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RESEARCH ARTICLE

EFFICIENT AND ECO-FRIENDLY MANAGEMENT OF DIFFERENT TYPES OF SOLID WASTE USING WINDROW COMPOSTING TECHNIQUE AND EFFECT OF SEWAGE AS ADDITIVE ON PHYSICO-CHEMICAL CHARACTERISTICS OF COMPOSTS

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ABSTRACT

Solid waste management is a crucial issue in developing countries due to large amounts of waste being generated from different sources. Aerobic windrow composting of various wastes was carried out to create compost from various wastes for use as a nutritious soil fertilizer and to optimize waste material by employing sewage as an addition to minimize composting time and improve soil nutritional value. Four composting windrows were formed with three different types of wastes i.e. first windrow was animal waste + garden waste treated by sewage water, second windrow was food waste + garden waste treated by sewage water, third windrow was mixture of wastes treated by sewage water, and the last windrow was also mixture of wastes but treated by tap water. The compost of mixture of wastes treated by sewage water was found better than the other three windrows as having pH 8.69, Organic Content 59.25%, Moisture Content 28.09%, Carbon 27.85%, Nitrogen 0.66%, C/N ratio 42.2, Phosphorous 1.4% and Potassium 0.84%. If composting of mixture of wastes like animal waste, food waste and garden waste treated with sewage water is carried out, then it will give better results and also reduce the composting period by 30%.

KEYWORDS

Aerobic windrow, nutritious soil, sewage water

1. INTRODUCTION

Garbage, rubbish, and sludge released by wastewater treatment plants, as well as other solid and gaseous elements that pollute the air, were referred to as solid waste (Mahar et al., 2007). It had different types like Municipal Solid Waste, Hazardous Wastes, Industrial Wastes, Agricultural Wastes and Bio-Medical Wastes (Adila and Nawaz, 2009). Household waste leftovers rejected or unwanted items made by animals and people had all been included in municipal solid waste (Hayder and Masood, 2011). Rising solid waste generation in large urban areas is posing a great problem for the organic part of solid waste management. Deteriorating environmental quality is a serious consequence of open dumping site and is rapidly increasing concern for public (Farooki and Qazi, 2000). Improper handling and management technologies have been a key source of concern for developing countries.

In Pakistan, primary and secondary collection methods were used to gather waste, with 90 percent of openly discharged rubbish being dumped in undesirable locations (Korhonen, 2004). In Pakistan's most populous cities, collected rubbish accounted for almost 60% of total waste.

(Javied et al., 2014). Around 70% of rubbish collected in Pakistan's major cities was deposited on roadways, while 30% was thrown on highways in the country's smaller towns (Masood, 2013). Refuse, trash, different things like food scratches, item bundles, paper, metal, pottery, calfskin, materials, plastics, elastic, bone and remains were likewise remembered for municipal solid waste. Solid waste management was a significant procedure included the waste diminishing partly, reusing of treated waste and reusing of waste for additional again usable items. The production of solid waste and deterioration was a basic issue for the agricultural countries (Chang and Chen, 2010). Total waste gathered and production rate for various urban communities in Pakistan is delineated in the table 1.

Table 1: Per Capita Municipal Solid Waste Generation in Pakistan

City	Waste Generation (Tons)	Waste Generation Rate (Kg/Capita/Day)	Waste Collection (%)	Waste Uncollected (%)
Karachi	9440	0.44	60-70	30-40
Islamabad	3841	0.624	85	15
Lahore	6510	0.5-0.65	61	39
Faisalabad	4883	0.45-0.5	59	41

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In Faisalabad most common method of the disposal of solid waste is open dumping which actually not environment friendly method (Basheer et al., 2018).

Figure 1: Waste Dumping on Sea Site and Drains

Physical composition of Faisalabad waste is shown and then its comparison with EMPC estimation is discussed in Table 2 (Environment Protection Agency, 2007).

