Feasibility of sewage sludge-wheat straw co-composting amended with biochar

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CONTENTS

- ❖ Status of sludge production and discharge
- ❖ Composition analysis and environmental pollution of sludge
- ❖ Main treatment methods of sludge
- ❖ Disadvantages and improvement of sludge composting
- ❖ Ways of cleaning compost by sludge
- ❖ Conclusions

Sludge production and discharge

1、Sludge production and characteristics

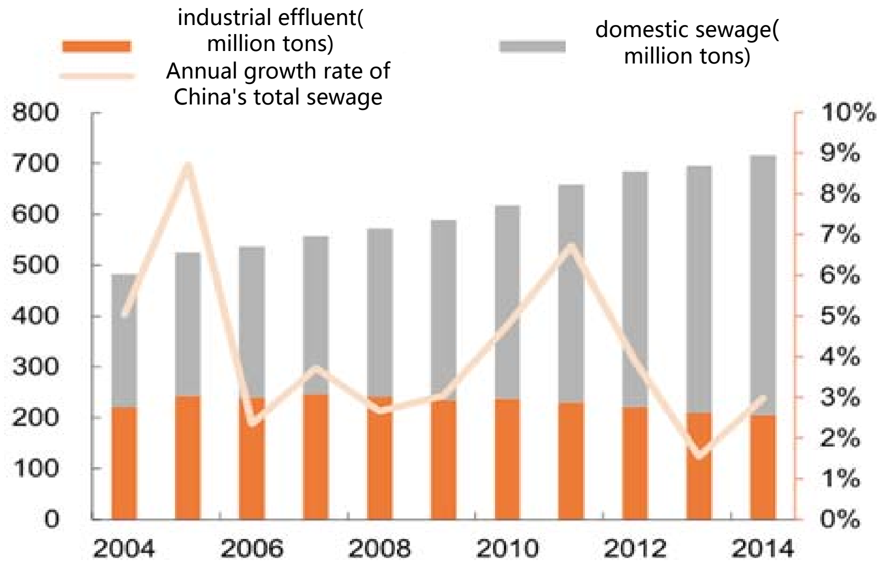
❖ Sludge : The product of sewage treatment is a very complex heterogeneous organism composed of organic fragments, bacteria, inorganic particles and colloids.

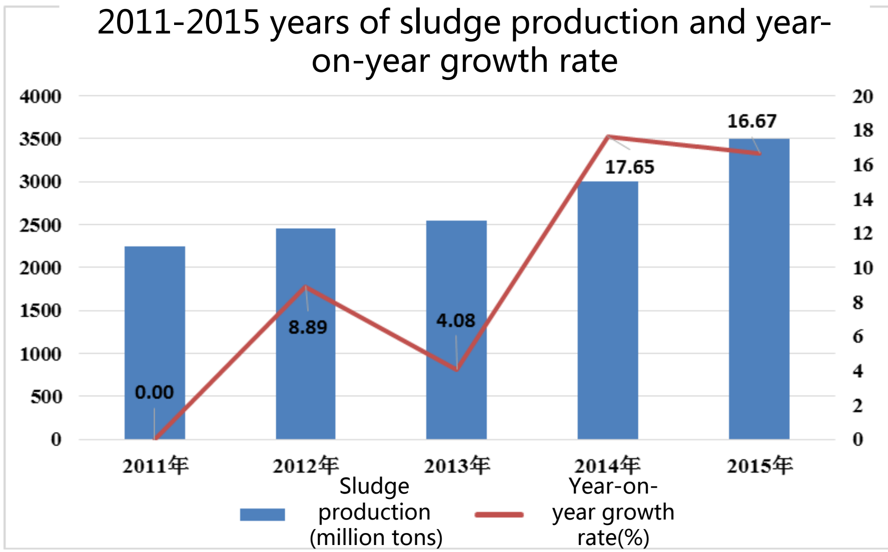
❖ Characteristics : High moisture content (over 80%) , High organic content , Liable to decay and stink , Fine particles , Small proportion , Colloidal liquid.

2、Sludge discharge

❖In 2015, China's daily sewage treatment capacity has reached 1.3 billion tons, annual output of sludge up to 350 million tons.

