Effect of biochar on nitrogen loss control and the change of Bacterial populations in sewage sludge composting

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- What are Sewage sludge and its beneficial uses
- Sewage sludge generation
- Sewage sludge management and greenhouse gases (GHGs) emission become as problem
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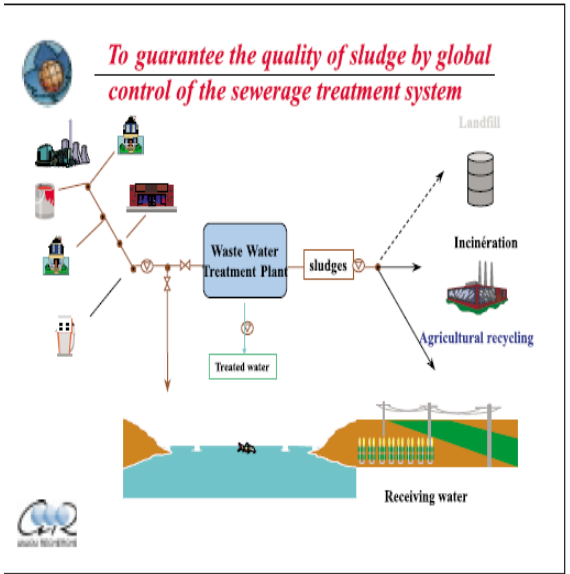
- Conclusion

What are Sewage Sludge ?



Among the solutions that will be still available, agricultural recycling is viewed as the cheapest way and (the most) compatible with the idea of sustainable development.

Sewage Sludge Generation

❖In the last 5 year, the world population increased from 2.0 to 3.0 billion, but sewage sludge generation increased from 0.68 to 1.3 billion tons, and per capita generation increased from 0.34 to 0.43 kg/day.

❖The trend of increasing sewage sludge generation is higher in China compared to other Asian countries. Among the total waste generated from East Asia and Pacific region, up to 70 % waste is generated from China and India.

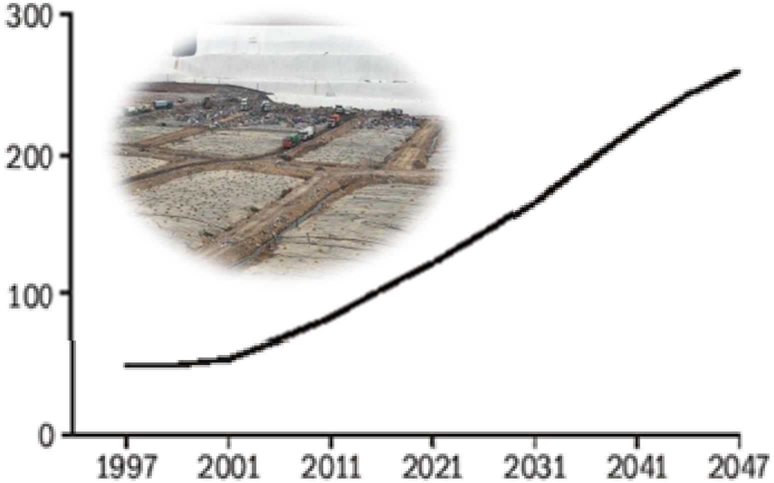


Fig. 1. Projected trends in the generation of sewage sludge (million tonnes/year) according to National Bureau of Statistics of the People's Republic of China, 2015.

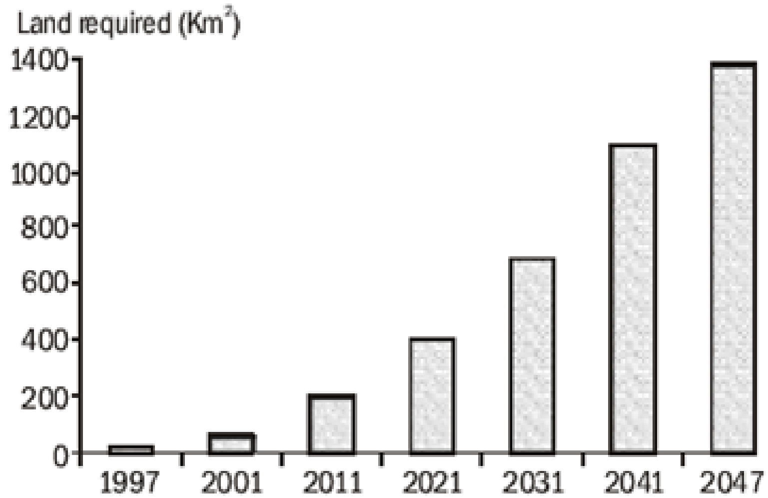
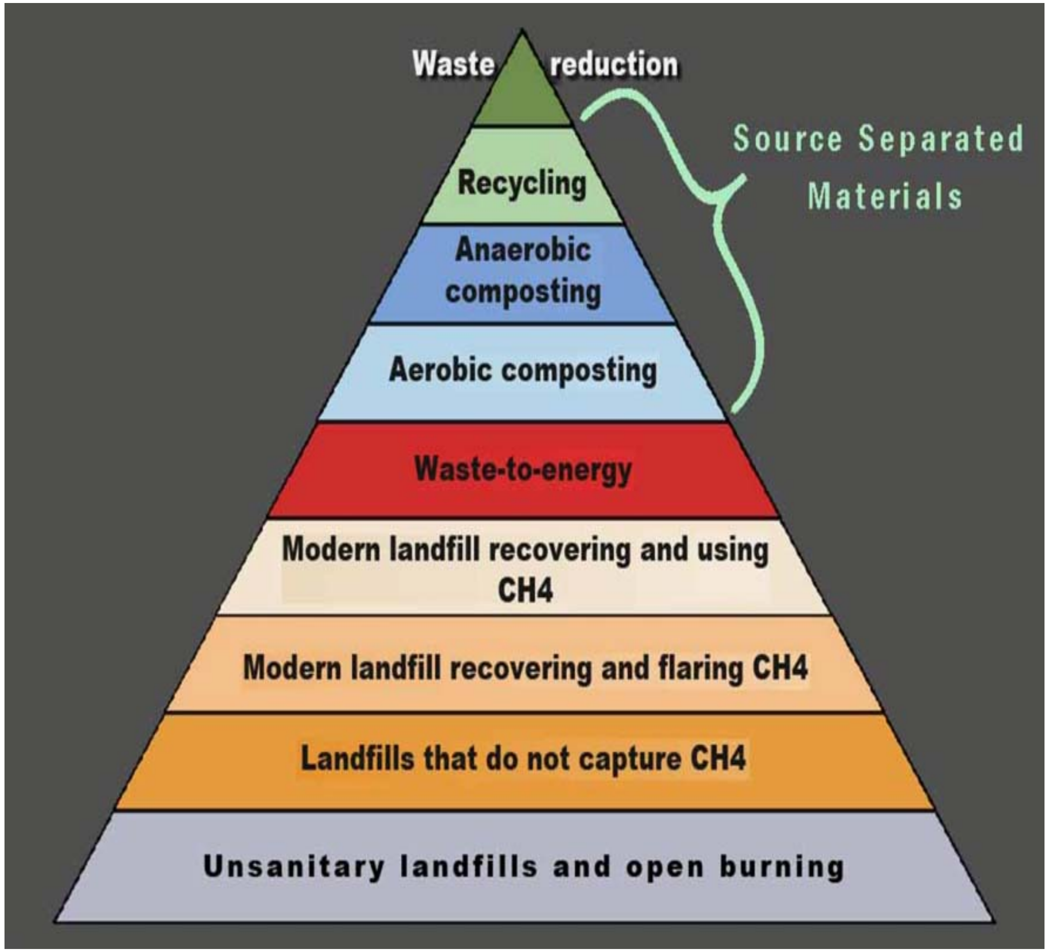


