



**ISSN Print: 2347-4203 ISSN Online: 2347-4211**  
**JOURNAL OF CIVIL ENGINEERING  
AND TECHNOLOGY**  
**(JCIET)**

<https://iaeme.com/Home/journal/JCIET>

**Peer Reviewed Journal**



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# ADDITION OF BAMBOO CHARCOAL IN COMPOSTING OF KITCHEN ORGANIC WASTE WITH PIG MANURE

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## ABSTRACT

*The co-composting of pig manure with kitchen organic waste presents an effective strategy for nutrient recycling and waste management. This study explores the incorporation of bamboo charcoal into compost piles to enhance compost quality and mitigate environmental risks. Over a 105-day period, four compost piles with varying bamboo charcoal proportions (0%, 5%, 10%, and 15%) were analysed for changes in physicochemical parameters and heavy metal dynamics. Temperature, pH, moisture content, and electrical conductivity were monitored every 5 days, while total nitrogen (TN), total organic carbon (TOC), and the C/N ratio were tested at 15-day intervals. Heavy metals including Zn, Cu, Pb, Cr, and Cd were assessed using atomic absorption spectrometry. Results showed that bamboo charcoal improved compost conditions by increasing initial pH and temperature, enhancing microbial activity. A decline in moisture content after day 45 indicated compost maturation. Electrical conductivity was lower in piles with higher charcoal content, reflecting reduced salinity and better compost stability. Nitrogen retention and TOC levels improved, contributing to*

*nutrient-rich compost. Heavy metal content, especially Zn and Pb, was reduced in piles with bamboo charcoal, confirming its role in metal immobilization.*

*This study concludes that bamboo charcoal is a sustainable, low-cost additive for enhancing compost quality, reducing pollution potential, and supporting decentralized waste management in rural areas.*

**Keywords:** Bamboo Charcoal, Pig Manure Composting, Heavy Metal Immobilization, Organic Waste Management, Nitrogen Retention.

**Cite this Article:** Hibu Munku, Mudo Puming, Jumbom Ruti, Tongbram Ashish kumar Singh. (2025). Addition of Bamboo Charcoal in Composting of Kitchen Organic Waste with Pig Manure. *Journal of Civil Engineering and Technology (JCIET)*, 11(1), 148-173.

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## I. Introduction

This chapter addresses the environmental issues linked to pig manure disposal and presents solutions, including the study's objectives, significance, and methodology. Untreated pig manure contains heavy metals, posing serious threats to the environment and public health when used directly as fertilizer [1], [15]. Plants absorb these metals, leading to bioaccumulation in human tissues through the food chain. This study proposes composting pig manure with bamboo charcoal, a porous material known for immobilizing heavy metals and reducing their mobility [2], [23]. Studies show that incorporating bamboo charcoal reduces Total Kjeldahl Nitrogen (TKN) loss and limits Cu and Zn leaching [2], [21]. Also, kitchen organic waste is utilized as a co-compost material. Instead of contributing to landfill loads, such waste is transformed into nutrient-rich compost when processed with pig manure [5], [10]. The increasing environmental burden of manure management underscores the need for a sustainable, cost-effective treatment strategy [13]. Thus, this project explores composting as an eco-friendly solution using pig manure and kitchen waste, with bamboo charcoal enhancing heavy metal absorption [2], [16].

### 1.1 Composting

Composting is a natural decomposition process historically refined in India during the 1930s through the Indore process [3]. This method involved layering organic wastes in trenches with minimal turning over a six-month period, resulting in predominantly anaerobic conditions.

Subsequent process improvements introduced regular turning to promote aerobic breakdown and reduce composting time.

Modern composting typically follows three steps [12], [14]:

- a) Pre-processing of municipal solid waste (MSW)
- b) Decomposition of the organic fraction
- c) Preparation and marketing of the final compost

Composting progresses through four biological and chemical stages:

- a) **Mesophilic Stage** (10°C–42°C): Mesophilic bacteria initiate the breakdown of easily degradable compounds, rapidly increasing the compost temperature and setting the stage for thermophilic bacteria [18].
- b) **Thermophilic Stage** (up to ~65–70°C): Decomposition intensifies as thermophilic microbes target proteins, lipids, and complex carbohydrates. This stage is key for pathogen kill and major organic breakdown [4].
- c) **Polymeric Stage**: As temperatures drop, humic substances such as humic acid and humus form through complex polymeric reactions involving ligno-proteins, enhancing soil-conditioning properties [17].
- d) **Curing/Maturing Stage**: Compost stabilizes and matures. A proper C/N ratio (~12:1) is critical to avoid nitrogen loss upon soil application. The curing phase typically lasts 8–12 weeks, ensuring microbial activity subsides and compost becomes safe for agricultural use [20].

## 1.2 Compost Maturity

According to Page (1982), compost maturity can be assessed through [6]:

- Physical stability: structural integrity
- Chemical stability: carbohydrate breakdown
- Biological stability: microbial activity levels

Indicators of mature compost include [11]:

- Volume reduction: pile shrinks by half
- Decomposition: original organic matter no longer identifiable
- Physical traits: crumbly texture, dark brown to black colour, earthy smell

These traits confirm that the compost has undergone adequate stabilization and is ready for use as a soil conditioner.

### 1.3 Need for Study

Composting is widely recognized for its environmental and agricultural benefits. It significantly reduces organic waste volume, controls Odors, and eliminates pathogens [7]. Moreover, it enhances soil health by suppressing weed germination and improving crop productivity [10], [19]. Beyond agricultural value, composting helps minimize landfill dependency, curbs methane emissions, and lowers costs related to transportation and incineration [12], [13]. Its low capital requirements and flexibility make it ideal for sustainable rural and urban waste management strategies [29]. Given its environmental and economic advantages, composting emerges as a highly beneficial and practical alternative to traditional waste disposal methods.

In rural regions, pig manure is commonly used directly as fertilizer without awareness of its chemical composition or potential hazards. Among livestock waste, pig manure has the highest concentration of heavy metals [15], [21]. These metals can leach into the soil, be absorbed by crops, and even contaminate groundwater [1], [30]. Therefore, the objective of this study was to decrease the mobility of heavy metals and loss of Total Kjeldahl nitrogen (TKN) with the addition of bamboo charcoal in composting, to minimize the load on solid waste management system, to replace artificial fertilizers, to prevent the heavy metals, present in pig manure from polluting soils nearby, to Compare and measurement of physico-chemical parameters of different piles.