Table 2: Physical Composition of Faisalabad's Waste as Compared to EPMC

Serial No.	Waste Component	Percentage Weight	Percentage EPMC
1	Plastic and Rubber	6.61	4.81
2	Metals	1.0	0.20
3	Paper and Cardboards	7.66	3.69
4	Rags and Textile Waste	6.54	5.20
5	Glass and Ceramics	2.42	1.30
6	Bones	2.40	2.89
7	Food waste	33.82	17.21
8	Leaf, grass and straw	7.35	15.59
9	Wood	1.07	0.70
10	Animal waste	2.35	0.80
11	Dust, dirt and stone	28.78	47.60
Total		100	100

Composting includes the stabilization and decomposition of organic fraction of MSW. Fewer amounts of greenhouse gases would be produced than the landfilling of waste materials (Lou and Nair, 2009). Composting could be a well-developed technique of fertilizer generation. Final product of composting had been used as soil conditioner or fertilizer. Fertilizer should have the essential nutrients like nitrogen, phosphorous and potassium for the plant's growth. Composting mainly of two types as following: Aerobic and Anaerobic. But there are several types of composting according to the methodology. The temperature has a significant impact on the population of bacteria, their pace, and the decomposition process (Kumar et al., 2010). Following microbes will help to complete the composting process (Adhikari et al., 2008).

- Psychrophiles-low temperature microbes
- Mesophiles-medium temperature microbes
- Thermophiles-high temperature microbes
- Chaetomium
- Earthworms

Chemical fertilizers affect microorganisms living in the soil. The acidity of chemical fertilizers also adversely affects the soil pH and makes it acidic, thereby changing the kinds of microorganisms that can live in the soil (Ye et al., 2020). Prolonged use of chemical fertilizers causes an increase in pests and kills the beneficial microbes present in the soil. The leaching away of chemical fertilizers pollutes the underground water. On the other hand, Organic compost improves the soil texture, allowing it to hold water longer, and increase the bacterial and fungal activity in the soil. So, they not only assist your plants, but they also help the soil (https://www.kellogggarden.com/blog/fertilizer/the-advantages-of-organic-fertilizers-overchemical-fertilizers/). Faisalabad has a population of about 4 million people, and daily waste creation is around 1350-1500 tons, but the storage capacity is approximately 900 tons, with only 600-700 tons deposited in open landfill site. Faisalabad's average daily solid trash production rate is 0.5 per people (Yasin and Usman, 2017).

Various methods of waste management system are used, such as land filling, incineration, and composting. Most municipal waste is incinerated, dumped, or deposited in empty houses, endangering the safety and welfare of human public. As a result, composting is the most effective method. Waste is collected, disposed of in landfills, and ignited in fresh environment, posing a population, odor, and health concern. The objectives of this study were to determine the different physical & chemical parameters of compost material produced from different types of wastes including temperature, pH, Moisture content, C/N, NPK contents and to optimize the waste material from different sources by using sewage as additive to reduce composting period and to enhance nutritional contents of the soil.

2. Material and Methods

2.1 Research Plan Flow Chart

This research study on aerobic windrow composting of different types of wastes was performed at university of agriculture Faisalabad. The research plan flow chart of this study is:

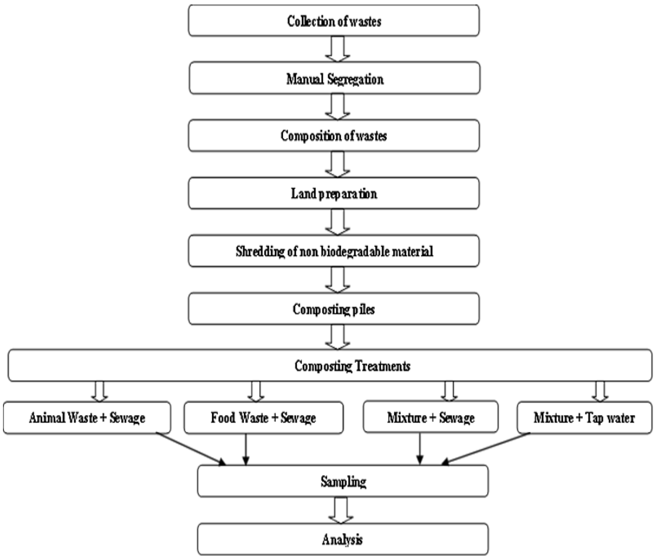


Figure 2: Research Plan Flow Chart

Secondly collection of food waste was done from Sabzi Mandi G.M.Abad. Animal waste was collected from agronomy fields of UAF and the garden waste was collected from faculty grounds of UAF. The study plan flow chart (Figure 2) depicts the method of efficiently conducting the research project by creating four windrows' piles of three types of waste (animal waste, food waste, and garden waste) and determining the physico-chemical parameters of the finished compost