Fig. 2. Cumulative land requirement for disposal of sewage sludge (Km^2) according to National Bureau of Statistics of the People's Republic of China, 2015.

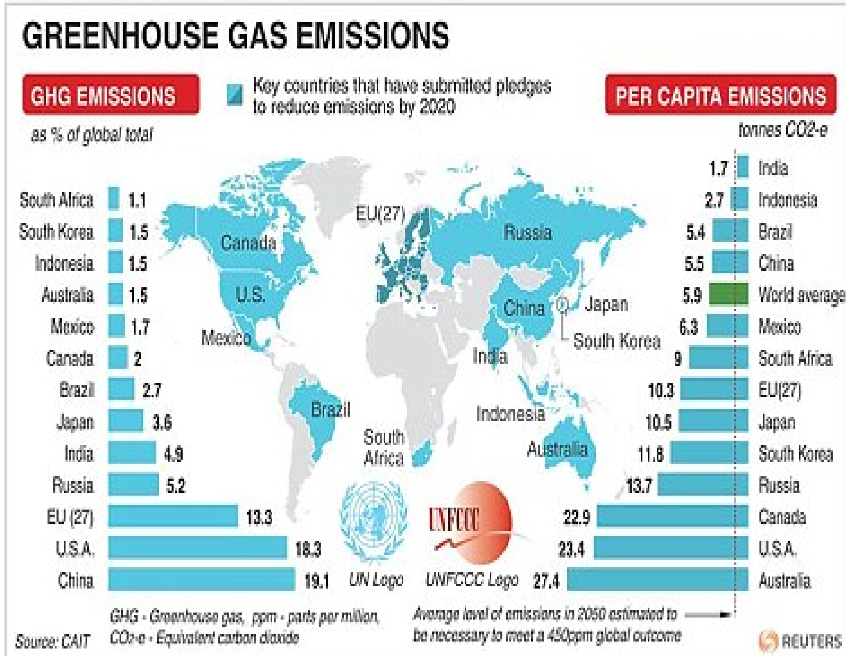
How to Manage Sewage Sludge ?

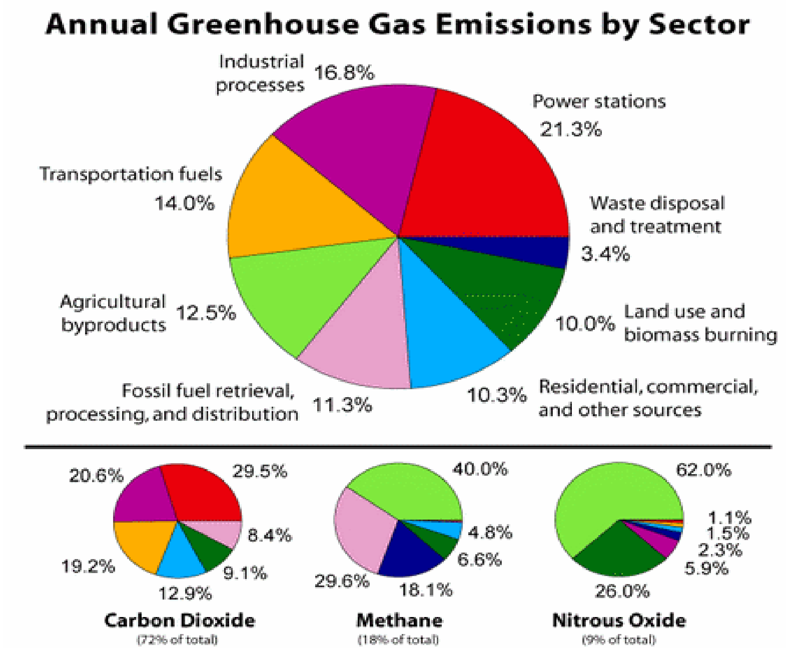
PRESENT MANAGEMENT PROCESS OF BIOSOLIDS AT CHINA



Integrated waste management hierarchy

Annual greenhouse gases emission by sector and global warming potential





Global warming equivalencies of primary GHGs

Gas	Global Warming Potential (GWP) [a]	Atmospheric Lifetime
Carbon Dioxide	1	50-200
Methane	21	12±3
Nitrous Oxide	310	120

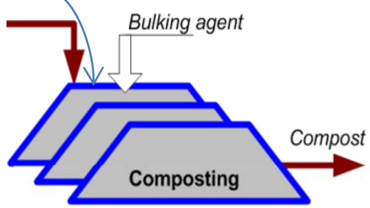
[a]GWP of CH4 and N2O were changed to 23 and 296 respectively in the Third Assessment done by the IPCC. The equivalencies from the second assessment, shown above, are still used by the EPA so that updated inventories can be compared with former inventories and trends can be tracked.