### 1.4 Plan of Work

- a) Materials were collected: pig manure from the Central Pig Breeding Farm, Karsingsa; kitchen waste from Siang Girls' Hostel, NERIST; rice husk from Ziro, Arunachal Pradesh; and bamboo charcoal was self-prepared.
- b) Compost piles were created using uniform quantities of pig manure, rice husk, and kitchen waste, with varying proportions of bamboo charcoal.
- c) A comparative analysis was conducted through field and lab testing, evaluating parameters such as Odour, colour, texture, pH, moisture content, Total Organic Carbon (TOC), Total Nitrogen (TN), and concentrations of heavy metals.

## II. MATERIALS AND METHODS

### 2.1 Site Location and Specification

The composting experiment was conducted under a temporary shed constructed at the Siang Girls' Hostel campus, NERIST. The shed measured 3 m × 1.2 m and housed a windrow platform raised approximately 0.3 m above ground level. The platform was layered with compacted pebbles to ensure a level surface, and flex sheets were laid on top to retain heat and moisture, especially crucial as the composting was done during the winter season [8]. To protect the compost from rain and to retain warmth, the structure was covered with tarpaulin from the top and sides. Additional flex sheets were used during continuous rainfall or when the ambient temperature dropped below 10°C [8].

### 2.2 Materials Used

#### a) Organic Kitchen Waste

A total of 24 kg of vegetable waste (including cabbage, potato and carrot) was collected from Siang and Subansiri Girl's Hostels, NERIST. The waste was chopped into small pieces (2–3 cm) to increase surface area for microbial action and enhance aeration, an essential step for faster decomposition [5].



**Fig. 1** Chopped vegetables

### **b) Pig Manure**

Pig manure was sourced from the Central Pig Breeding Farm, Karsingsa, Arunachal Pradesh. It's noteworthy that about 2 kg of minerals are added to every 100 kg of pig feed, contributing to the manure's heavy metal content [15], [24].



**Fig. 2** Pig manure

### **c) Bamboo Charcoal**

Discarded bamboo from campus construction sites was collected and burned at 600–1000°C to produce bamboo charcoal. This biochar is known for its high porosity and ability to immobilize heavy metals during composting [2], [23].



Fig. 3 Bamboo charcoal

**d) Rice Husk**

Rice husk was collected from Ziro, Arunachal Pradesh and served as a bulking agent. In addition to improving porosity and moisture retention, rice husk is a good carbon source, enhances microbial energy and supports the carbon-to-nitrogen balance in compost piles [8].



Fig. 4 Sieved rice husk

### 2.3 Feeder Chart

Below is the feed composition for mature pigs at the Central Pig Breeding Farm, Karsingsa. The chart reflects the inclusion of 2 kg of mineral content per 100 kg of feed [24].

**Table 1** Feeder chart for matured pigs

Sl. No.	Food material	Quantity (Kg)
1	Maize	37
2	Wheat	20
3	Rice Polish	10
4	Ground nut cake	10
5	Soya	10
6	Mustard oil cake	10
7	Minerals	2
8	Salt	1
Total		100

### 2.4 Experimental Setup

The experimental setup included four compost piles inside the temporary shed, each measuring approximately 0.43 m × 0.8 m × 0.45 m and composted over a period of 100 days [8]. Each pile received the following base composition:

- 10 kg pig manure
- 6 kg kitchen waste
- 4 kg rice husk

Watering and regular turning were done at 10-day intervals. To minimize heat loss and moisture evaporation, piles were covered at night with flex sheets [5], [8].



**Fig. 5** Layout of piles

The four pile compositions were:

- **Pile 1:** Pig manure + Kitchen waste + Rice husk
- **Pile 2:** Same as Pile 1 + 5% Bamboo charcoal
- **Pile 3:** Same as Pile 1 + 10% Bamboo charcoal
- **Pile 4:** Same as Pile 1 + 15% Bamboo charcoal

**Table 2 Instruments** used for the analysis of various parameters are presented

Sl. No.	Parameters	Name of the Instrument used
1	Temperature	Thermometer
2	pH	pH meter
3	Electrical conductivity	Multiparameter
4	Moisture content	Hot air oven
5	Total nitrogen	Automated kjeldahl nitrogen analyser
6	Carbon	Titration (Walkley and Black,1934)
7	Heavy metal content (Cu, Zn, Pb, Cr,Cd)	Atomic absorption spectrometry (AAS)

### III. RESULTS AND DISCUSSION

This chapter presents the results and discussion based on the analysis of various physico-chemical parameters, nitrogen content and heavy metal content in compost piles prepared with pig manure, kitchen organic waste, rice husk and varying proportions of bamboo charcoal.

#### 3.1 Physico-Chemical Characteristics

This section evaluates key composting parameters such as temperature, moisture content, electrical conductivity, total organic carbon (TOC), total nitrogen (TN) and the carbon-to-nitrogen (C/N) ratio.

##### 3.1.1 Effects of bamboo charcoal on temperature during composting

Temperature is a vital factor in aerobic composting, as high temperatures promote efficient microbial activity and pathogen elimination (typically  $>55^{\circ}\text{C}$ ) [5], [12]. Incorrect temperature ranges can slow decomposition or damage microbes. Compost temperatures were measured at 20 cm depth from all sides of the piles at five-day intervals using a compost thermometer [8].



**Fig. 6** Thermometer for measuring temperatures

The composting process occurred during peak winter (January), with frequent rainfall, leading to temperature fluctuations. The highest temperatures were observed at the beginning.

Temperature variations among Pile-1 to Pile-4 were minimal, though there was a general trend of increased temperature with higher pile weight [8].