China's sludge production is expected to reach 600-900 million tons by 2020。





Sludge composition and environmental pollution

1、Sludge composition

Sludge composition

- solid phase
  - Oganic phase
    - Elemental composition：C、H、N、O、S and Cl
    - Chemical composition
      - Toxic organic composition：Toxic organic matter content
      - Composition of organic functional compounds:Alcohols,acids, esters,hydrocarbons,aromatic compounds
      - Organic biomass composition：Soluble sugars; cellulose; lignin; fats; protein.
    - Microbial composition: Pathogens, bacteria, parasites eggs, insects eggs.
  - Inorganic phase
    - Toxicity of inorganic substances：As、Cd、Cr、Hg、Pb、Cu、Zn and Ni.
    - Nutrient composition：N、P、K and their compounds.
    - Inorganic minerals：Fe、Al、Ca、Mg and Si etc.
- mobile phase
  - Moisture：free moisture, interstitial water, surface (attachment) moisture, etc.
  - Water soluble components.

2、Environmental pollution of sludge

Sludge

Nutrient (N, P, K etc.)

Pathogenic microorganisms

Heavy metals(Cu、Zn、Pb、Cd、Cr、As、Hg)

Antibiotics and resistance genes

Pile up at will

Air Pollution (stench、H_2S)