Technology Development

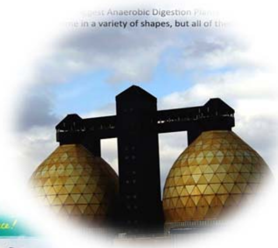
Types

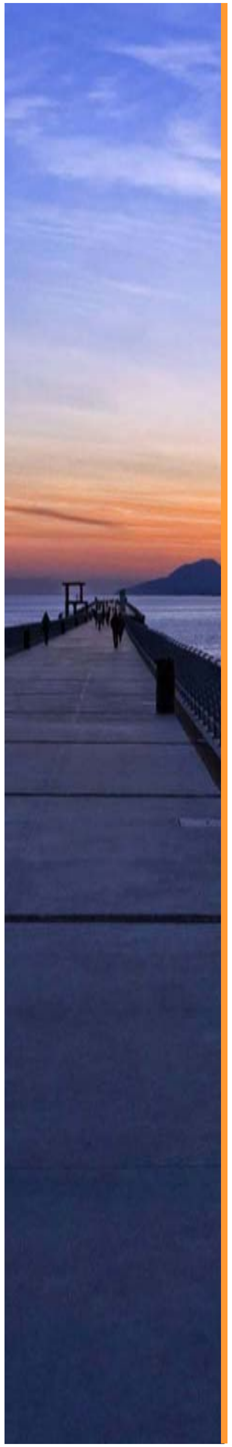
- Mechanical
  - Reactor
  - Turning devices

- Physico-chemical
  - Additives
  - C/N ratio



- Biological
  - Anaerobic digestion
  - Composting
  - Microbial consortium





Main Goals of a Waste Management System

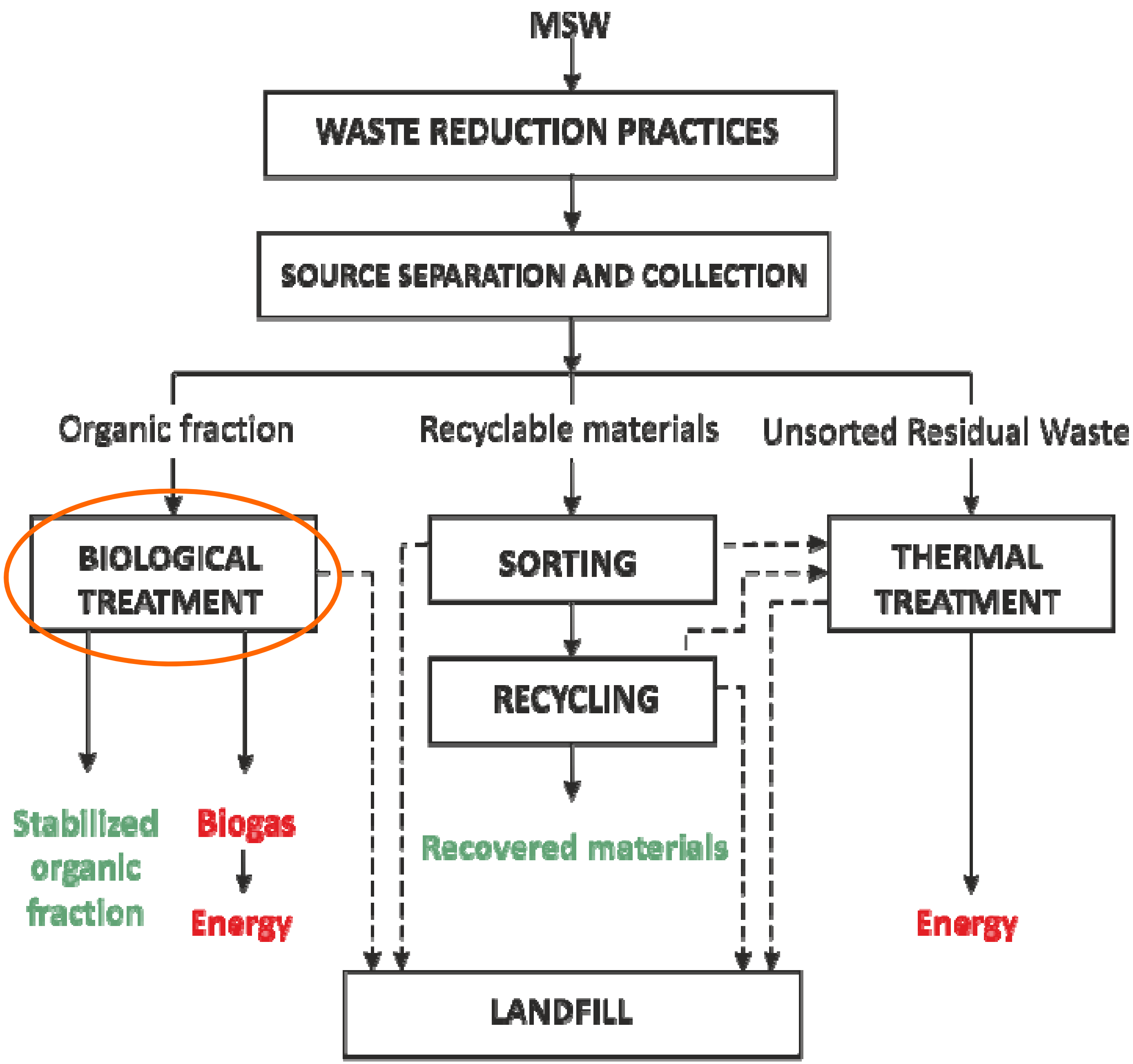
i) Protection of human health and the environment, than reduction of emissions, monitoring of toxicological effects and minimization of health risks, minimization of GHSs;

ii) Conservation of resources, such as materials, energy, and land;

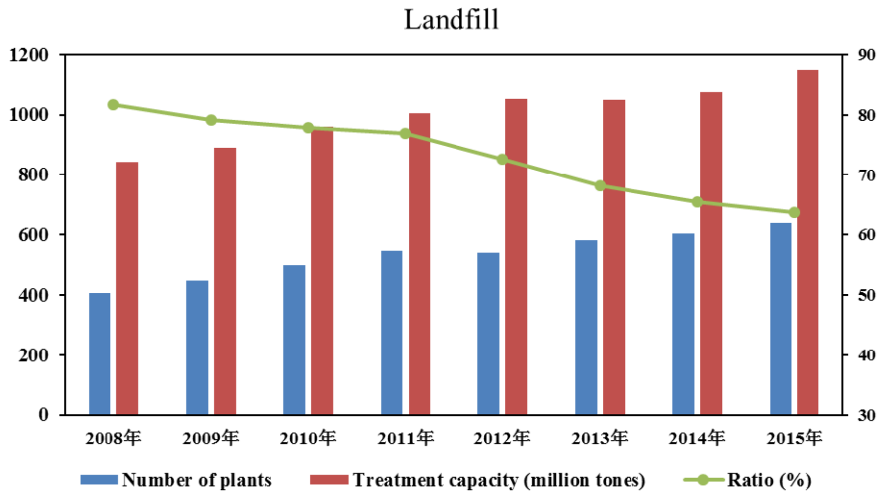
iii) *After-care-free* waste management, meaning that neither landfills nor WtE, recycling or other treatments leave problems to be solved by future generations;