**Table 3** Temperature (°C) during different stages of composting.

Time(days)	Pile -1	Pile-2	Pile-3	Pile-4
5	32.00	37.00	38.00	40.00
10	32.33	35.60	37.00	38.50
15	31.00	32.03	34.50	35.00
20	29.00	29.08	30.05	30.70
25	27.50	28.00	28.30	28.90
30	27.00	27.50	27.80	28.00
35	23.30	23.80	24.00	24.50
40	21.90	22.50	22.80	23.00
45	19.80	21.00	21.50	21.90
50	19.00	20.00	20.10	20.30
55	19.30	19.50	20.00	20.50
60	26.90	27.00	27.50	27.80
65	24.90	25.00	26.50	26.90
70	25.80	26.10	26.60	27.00
75	23.90	24.00	24.50	24.90
80	21.00	21.90	22.20	22.90
85	26.00	26.30	26.80	27.00
90	27.00	27.50	27.90	28.00
95	27.20	27.50	27.80	27.90
100	28.00	28.20	28.50	28.60

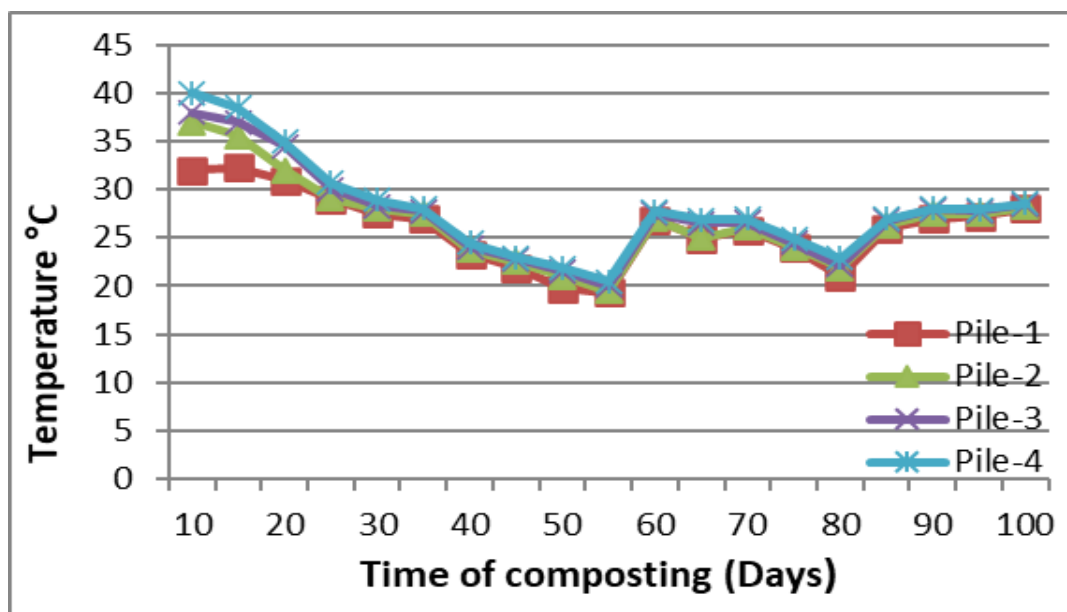


Fig. 7 Change in temperature (°C) during different stages of composting

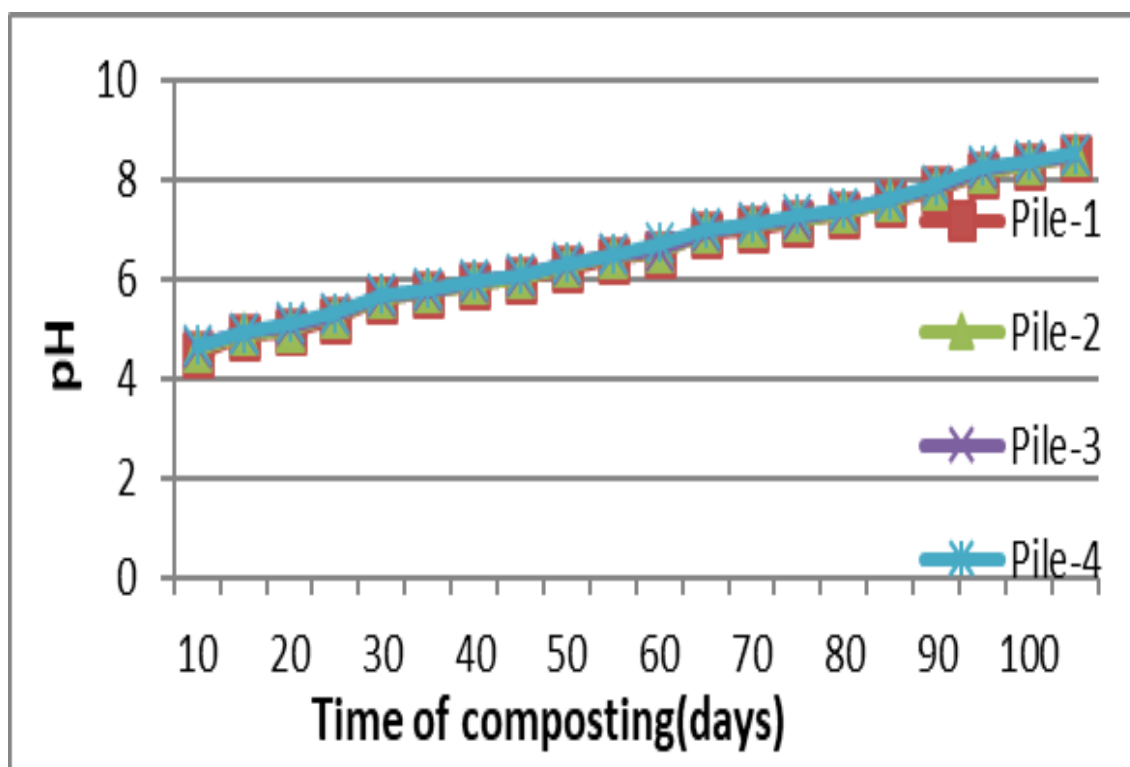
### 3.1.2 Effects of bamboo charcoal on pH

pH levels were measured every five days using a multiparameter device. Initially, all compost piles had acidic pH values (Pile-1: 4.50, Pile-2: 4.59, Pile-3: 4.63, Pile-4: 4.67), which gradually shifted to alkaline by the end of composting (Pile-1: 8.45, Pile-2: 8.48, Pile-3: 8.50, Pile-4: 8.52). This shift corresponds to microbial activity and the transition from mesophilic to thermophilic phases [2], [9]. Bamboo charcoal likely contributed to this pH change due to its porous nature and ability to trap impurities [2], [23].

Table 4 pH during different stages of composting

Time(days)	Pile -1	Pile-2	Pile-3	Pile-4
5	4.50	4.59	4.63	4.67
10	4.87	4.89	4.92	4.93
15	4.95	4.99	5.05	5.11
20	5.21	5.25	5.30	5.32
25	5.60	5.63	5.65	5.70
30	5.71	5.74	5.76	5.82
35	5.89	5.91	5.94	5.99
40	6.01	6.04	6.06	6.10

45	6.21	6.25	6.29	6.32
50	6.42	6.45	6.49	6.50
55	6.52	6.55	6.59	6.71
60	6.91	6.95	6.98	7.00
65	7.00	7.09	7.11	7.12
70	7.14	7.18	7.22	7.29
75	7.32	7.36	7.39	7.42
80	7.55	7.57	7.60	7.62
85	7.80	7.83	7.85	7.90
90	8.12	8.16	8.20	8.25
95	8.28	8.31	8.35	8.39
100	8.45	8.48	8.50	8.52



**Fig. 8** Change in pH during different stages of composting

### 3.1.3 Effects of bamboo charcoal on moisture content

Moisture content is essential for microbial metabolism, ideally ranging from 35–45%. In this study, the moisture content of all piles decreased over time, indicating compost maturity

[5]. Initial fluctuations were observed due to winter conditions, but after 45 days, moisture levels steadily declined, reaching around 40% in all piles by day 100 [8].