2.2 Materials

The following elements were utilized in this study to prepare aerobic windrow composting:

- Food Waste
- Animal Waste
- Garden Waste
- Tap Water
- Sewage Water

2.3 Collection of Wastes for Composting

Food waste was collected manually from Sabzi Mandi G.M.A bad in big sags. The animal waste was collected manually from agronomy fields UAF. The garden waste was collected from different faculty grounds of UAF as shown in Figures. Waste was picked on a regular basis and transferred to a shredder nearby the Biogas plant in the agronomy fields. For optimal shredding, food waste and garden trash were dried in sunlight first (Fatin and Saad, 2014). Sewage water was obtained from a neighboring Madhuana wastewater drain at Khurrianwala. The qualities of sewage water were discovered as pH=8.36, TDS=1906mg/L, EC=2450mS/cm.

Figures 3: Collection of Wastes

2.4 Preparation of composting pads

Four composting heaps with prescribed dimensions of 3 ft length, 1.5 ft width, and 0.5 ft height were created as part of this study. Four composting piles were created, each with a 1 ft gap between them and from the sides. The composting pile was twice as wide as it was tall (Tchobaneglous and Vigil, 1993). During the process of building composting piles, the ground was dug up to a depth of one foot. The deep soil was abundant in microorganisms, which was necessary for the useful composting process. The four windrows are laid out in the Figure 4.

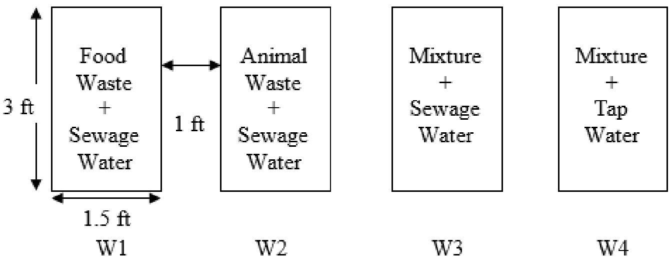


Figure 4: Layouts of the Windrows

2.5 Formation of Composting Windrows

After shredding, garbage was refilled in bulges to transfer it into the composting heaps research field, and then weighed in equal proportions to form four windrow composting heaps. To fill composting mounds, all crushed trash was manually mixed in equal amounts.

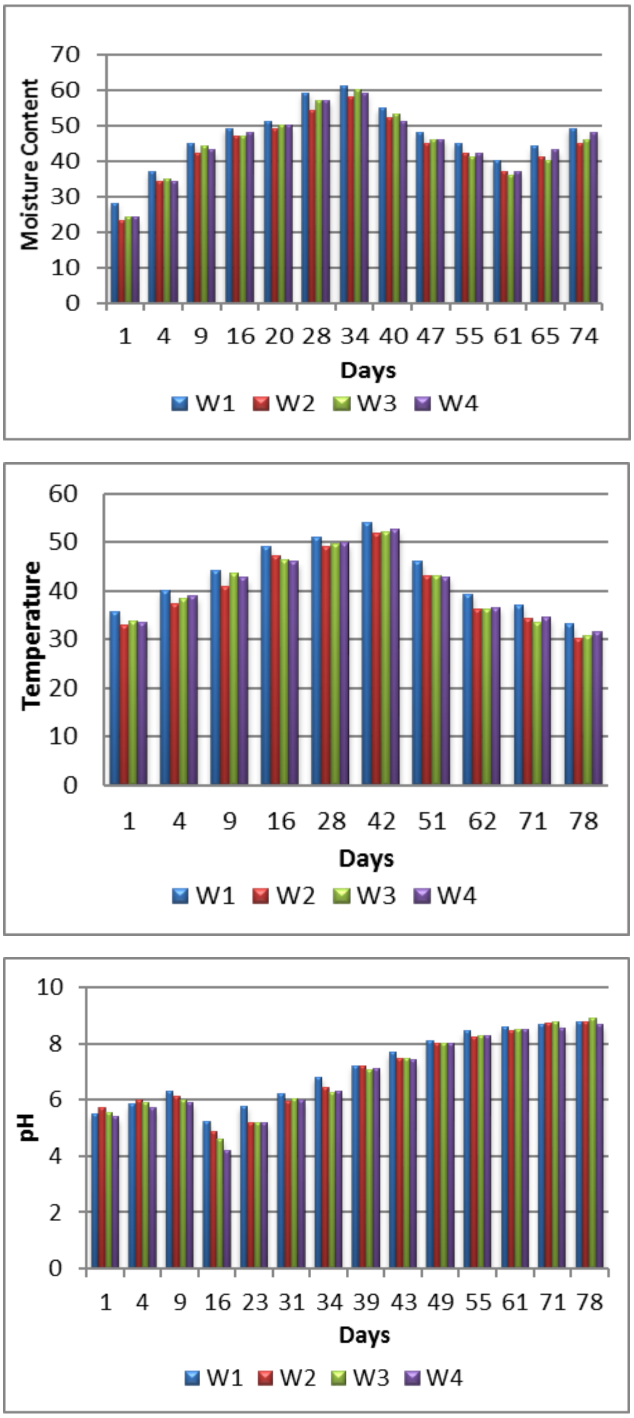
Table 3: No. of Windrows, Treatments and Weights of Wastes