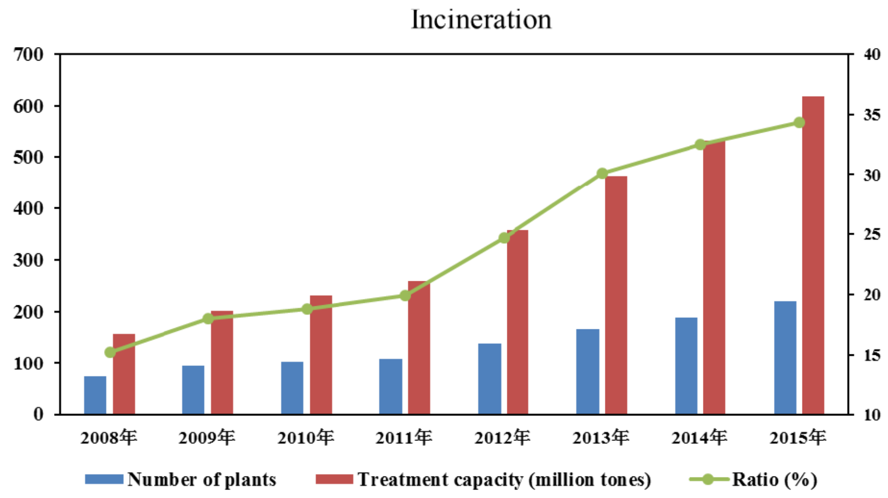
iv) Economic sustainability of the whole cycle of MSW management, also in a welfare economy perspective.

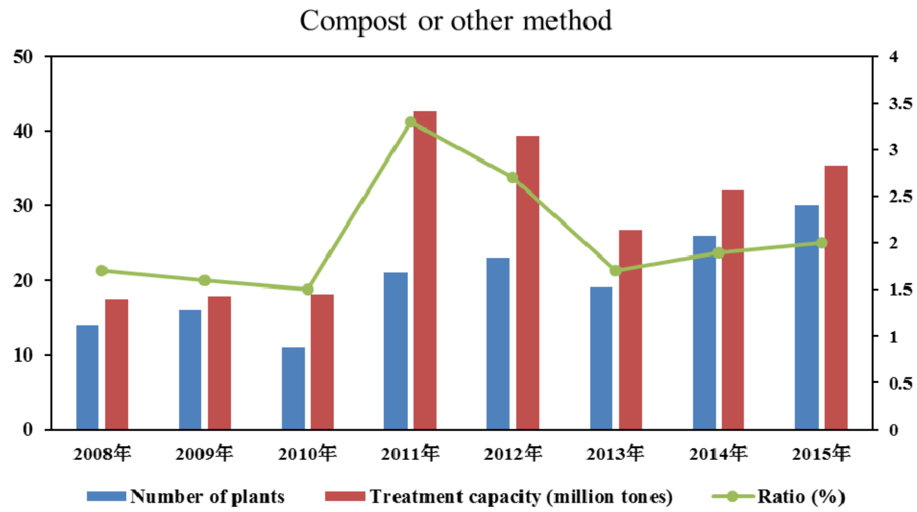
A Sustainable WM system



The status of MSW utilization in China (2008-2015) (National Bureau of Statistics, 2009-2016)







What is Composting

Composting is a process of biological decomposition of organic solid waste that is carried out by a group of active micro-organisms which break down the complex organic materials and hasten the process of composting under aerobic condition at an elevated temperature.

Organic material (MSW)

Moisture

Inoculums (Microorganism)

Oxygen

Optimum composting parameters

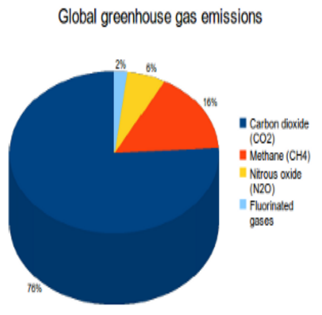
Parameter	Optimum range	Reference
C/N ratio	25-35	Haug, 1993; Choi, 1999
Moisture content	40-60%	He, 2008
Particle size	About 1 cm	P. Bueno, 2008
Temperature	50°C-65 °C	Epstein, 1983; Leton, 1990
pH	7-9	K. Nakasaki, 1993
Aeration rate	0.35 to 5 L $h^{-1}kg^{-1}$	US. EPA

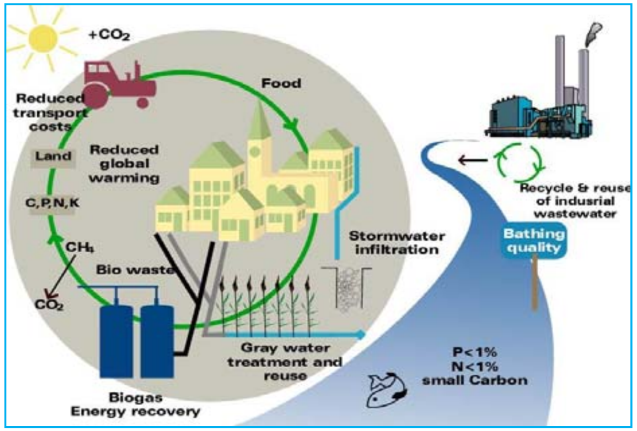
Compost

Source: www.recycledorganics.com

Challenges of Sewage Sludge Composting

- ❖ No suitable solid waste composting mix formulation
- ❖ Improper program setting (high turning frequency, high temperature of heater)
- ❖ Serious odour problem, huge amount of VFA and GHG generated due to inefficient degradation
- ❖ High moisture and heavy metals content of sewage sludge
- ❖ Efficiency of commercially available inoculum not good
- ❖ Huge quantities of incomplete digested organic wastes and heavy metals.





Composting is one of the possible opportunities for sewage sludge management

Households	→	Domestic composter
Small community, etc.	→	Commercial composter
	→	Centralized composting facility
Small city, etc.	→	Centralized composting facility

Aims of this study

1. Formulation of novel feedstock mixture of sewage sludge- wheat straw amended with additives

2. To evaluate heterogeneity of additives amendment for nitrogen conservation by N_2O and NH_4 reduction

3. To study the relationship between the mechanisms involved in the total gaseous emission, carbon, nitrogen losses and humification of the composting mixtures.

4. The evaluation of maturity parameters and end product quality

Methodology

Formulation of starting mixture (Sewage sludge +WS+ additives)

Mixing of additives: Biochar **(0, 4, 6, 12 and 18% dry weight basis)**

Monitored the gaseous emission, temperature, pH, C/N ratio and NH_4^+-N, during 0, 3, 7, 10, 14, 21, 28, 35 and 42 days of the composting period.