**Table 5** Moisture content variations of different piles with respect to days

Time(days)	Pile -1	Pile-2	Pile-3	Pile-4
5	61.00	58.02	57.00	56.05
10	61.50	59.00	57.50	54.00
15	68.27	66.17	63.80	60.04
20	59.51	57.64	56.60	54.00
25	57.22	55.62	54.30	52.00
30	68.19	65.31	63.14	61.00
35	58.00	56.50	55.00	54.30
40	61.05	60.00	58.00	57.70
45	67.00	65.50	63.00	61.10
50	64.00	62.50	61.00	59.50
55	60.00	58.90	57.00	55.00
60	58.00	56.60	54.90	53.00
65	57.52	56.00	54.12	52.00
70	55.00	52.00	50.14	48.00
75	52.00	50.00	48.25	47.00
80	50.00	48.80	47.00	45.50
85	49.00	47.00	46.10	44.04
90	45.00	44.00	43.12	42.00
95	43.00	41.90	40.90	40.10
100	40.60	40.00	39.50	39.00

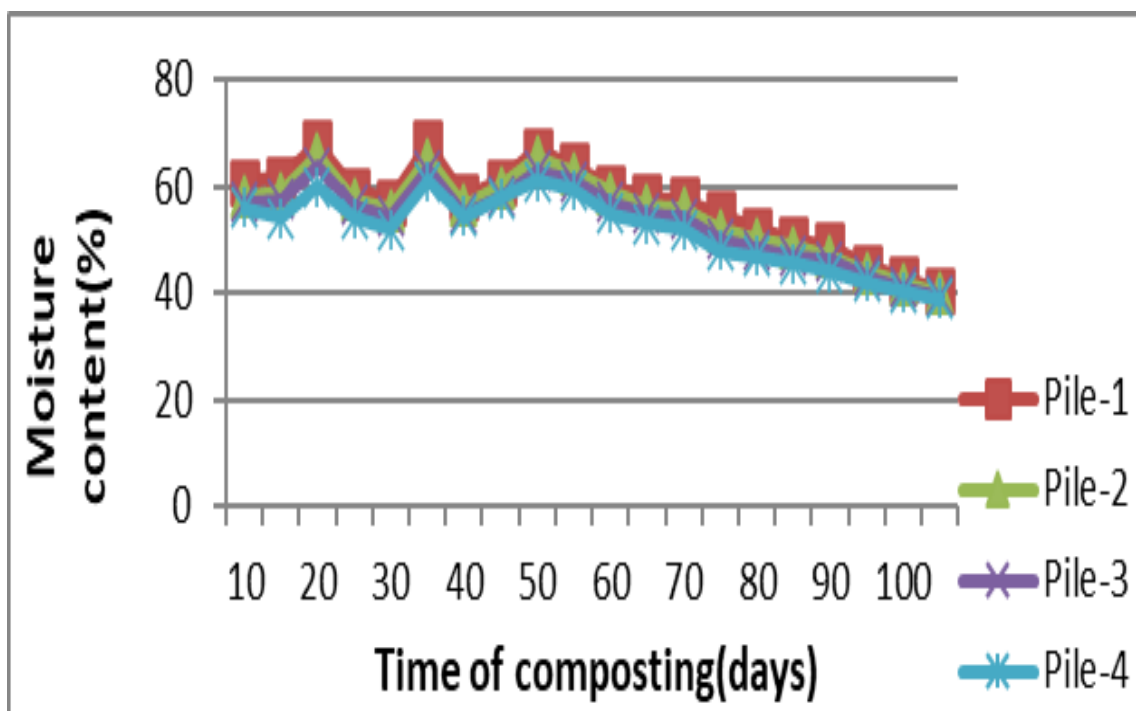


Fig. 9 Moisture content variations of four pile

### 3.1.4 Effects of bamboo charcoal on electrical conductivity (EC)

EC reflects the salinity and soluble salt content in compost. High EC values early in composting (up to 2.87 dS/m) decreased after 30 days. Final EC values were Pile-1: 0.79, Pile-2: 0.76, Pile-3: 0.66 and Pile-4: 0.58. The reduction in EC is attributed to the absorptive capacity of bamboo charcoal [9], [23].

Table 6 Electrical conductivity variations of different piles with respect to days

Time(days)	Pile -1	Pile-2	Pile-3	Pile-4
5	0.47	0.41	0.40	0.32
10	0.89	0.85	0.84	0.79
15	1.12	1.10	1.00	0.99
20	2.21	2.13	2.06	1.72
25	2.41	2.14	2.10	1.43
30	2.87	2.45	2.38	2.18
35	1.94	1.67	1.54	1.43
40	1.75	1.71	1.55	1.54
45	1.72	1.44	1.43	1.42

50	1.56	1.58	1.57	1.51
55	1.44	1.41	1.39	1.37
60	1.39	1.37	1.35	1.31
65	1.24	1.05	1.00	0.89
70	1.23	1.14	1.02	0.89
75	1.21	1.19	1.15	1.09
80	1.19	1.15	1.17	1.09
85	1.08	0.95	0.69	0.66
90	1.07	0.83	0.73	0.65
95	0.98	0.95	0.91	0.89
100	0.79	0.76	0.66	0.58

