, F. (Eds)., Compost: Production, Quality and Use, *Elsevier Applied Sc.,* Essex, pp. 30-50.