Compost maturity was evaluated and compared with HKORC/TMECC compost quality standard.

Collection of Sewage Sludge and mixing with bulking agents

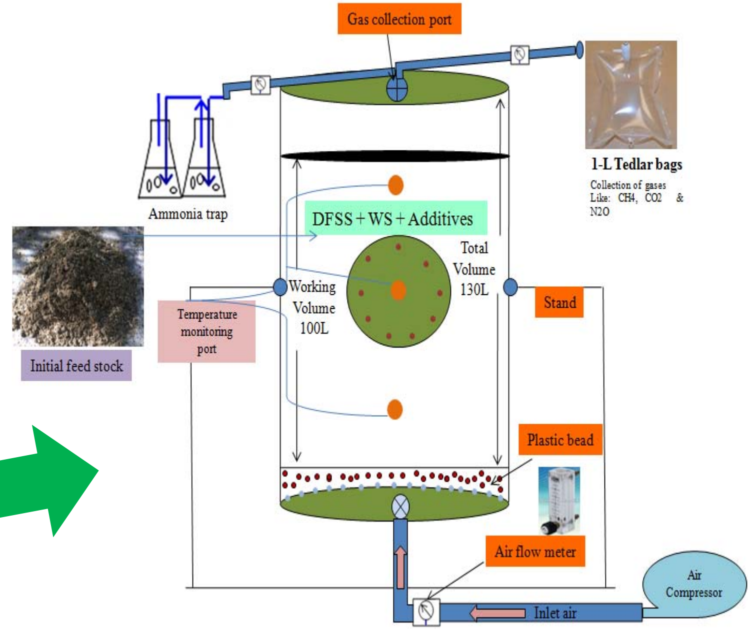



Flow Diagram of Composting Process

Biosolids + Wheat straw (Mixed 1:1 dry weight basis)

Biochar : 0, 4, 6, 12 and 18% (dry weight basis)

In vessel -130-L Composter

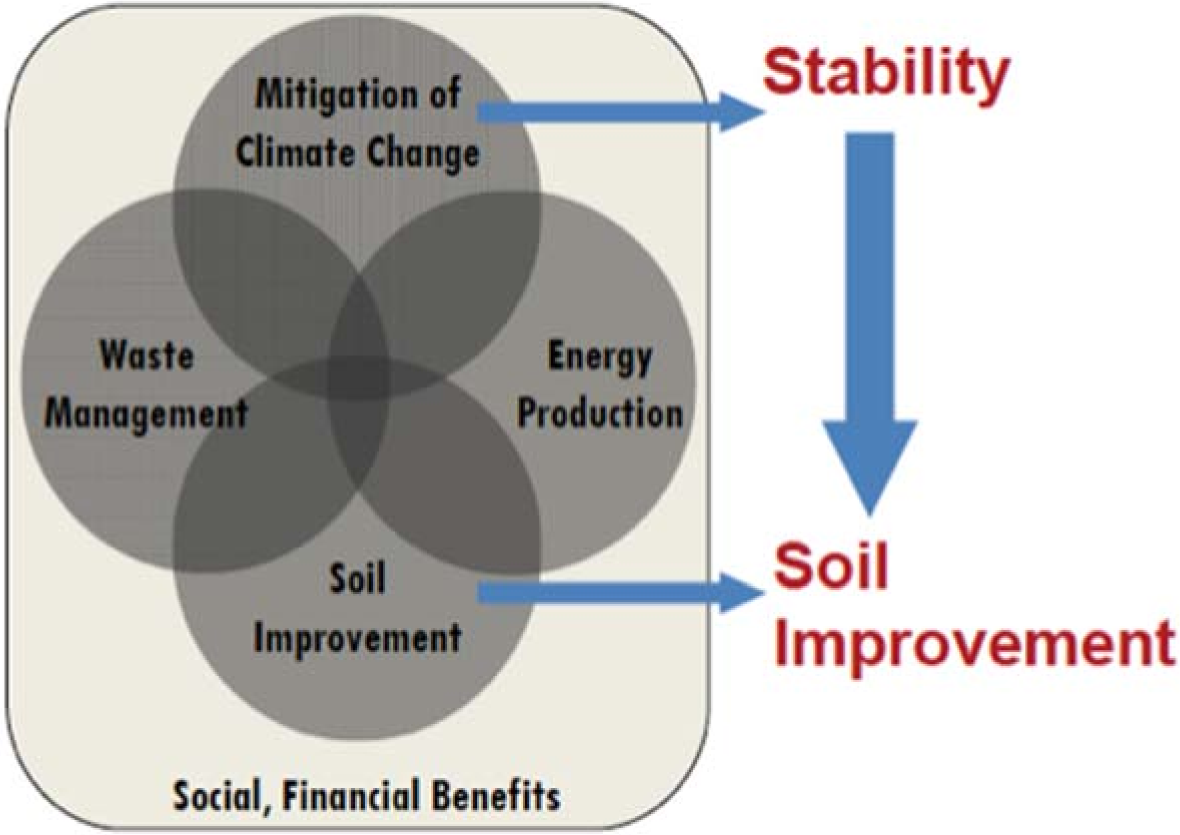


0.35 L h kg

Composting without additives (Control)