Windrows	Wastes	Treatments	Total weight (kg)	Ratio (%)
W1	Animal Waste	Sewage Water	15	100
W2	Food Waste	Sewage Water	15	100
W3	Mixture	Sewage Water	15	100
W4	Mixture	Tap Water	15	100

3. Results and Discussions

3.1 Monitoring Throughout Composting

Aerobic windrow composting process was performed by establishing four different wastes treatments. First windrow contained animal waste that had been treated with sewage water, the second contained food waste that had been treated with sewage water, the third contained a mixture of wastes that had been treated with sewage water, and the fourth contained a mixture of wastes that had been treated with tap water. Throughout the research experiment, environmental, physico-chemical characteristics such as moisture content, temperature, and pH were monitored at the interval of days.



Figures 7: Moisture Content, Temperature & pH Analysis of all windrows

After applying stat on temperature, pH and moisture content it was observed that the p value is greater than the alpha reported in following tables the variance analysis (ANOVA) under randomizes randomization (CRD) revealed that the results were not significant.

Table 4: Statistical analysis of temperature in windrows

SUMMARY				
Groups	Count	Sum	Average	Variance
T1	39	1612.6	41.34872	49.57888
T2	39	1613.8	41.37949	48.87167
T3	39	1614.98	41.40974	49.10924

Table 5: ANOVA Test results of temperature analysis in windrows

ANOVA Test						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	0.072622	2	0.036311	0.000738	0.999262	3.075853
Within Groups	5607.272	114	49.1866			
Total	5607.345	116				
Abbreviation: SS (Sum of Squares); Df (Degree of Freedom); MS (Mean Squares);						

Table 6: Statistical analysis of pH in windrows

SUMMARY				
Groups	Count	Sum	Average	Variance
pH1	39	248.03	6.359744	1.093418
pH2	39	249.16	6.388718	1.113211
pH3	39	247.8	6.353846	1.177919

Table 7: ANOVA Test results of pH analysis in windrows

ANOVA Test						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	0.027174	2	0.013587	0.012043	0.98803	3.075853
Within Groups	128.6129	114	1.128183			
Total	128.64	116				

Table 8: Statistical analysis of moisture content in windrows

SUMMARY				
Groups	Count	Sum	Average	Variance
M1	52	2323	44.67308	87.24397
M2	52	2378	45.73077	83.65158
M3	52	2319	44.59615	83.46116

Table 9: ANOVA Test results of moisture content analysis in windrows

ANOVA Test						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	41.80769	2	20.90385	0.24655	0.781803	3.055162
Within Groups	12972.19	153	84.78557			
Total	13014	155				

3.1.1 Temperature Analysis

The temperature of the composting pads increased throughout the first 30-40 days of the composting operation. The ambient temperature during the composting operation was found to be 38.5, 43, and 48.2^{0}C during April, May, and June, respectively. Temperature of 1st and 2nd windrows was higher than the other two piles because of less organic content. 3rd windrow had the lowest temperature throughout the composting period because it had the highest organic content as compared to the other three piles. The temperature of all windrows began to drop after the 30th day. On a temperature-based assessment, microbial growth was at its height during the first month of the composting process. Temperatures in all windrows ranged from 32 to 54^0 C over the first month. W1 of animal waste treated with sewage water recorded the highest temperature of 53.9^{0}C. As shown in table 4, the analysis values of temperature in windrow ranges from 30.1 ^{0}C to 53.9 ^{0}C with an average value of 41.38^{0}C$\pm$ 7.04.