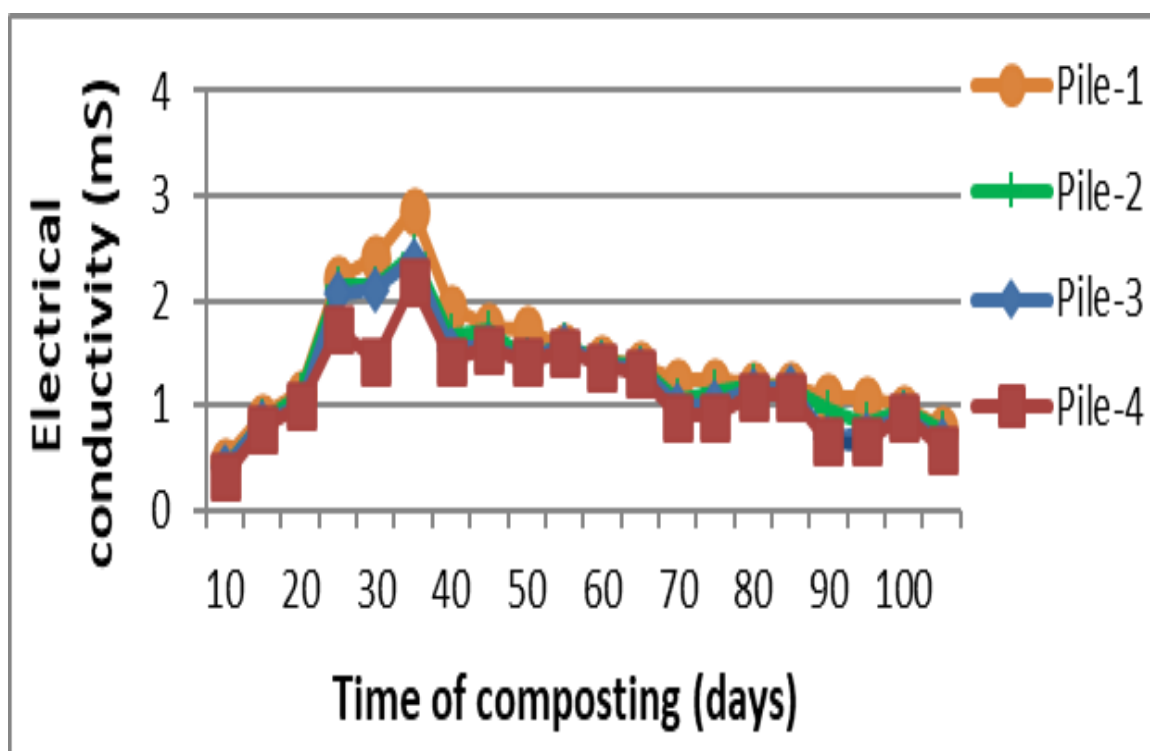


Fig. 10 Electrical conductivity variations of four piles

### 3.1.5 Effects of bamboo charcoal on TOC, TN, and C/N ratio

TOC was analysed using the Walkley-Black method [14]. While Pile-1 and Pile-3 showed a steady increase in TOC, Pile-2 and Pile-4 experienced fluctuations. Adverse weather conditions may have affected microbial activity. TN levels generally increased with the

addition of bamboo charcoal. For instance, at day 45: Pile-1 (0% BC): 0.83%, Pile-2 (5% BC): 0.90%, Pile-3 (10% BC): 0.94%, and Pile-4 (15% BC): 0.98%.

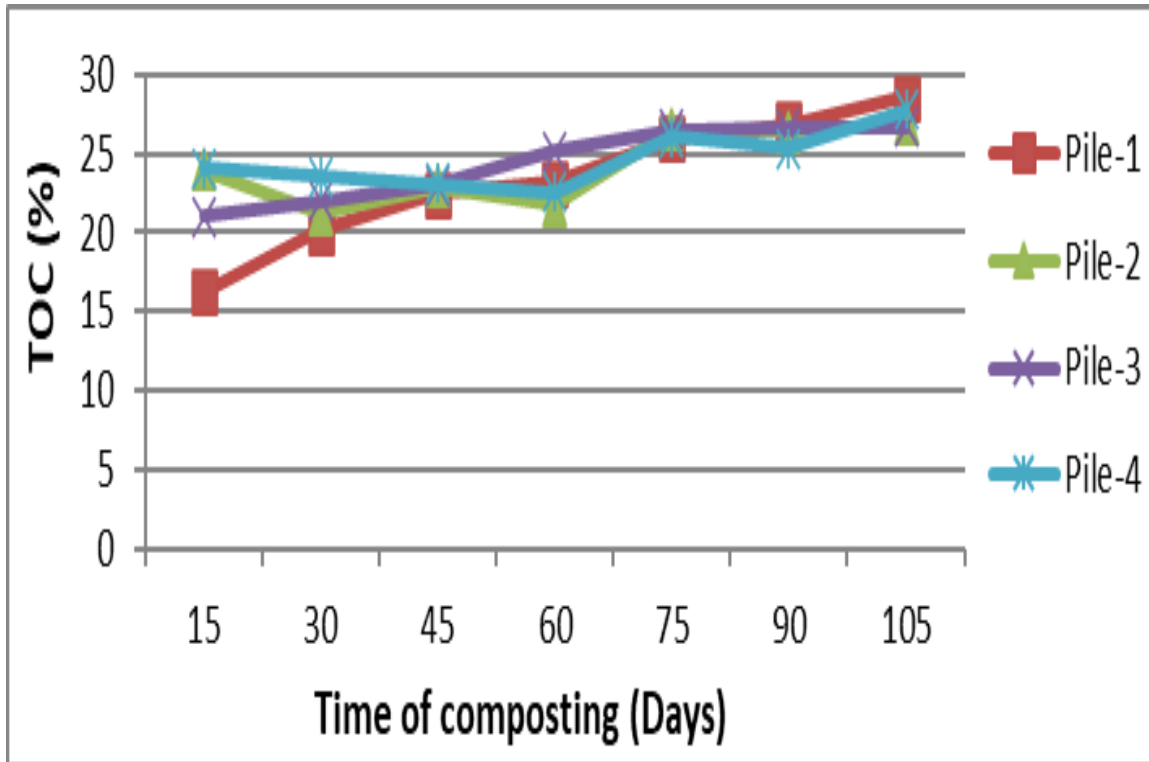


Fig. 11 Grinded compost

**Table 7** Total organic carbon variations of four piles.

Time(days)	Total organic carbon			
	Pile-1	Pile-2	Pile-3	Pile-4
15	16.23	24.01	21.05	24.09
30	20.12	21.21	22.01	23.50
45	22.42	22.91	23.01	23.12
60	23.14	21.71	25.14	22.57
75	26.00	26.51	26.51	26.04
90	26.86	26.45	26.61	25.29
105	28.55	26.90	26.71	27.72

The C/N ratio, critical for microbial balance, is expected to decrease with compost maturity. Despite some fluctuations, final C/N ratios were lower than initial readings, confirming compost stabilization [14], [23]. At day 105: Pile-1: 25.95, Pile-2: 22.23, Pile-3: 21.36, and Pile-4: 21.32.