Composting with additives

Biochar Systems – Biochar Product

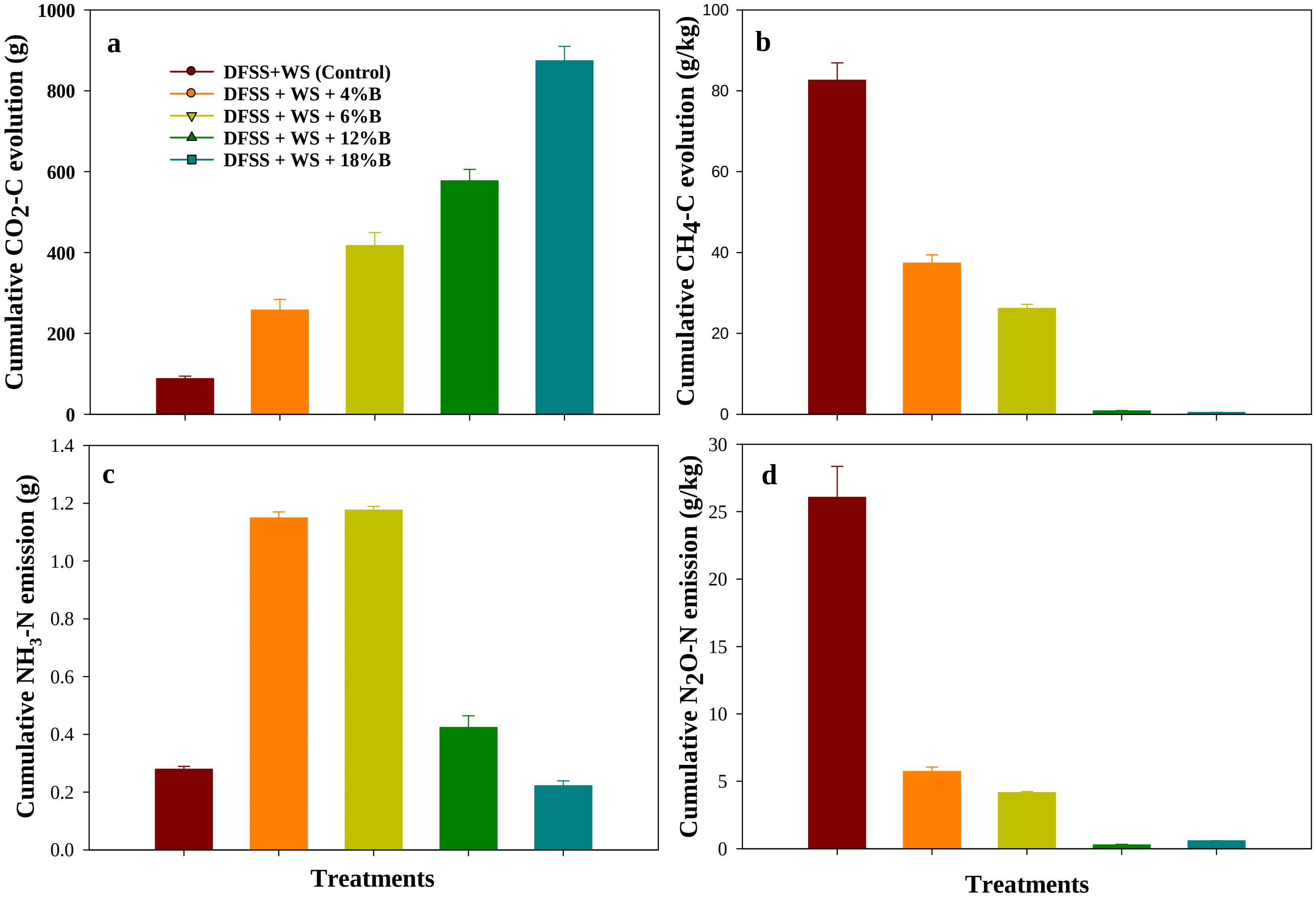


Initial Properties of Mixing Ratio

Parameters	DFSS	WS	Biochar	Mix
Moisture content (%)	81.24±1.85	10.43±0.20	2.42±0.50	56.23±1.45
pH (solid:water = 1:5)	7.27±0.04	4.93±0.14	8.78±0.10	8.12± 0.05
EC (mS cm^{-1}) (Solid: water = 1:5)	5.10±0.16	0.71±0.03	0.98 ±0.03	3.05± 0.03
Total organic matter (%)	79.28±2.18	97.86±2.74	96.23±2.84	93.63± 2.78
Total organic carbon (%)	41.38±2.40	62.30±2.41	67.75±1.78	44.89± 1.02
Total Kjeldahl nitrogen (%)	2.81±0.15	0.80±0.03	0.58±0.02	1.78± 0.05
C:N ratio	14.72± 0.05	77.90±0.25	116.81 ± 1.43	25.21± 0.12

DFSS or Biosolids (dewatered fresh sewage sludge) and WS (wheat straw)

Gaseous emission



16SRNA technology for microbial dynamics

❑Heat-map of species abundance is clustering; the genus classification position clustering (horizontal) and top 35 genera sample clustering (vertical clustering).

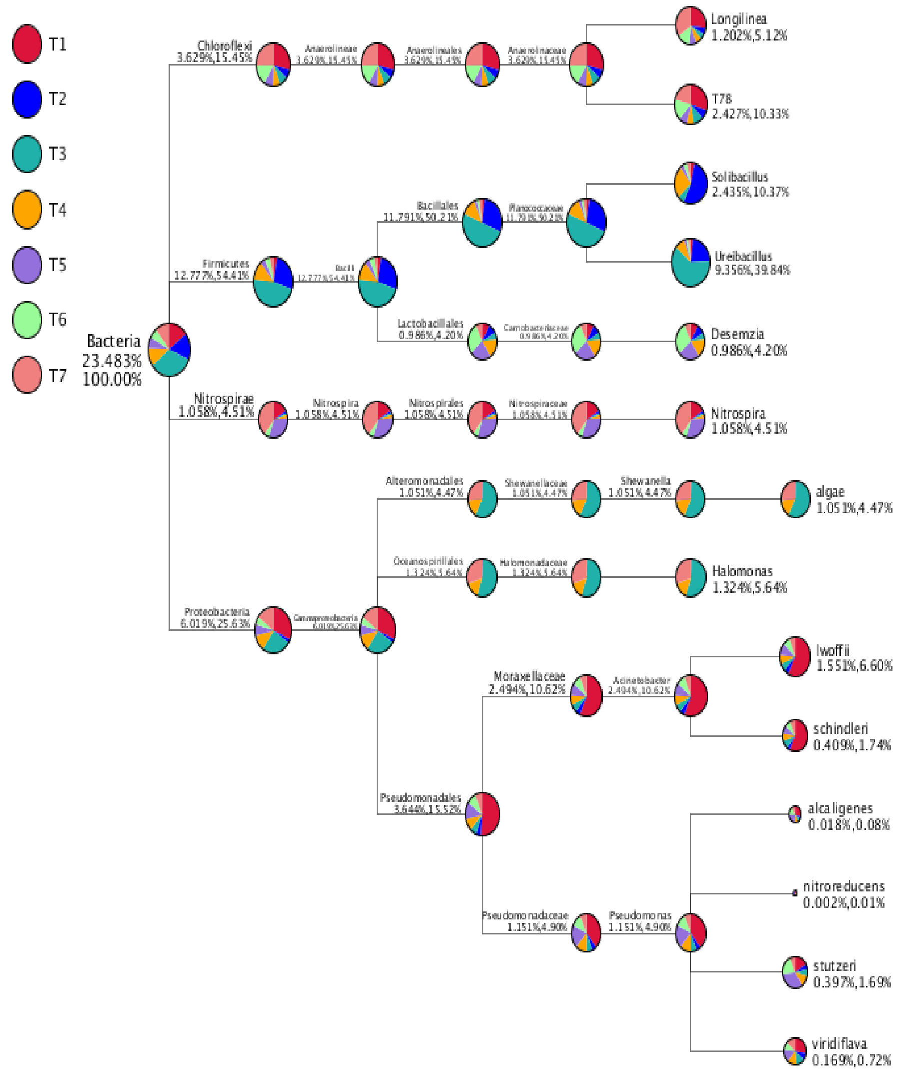
❑Different color means the different relative abundance of the genus in the all seven treatments (red means great abundance).