3.1.2 Analysis of Moisture Content

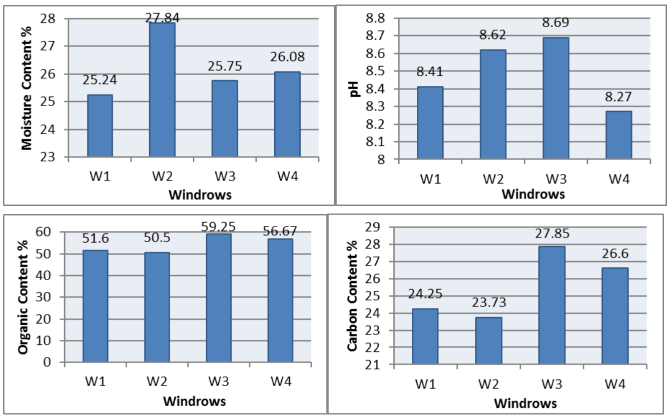
Moisture content study revealed that microbiological requirements were met, with moisture average values ranging from 40 to 60%. For the first week, moisture content of all the four windrows was measured by oven dry method. But then it was measured by moisture meter. Moisture content during monitoring process for W1, W2, W3, and W4 was displayed cumulatively to determine the best bacterial growth. The final wetness of the product for packaging should be as low as possible in order to sell as fertilizer on the market. Moisture content in windrows ranges from 23 to 61% with an average value of 45.7 $\pm$ 9.2. Moisture content varies inversely as temperature varies. 2nd windrow of food waste treated with sewage water had a higher final moisture content value over other composting heaps because of temperature.

3.1.3 Analysis of pH

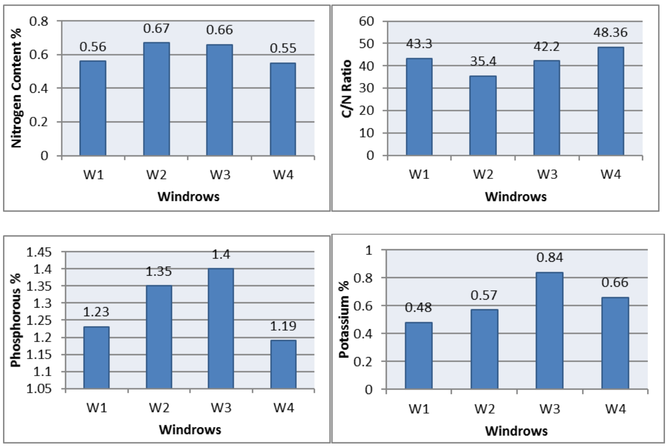
In comparison to other 3 composting heaps, the pH of the third composting pile of mixed wastes irrigated with sewage water had the greatest pH, indicating higher organic production for the degradation of lignin and cellulose. All the pH values lied in the specified range for composting 5.5-8 (Zakarya et al., 2018). The pH of the fourth pile of mixed wastes irrigated with tap water was lower than pH of the previous piles. pH in windrows ranges from 4.21 to 8.88 with an average value of 6.38 $\pm$ 1.06. The pH in every four piles was within the normal range, with the exception of the fourth pile, which had a pH of 8.27. The pH of the finished compost material was constructed to distinguish between these pH values of W1, W2, W3, and W4, which reveals the higher pH value for W3 of mix wastes mixed with sewage water. pH increased by application of sewage water due to presence of many chemicals and pollutants like carbonates, bicarbonates or hydroxide compounds which increases the pH. As a result, the fertiliser produced by composting a mix of wastes treated with sewage water was of higher quality than that of the fertilisers produced by other three composting methods.

3.2 Analysis of Final Compost

All the physico-chemical characteristics i.e. pH, moisture content, organic content, carbon content, nitrogen content, C/N ratio, phosphorous content and potassium content of the final ready compost were measured and depicted in figures.



Figures 10: Moisture content, pH, Organic content and Carbon Analysis of Final Compost



Figures 11: Nitrogen, C/N, Phosphorous and Potassium Analysis of Final Compost

3.2.1 Analysis of Moisture Content

Moisture content study revealed that microbiological requirements were met, with moisture average values ranging from 40 to 60%. As illustrated in Figure 10 (a), moisture content during monitoring process for W1, W2, W3, and W4 was displayed cumulatively to determine the best bacterial growth.