**Fig. 12** Total organic carbon variations of four piles

**Table 8** Total Nitrogen variations of four piles.

Time(days)	Total Nitrogen			
	Pile-1	Pile-2	Pile-3	Pile-4
15	0.52	0.94	0.68	0.95
30	0.81	0.68	0.94	1.00
45	0.83	0.90	0.94	0.98
60	0.90	0.93	0.95	0.97
75	0.97	1.01	1.05	1.08
90	1.02	1.09	1.10	1.16
105	1.10	1.21	1.29	1.30

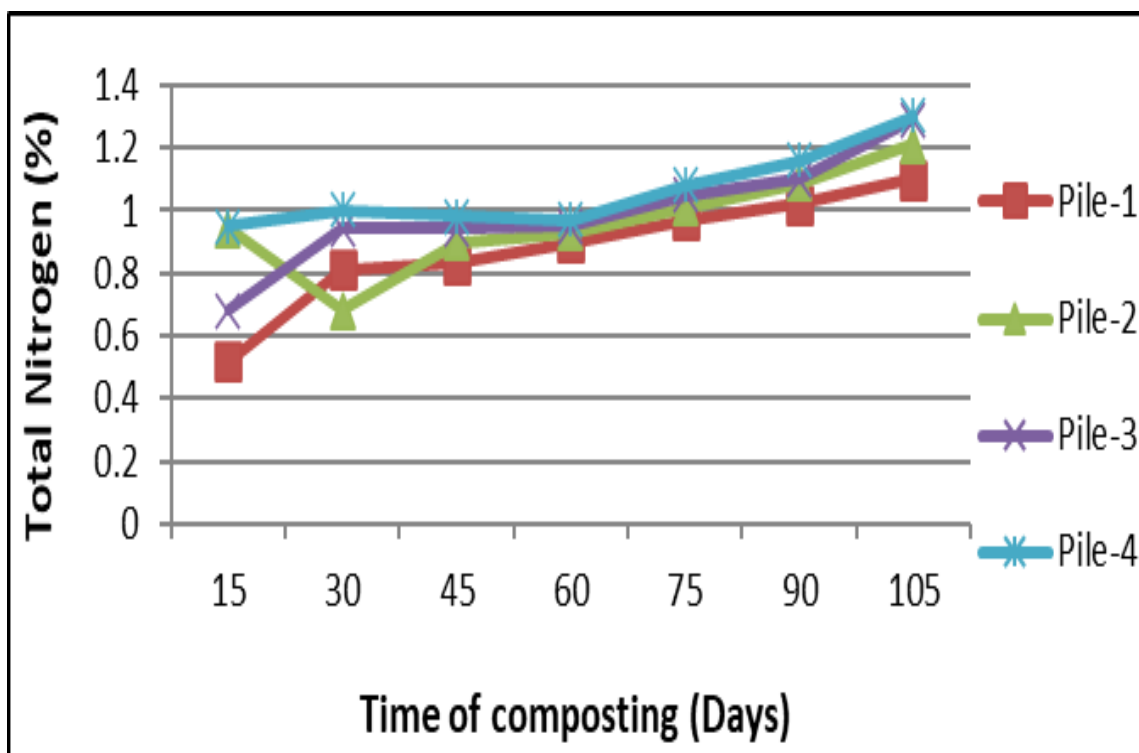


Fig. 13 Total nitrogen variations of four piles

Table 9 C/N variations of four piles

Time(days)	C/N Ratio			
	Pile-1	Pile-2	Pile-3	Pile-4
15	31.21	25.54	30.95	25.35
30	24.83	22.56	23.41	23.50
45	27.01	25.45	24.47	23.59
60	25.71	23.34	26.46	23.26
75	26.80	26.24	25.24	24.11
90	26.33	24.26	24.19	21.80
105	25.95	22.23	21.36	21.32

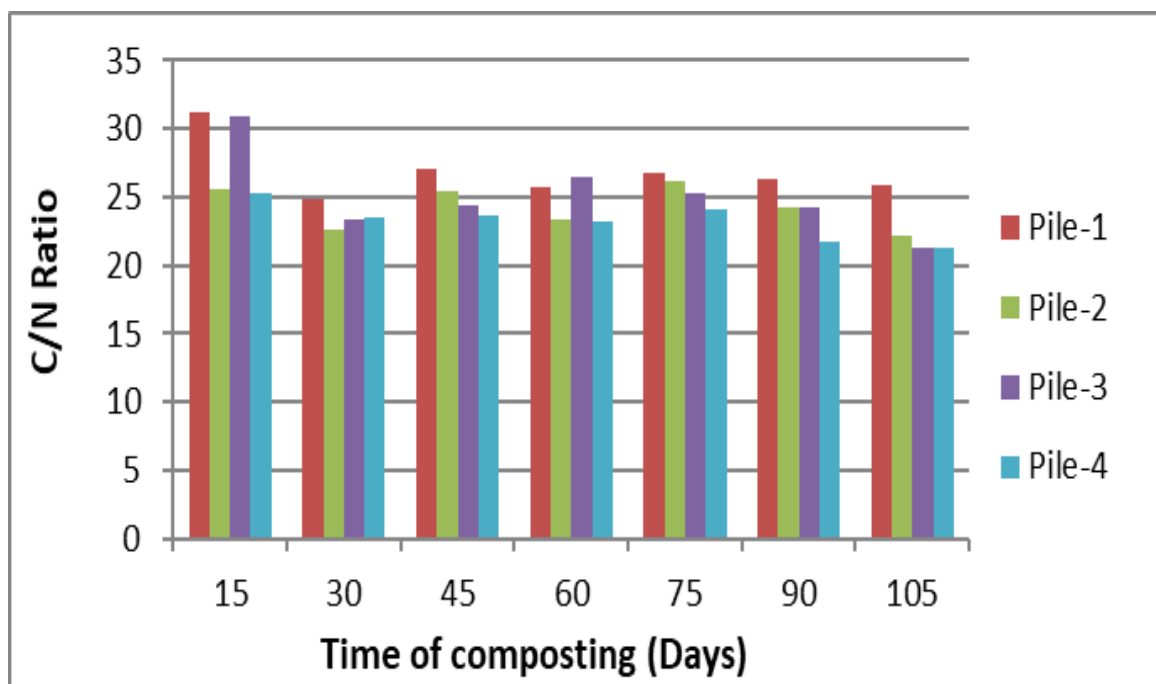


Fig. 14 C/N ratio variations of four piles

### 3.2 Heavy Metal Variations in Different Compost Piles

Manure contains beneficial nutrients but may also carry heavy metals that pose environmental risks. Swine manure has been found to contain elevated levels of Zn, Cu, Cr, Cd, Pb, and other metals [3], [17]. The composting experiment involved four piles with increasing bamboo charcoal content to assess its effect on metal reduction [23], [26]. Heavy metal testing was conducted at the Institute of Advanced Study in Science and Technology (IASST), Guwahati [23]. Zinc was the most prominent element detected, with levels reducing as bamboo charcoal increased [26], [30]. Pig manure initially contained 0.3937 ppm of Zn. Final Zn levels in compost were:

- **Pile-1:** 0.1025 ppm
- **Pile-2:** 0.0916 ppm
- **Pile-3:** 0.1149 ppm
- **Pile-4:** 0.0913 ppm

This confirmed that bamboo charcoal effectively reduces metal concentrations in compost.

**Table 10** Permissible limit of heavy metals in drinking water as per MSW management and handling rules, 2000

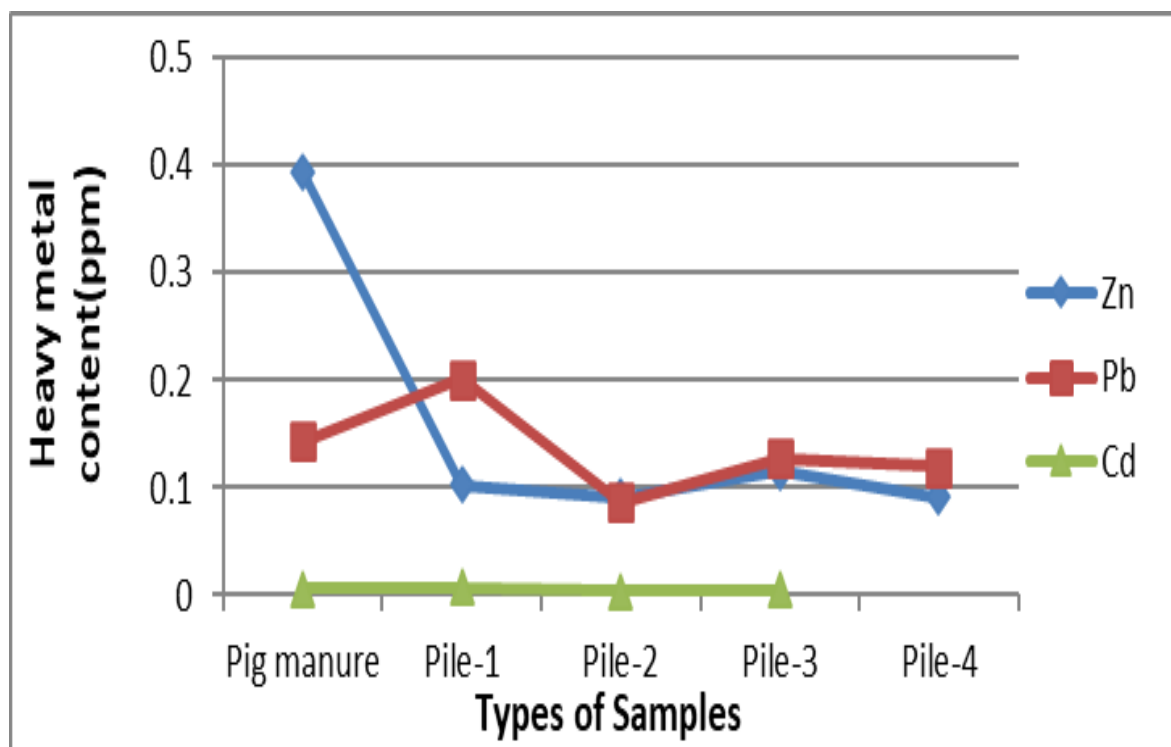
Elements	Concentration not to exceed (mg/kg)
Zn	1000
Cu	300
Pb	100
Cr	50
Cd	5
As	10
Hg	0.15
Ni	50



**Fig. 15** Filtered compost liquid for heavy metal testing

**Table 11** Heavy metal content in different samples

Sample	Cu	Zn	Pb	Cd	Cr
Pig Manure	-0.0833	0.3937	0.1437	0.0059	-0.0918
Pile-1	-0.051	0.1025	0.2009	0.0072	-0.0754
Pile-2	-0.0543	0.0916	0.0865	0.0043	-0.1311
Pile-3	-0.064	0.1149	0.1274	0.0049	-0.1246
Pile-4	-0.0704	0.0913	0.1192	-0.0013	-0.1016



**Fig. 16** Variations of four piles

#### IV CONCLUSION

This study assessed the effectiveness of bamboo charcoal as an additive in composting pig manure with kitchen waste over a 105-day period. The objective was to enhance compost quality, reduce environmental risk and promote sustainable alternatives to landfill disposal. Key findings revealed that higher bamboo charcoal content led to elevated compost temperatures and pH, improved microbial activity, reduced electrical conductivity, stabilized moisture levels and increased nitrogen retention [9], [14]. Zinc, the most prevalent heavy metal in pig manure, was notably reduced with bamboo charcoal treatment, indicating its heavy metal immobilization potential [26], [30].

The advantages of this approach include improved compost maturity, nutrient stabilization, pathogen suppression and reduced heavy metal mobility—making the final product more suitable and safer for agricultural applications. The study also demonstrated that locally available resources like bamboo can be effectively used for environmental remediation and waste valorisation [9], [23]. However, limitations of the study include the small experimental scale, limited range of heavy metals analysed and climatic constraints (such as winter temperatures and rainfall) that may have influenced microbial dynamics and degradation

rates. The composting trials were restricted to indoor setups, which may differ from open field conditions [10], [12]. Potential applications of this research include its integration into rural and peri-urban waste management systems, especially in regions with high bamboo availability. The charcoal-enhanced compost can be used as a natural, low-cost soil amendment for farming, horticulture and landscaping [1], [20]. Also, the process can contribute to circular economy practices by converting agricultural and organic waste into value-added products [4], [22].