16SRNA technology for microbial dynamics

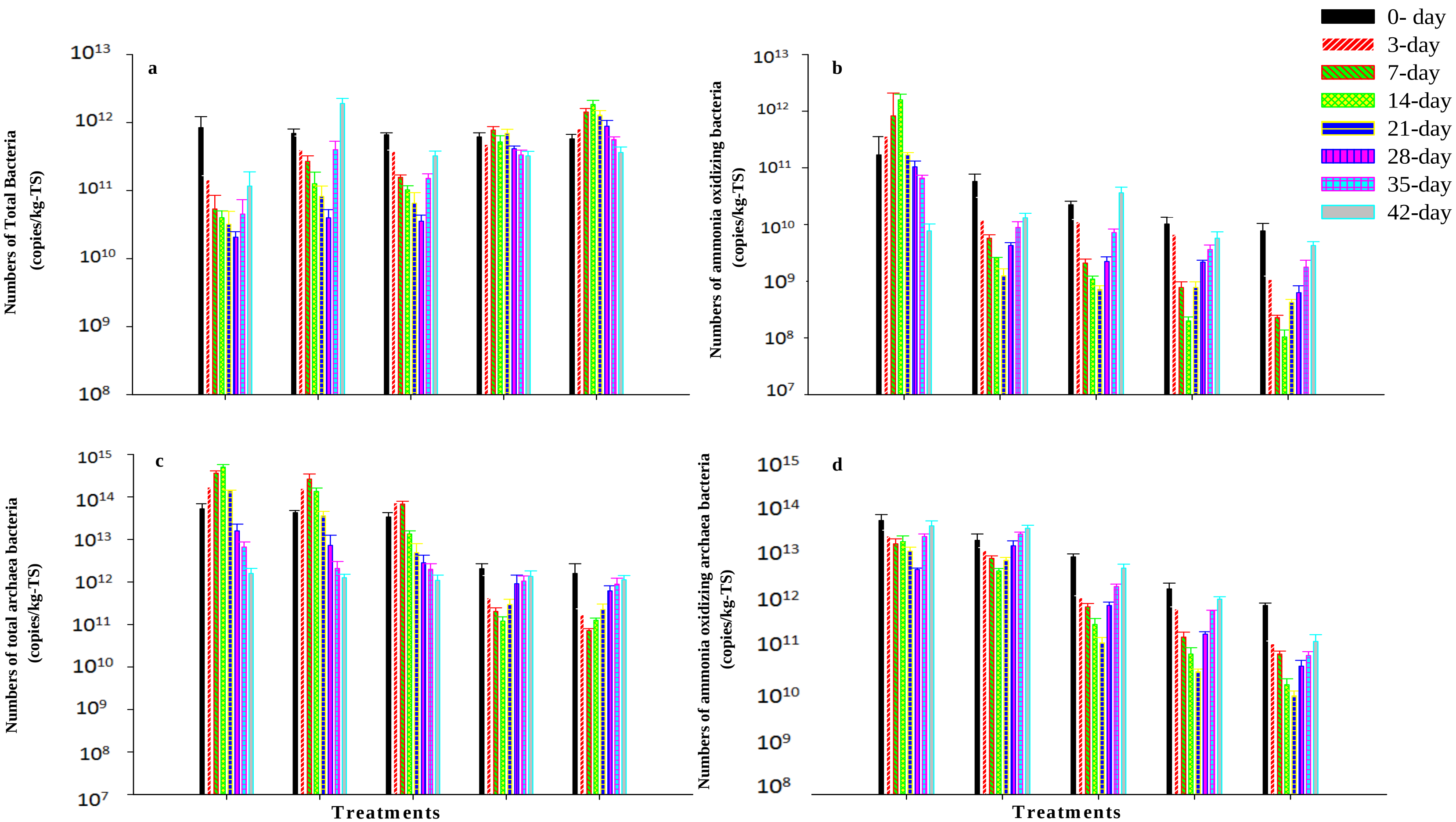
❑**The relative abundance of each class based on 16S rDNA sequence analysis. The relative abundance is expressed in percentage and classification tree of complex samples.**

❑**Different color of circle fan means different sample; the size of the fan means the relative abundance of proportional size on classification level of samples; the numbers below the classification name stands for the average percentage of relative abundance on this classification level in all samples.**

❑**There were two numbers, the former one means the percentage of all species, the latter one means the percentage of selected species.**



Changes in the gene copy numbers of total bacteria (a), ammonia oxidizing bacteria (b), Total archea (c) and ammonia oxidizing archea (B) during composting