3.2.2 Analysis of pH

In comparison to other 3 composting heaps, the pH of the third composting pile of mixed wastes irrigated with sewage water had greatest pH, indicating higher organic production for degradation of lignin and cellulose. The pH of fourth pile of mixed wastes irrigated with tap water was lower than pH of the previous piles. Final pH analysis of windrows is shown in Figure 10 (b).

3.2.3 Analysis of Organic Content

Organic content of 2nd pile was low as compared to all other three piles. Organic contents of all the windrows were within the defined range 50-60%(https://umaine.edu/soiltestinglab/wpcontent/uploads/sites/227/2016/07/Compost-Report-Interpretation-Guide.pdf).Final organic content analysis results were shown in Figure 10 (c).

3.2.4 Analysis of Carbon Content

Carbon content of 2nd pile was recorded as 23.73% because food waste was rich in green material and less in brown material. Carbon content depends on the organic content and brown material added. 3rd pile had highest carbon content because of organic content shown in Figure 10 (d).

3.2.5 Analysis of Nitrogen Content

Nitrogen content of 2nd pile of food waste treated with sewage water had the highest Nitrogen content as 0.67% because of rich in green material as compared to other piles with N.C of 0.56%, 0.66% and 0.55% as illustrated in Figure 11 (a).

3.2.6 Analysis of C/N Ratio

First pile containing animal waste treated with sewage water having a C/N ratio of 35.5:1 less than the other three piles as illustrated in Figure 11 (b). The C/N ratio of the second pile of food waste treated with sewage water is 43.43:1, the C/N ratio of the fourth pile of mixed wastes treated with tap water is 48.36:1, and the C/N ratio of the third pile of mixed wastes treated with sewage water is 46.5:1. Typical value of C/N ratio varies 5-30:1 (Yu and Huang, 2009).

3.2.7 Analysis of Phosphorus Content

In comparison to the other three piles, the third pile, which contains a mixture of wastes treated with sewage water, has the greatest Phosphorus content as 1.4% because of human excreta, household detergents and some trade and industrial effluents. Phosphorus content is usually around 0.9 %. Food waste is rich in phosphorous because of bone meal, crab and shrimp waste, burned cucumber skins, hair and mushroom compost. Eggs are also a great source of phosphorous. Figure 11 (c) shows the final phosphorous content of all windrows.

3.2.8 Analysis of Potassium Content

Potassium content of all the four windrows' samples were analyzed as 0.48% for 1st pile, 0.57% for 2nd pile, 0.84% for 3rd pile and 0.66% for the 4th pile and shown in Figure 11 (d). 3rd windrow had the highest Potassium content as the manure is rich in potassium and kitchen waste like banana peels are also rich in potassium. Besides this, sewage water was also rich in potassium.

Food and animal wastes are completely biodegradable, and it can be decomposed to make fertilisers, which can be used instead of chemical fertilisers. Sewage had a complicated combination of compounds, including high levels of nitrate, ammonia and phosphorus, as well as strong conductance and pH. It was observed that W4, in which tap water was applied to maintain the moisture contents, took 3 months for the production of final compost. On the other hand the remaining three windrows W1, W2 & W3, in which sewage was applied; final compost product was achieved in only 2 and a half months. Moreover, sewage water had better effect on mixture of all types of wastes rather than individuals. Lahore compost limited (LCL) prepares its compost within 40 days by the use of compost activators.

4. Conclusion

Food waste management systems are not properly collected, transported, or disposed of due to shortage of collection, conveyance, and disposal systems. To manage this vast quantity of trash, management should use an aerobic composting approach. Composting systems can be started at a minimal cost and without the need for expert training. Temperature analysis was in the range from 27-530C and moisture content was in the range from 25-30% for all the windrows. 3rd windrow (Mixtures of wastes treated with Sewage water) was having the best NPK contents as compared to all others piles i.e. carbon 27.85%, nitrogen 0.66%, C/N ratio 42.2, Phosphorous 1.4% and potassium 0.84%.

Recommendation

It was concluded from the research experiment that the compost prepared from mixture of wastes had the best NPK contents, so it can be used in replace of chemical fertilizer as a soil conditioner. It is recommended that to get better compost, different types of wastes like animal waste, food waste and garden waste should be taken in equal proportions and treated with sewage water. Green material should be added to maintain the C/N ratio about 30.

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