## REFERENCES

- [1] J. Ciba, T. Korolewics, and M. Turek, the occurrence of metals in composted municipal wastes and their removal, *Water, Air, and Soil Pollution*, 111(2), 1999, 159–170.
- [2] Y.X. Chen, X.D. Huang, Z.Y. Han, X. Huang, B. Hu, D.Z. Shi, and W.X. Wu, effects of bamboo charcoal and bamboo vinegar on nitrogen conservation and heavy metals immobility during pig manure composting, *Chemosphere*, 78(9), 2010, 1177–1181.
- [3] H. Theisen, S.A. Vigil, and G. Tchobanoglous, *integrated solid waste management: engineering principles and management issues* (New York: McGraw-Hill, 1993).
- [4] J.H. Hsu and S.L. Lo, chemical and spectroscopic analysis of organic matter transformations during composting of pig manure, *Environmental Pollution*, 104(2), 1999, 189–196.
- [5] G.F. Huang, J.W.C. Wong, Q.T. Wu, and B.B. Nagar, effect of C/N on composting of pig manure with sawdust, *Waste Management*, 24(8), 2004, 805–813.
- [6] G.F. Huang, M. Fang, Q.T. Wu, L.X. Zhou, X.D. Liao, and J.W.C. Wong, co-composting of pig manure with leaves, *Environmental Technology*, 22(10), 2001, 1203–1212.
- [7] I. Bagra, windrow composting of vegetable waste using naturally available activated materials, M.Tech diss., NERIST, Arunachal Pradesh, 2019.

- [8] M.S. Jain, R. Jambhulkar, and A.S. Kalamdhad, biochar amendment for batch composting of nitrogen-rich organic waste: effect on degradation kinetics, composting physics and nutritional properties, *Bioresource Technology*, 253, 2018, 204–213.
- [9] M. Kithome, J.W. Paul, and A.A. Bomke, reducing nitrogen losses during simulated composting of poultry manure using adsorbents or chemical amendments, *Soil Sci. Soc. Am. J.*, 28(1), 1999, 194–201.
- [10] B. Manohara and S.L. Belagali, characterization of essential nutrients and heavy metals during municipal solid waste composting, *International Journal of Innovative Research in Science, Engineering and Technology*, 3(2), 2014, 9664–9672.
- [11] M. Rawat, A.L. Ramanathan, and T. Kuriakose, characterisation of municipal solid waste compost from selected Indian cities—a case study for its sustainable utilisation, *International Journal of Environmental Research*, 7(1), 2013, 45–53.
- [12] Cornell Waste Management Institute, municipal solid waste composting: biological processing (Ithaca, NY: Cornell University, 2001).
- [13] Government of India, municipal solid waste management and handling rules (New Delhi: Ministry of Environment and Forests, 2000).
- [14] R. Rynk, on-farm composting handbook (Ithaca, NY: Northeast Regional Agricultural Engineering Service, NRAES-54, 1992).
- [15] F. Zhang, Y. Li, M. Yang, and W. Li, content of heavy metals in animal feeds and manures from farms of different scales in northeast China, *International Journal of Environmental Research and Public Health*, 9(8), 2012, 2658–2668.
- [16] J. Singh and A.S. Kalamdhad, reduction of heavy metals during composting, *International Journal of Environmental Protection*, 2(9), 2012, 36–43.
- [17] J. Singh and A.S. Kalamdhad, bioavailability and leachability of heavy metals during composting—a review, *International Research Journal of Environmental Sciences*, 2(4), 2013, 59–64.

- [18] S.A. Tweib, R.A. Rahman, and M.S. Kalil, a literature review on composting, in Proc. Int. Conf. Environment and Industrial Innovation (IPCBEE), 12 (Singapore: IACSIT Press, 2011) 23–28.
- [19] E. Vanlalmawii and M. Awasthi, municipal solid waste composting—a review, *International Journal of Scientific Research*, 4(2), Special Issue-1, 2016, 101–105.
- [20] [20] Z. Zhang, D. Liu, Y. Qiao, S. Li, Y. Chen, and C. Hu, mitigation of carbon and nitrogen losses during pig manure composting: a meta-analysis, *Science of the Total Environment*, 783, 2021, 147103.
- [21] D.M. Zhou, X.Z. Hao, Y.J. Wang, Y.H. Dong, and L. Cang, copper and Zn uptake by radish and pakchoi as affected by application of livestock and poultry manures, *Chemosphere*, 59(2), 2005, 167–175.
- [22] N. Zhu, effect of low initial C/N ratio on aerobic composting of swine manure with rice straw, *Bioresource Technology*, 98(1), 2007, 9–13.
- [23] C.M. Malin, L.A. Sullivan, and A.A. Samson, role of biochar in the stabilization of heavy metals during composting, *Compost Science & Utilization*, 27(3), 2019, 203–210.
- [24] M. Jindo, Y. Mizumoto, F. Sawada, Y. Sonoki, and T. Sameshima, influence of biochar addition on composting of sewage sludge and rice husk mixture, *Waste Management*, 56, 2016, 136–143.
- [25] A.K. Biswas, K.R. Narayan, and A. Chakrabarti, a review on effects of biochar on compost characteristics, *Waste and Biomass Valorization*, 12, 2021, 4561–4574.
- [26] L. Zhang, H. Zeng, and B. Li, changes in microbial communities during co-composting of pig manure with biochar, *Bioresource Technology*, 265, 2018, 292–299.
- [27] A. Gairola and A.S. Kalamdhad, effects of various additives on heavy metal stabilization during sewage sludge composting, *Environmental Technology*, 35(19), 2014, 2431–2438.

- [28] S. Awasthi, V.K. Pandey, and H. Zhang, effects of biochar amendment on compost quality and greenhouse gas emissions, *Science of the Total Environment*, 696, 2019, 133877.
- [29] T. Rajkumar and P. Chidambaram, utilization of bamboo biochar in food waste composting: effects on emissions and compost quality, *International Journal of Environmental Science and Technology*, 19, 2022, 5311–5322.
- [30] P. Sharma, R.K. Singh, and A. Sharma, composting and biochar amendment to mitigate nitrogen loss and metal mobility, *Journal of Cleaner Production*, 305, 2021, 127117.
- [31] N. Biddlestone and K.R. Gray, Composting, in D.A. Stafford, B.W. Hawkes, and R. Horton (Eds.), *Waste Recycling: A Guide for the Chemical and Process Industries*, (London: Applied Science Publishers, 1985) 95–113. (12).

**Citation:** Hibu Munku, Mudo Puming, Jumbom Ruti, Tongbram Ashish kumar Singh. (2025). Addition of Bamboo Charcoal in Composting of Kitchen Organic Waste with Pig Manure. *Journal of Civil Engineering and Technology (JCIET)*, 11(1), 148-173.

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