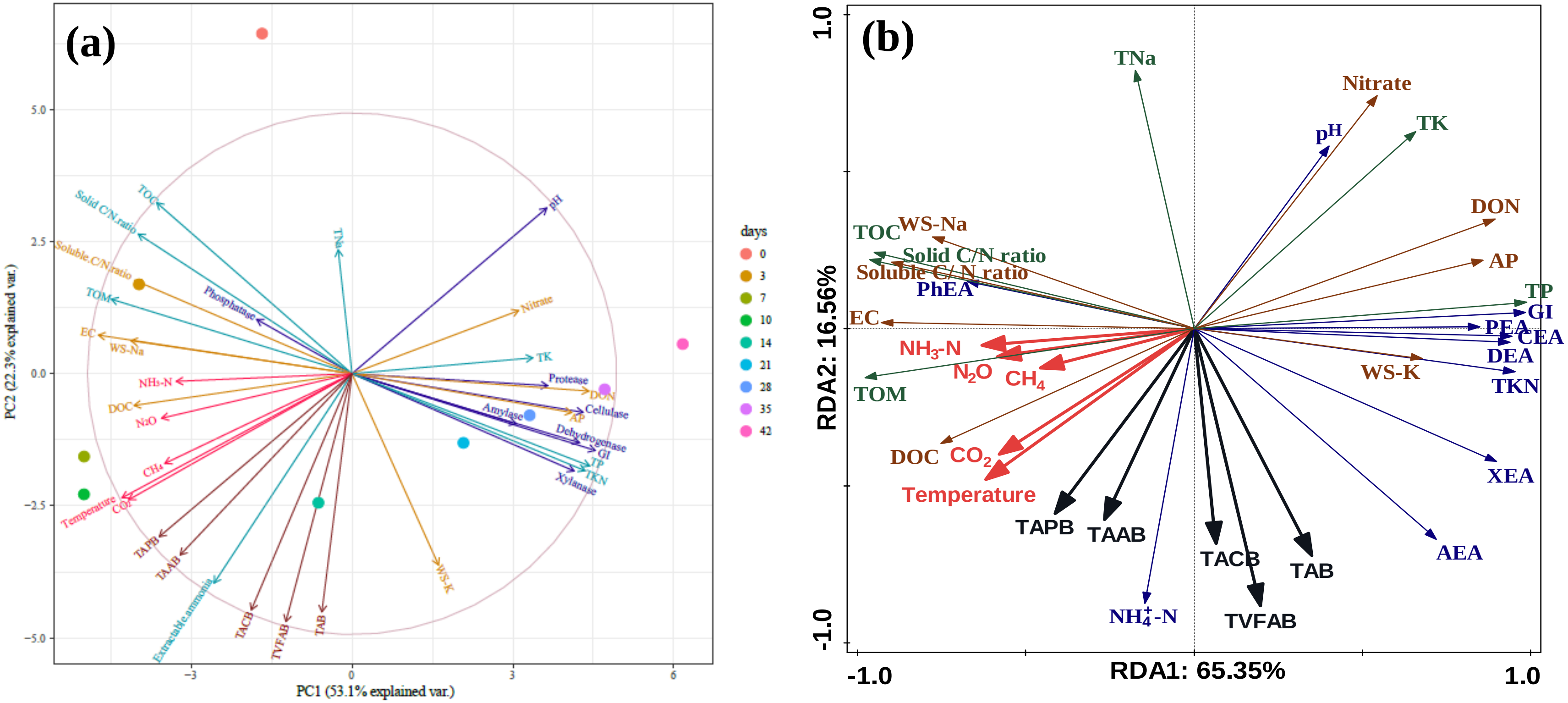
Nitrogen Balance

Treatments		Nitrogen in compost (%)			Nitrogen loss (%)				
		NH_4^+-N	NO_3-N	Org-N [a]	NH_3 loss	N_2O loss	Sample loss	Total N losses	Other loss [b]
C	Initial	0.07± 1.6	0.01 ± 0.00	66.70 ± 4.7	-	-	-	-	-
	Final	0.23 ± 5.3	0.07 ± 0.01	38.48 ± 1.2	1.02 ± 0.00	2.5 ± 0.07	1.01 ± 0.00	1.5 ± 0.02	6.03 ± 0.24
B-1	Initial	0.04 ± 1.8	0.01 ± 0.00	68.91± 5.6	-	-	-	-	-
	Final	0.06 ±3.1	0.13 ± 0.01	45.84 ± 2.0	0.11 ± 0.00	0.57 ± 0.02	0.92 ± 0.00	1.1 ± 0.03	2.7 ± 0.15
B-2	Initial	0.04 ± 2.5	0.00 ± 0.00	72.50 ± 3.7	-	-	-	-	-
	Final	0.05 ± 2.9	0.14 ± 0.02	47.41 ± 1.4	0.11 ± 0.00	0.41 ± 0.03	0.84 ± 0.02	1.8 ± 0.04	3.16 ± 0.05
B-3	Initial	0.05 ± 3.1	0.00 ± 0.00	74.62 ± 3.4	-	-	-	-	-
	Final	0.03 ± 2.2	0.14 ± 0.00	52.84± 2.0	0.04 ± 0.01	0.02 ± 0.00	0.95 ± 0.04	1.2 ± 0.01	2.21 ± 0.05
B-4	Initial	0.05 ± 3.4	0.00 ± 0.00	76.44 ± 2.9	-	-	-	-	-
	Final	0.04 ± 2.8	0.14 ± 0.01	54.51 ± 1.1	0.02 ± 0.01	0.05 ± 0.01	0.91 ± 0.03	1.1 ± 0.03	2.08 ± 0.03

[a] The organic N = TN - NH_4^+ -N - NO_3^--N; [b] Calculate number, other losses = total N losses - NH_3 loss - N_2O loss - sample loss.

C: Dewatered fresh sewage sludge + wheat straw (Control); B-1: Dewatered fresh sewage sludge + wheat straw + 4% biochar; B-2: Dewatered fresh sewage sludge + wheat straw + 6% biochar; B-3: Dewatered fresh sewage sludge + wheat straw + 12% biochar and B-4: Dewatered fresh sewage sludge + wheat straw + 18% biochar. Results are the mean of three replicates ± standard deviation.

Principal Component and Redundancy Analysis



Compared the nutrient value between standards and final product after 42 days

Parameter	Standard values		Biochar 12%	Control
	HKORC[a]	TMECC[b]/ others		
Ammoniacal-N (mg/kg dw)	< = 700	75-500	305.8 ± 16.6	1965±32
CO_2 evolution rate (g C/kg VS/day)	< = 2	2-4	2.43 ± 0.30	7.68 ± 0.54
C:N ratio	≤ 25	≤ 25	15.43 ± 1.0	25.59 ± 1.7
pH Value	5.5 - 8.5		7.69 ± 0.02	6.69 ± 0.04
Organic matter (% dw)	> 20	>40[c]	85.55 ± 3.04	93.32 ± 2.51
Seed germination index (%)	>=80	80-90	105.4± 5.5	61.69± 4.61
Total nitrogen (as N % dw)	> = 4	-	2.06 ± 0.03	1.45 ± 0.05
Total phosphorous (as P_2O_5 % dw)		-	1.64 ± 0.26	1.38 ± 0.07
Total potassium (as K_2O % dw)		-	1.13 ± 0.18	1.85 ± 0.09
Total N, P, K (% dw)		-	4.83 ± 0.30	4.68 ± 0.13

Conclusions

❖12%Biochar added sewage sludge treatments significantly reduced the N_2O and NH_3 emission by 95.14–97.30% and 58.03–65.17% as compare to control treatments.

❖Furthermore, it was estimated that the 12% biochar could enhance the humification with maximum reduction of total N loss and GHGs emissions.

❖In addition, the PCA and RDA analysis were also showed significant variation and correlation among the gaseous emission and nutrients transformation during the composting.

❖The higher dosage of biochar could decreased the abundance of total bacteria and ammonia oxidizing bacteria during the themophilic phase but considerably increased maturation phase.

❖Overall, the addition of 12%Biochar for composting demonstrated to be a beneficial practice for the management of sewage sludge .

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Questions?

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Thank You…