Water pollution: Water eutrophication, groundwater pollution

Soil pollution:Heavy metals, plant poisoning

Microbial contamination:Mosquitoes sinus, bacteria damage




3、Xi'an sludge accumulation and heavy metal pollution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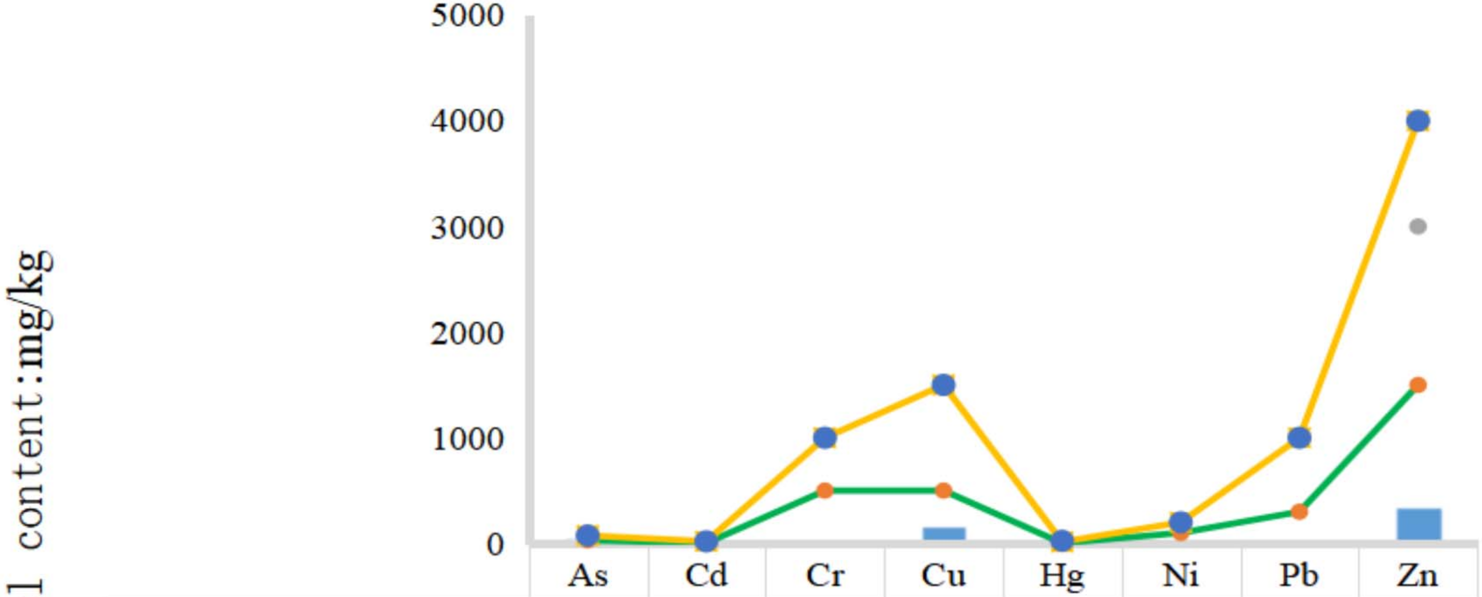
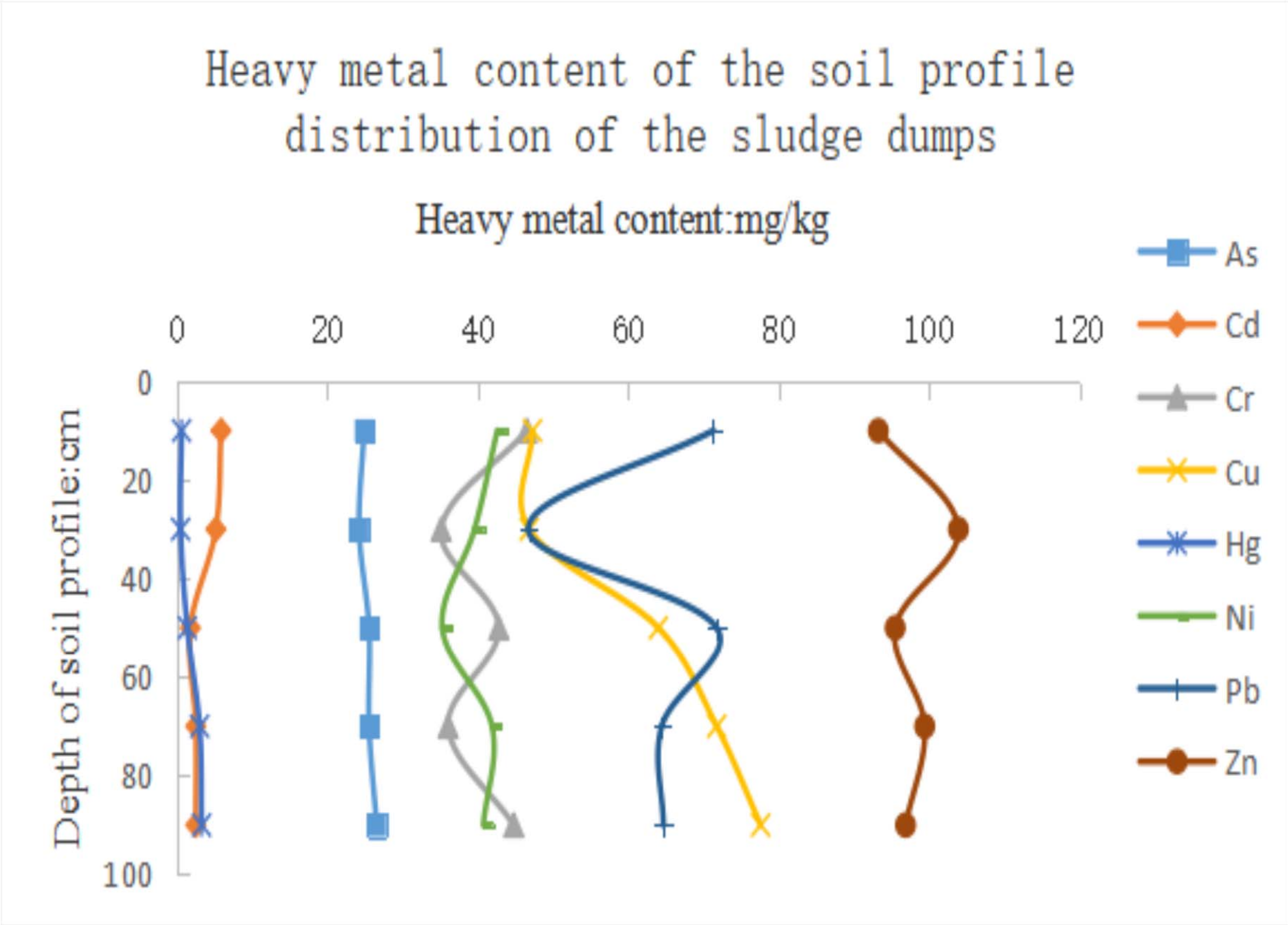
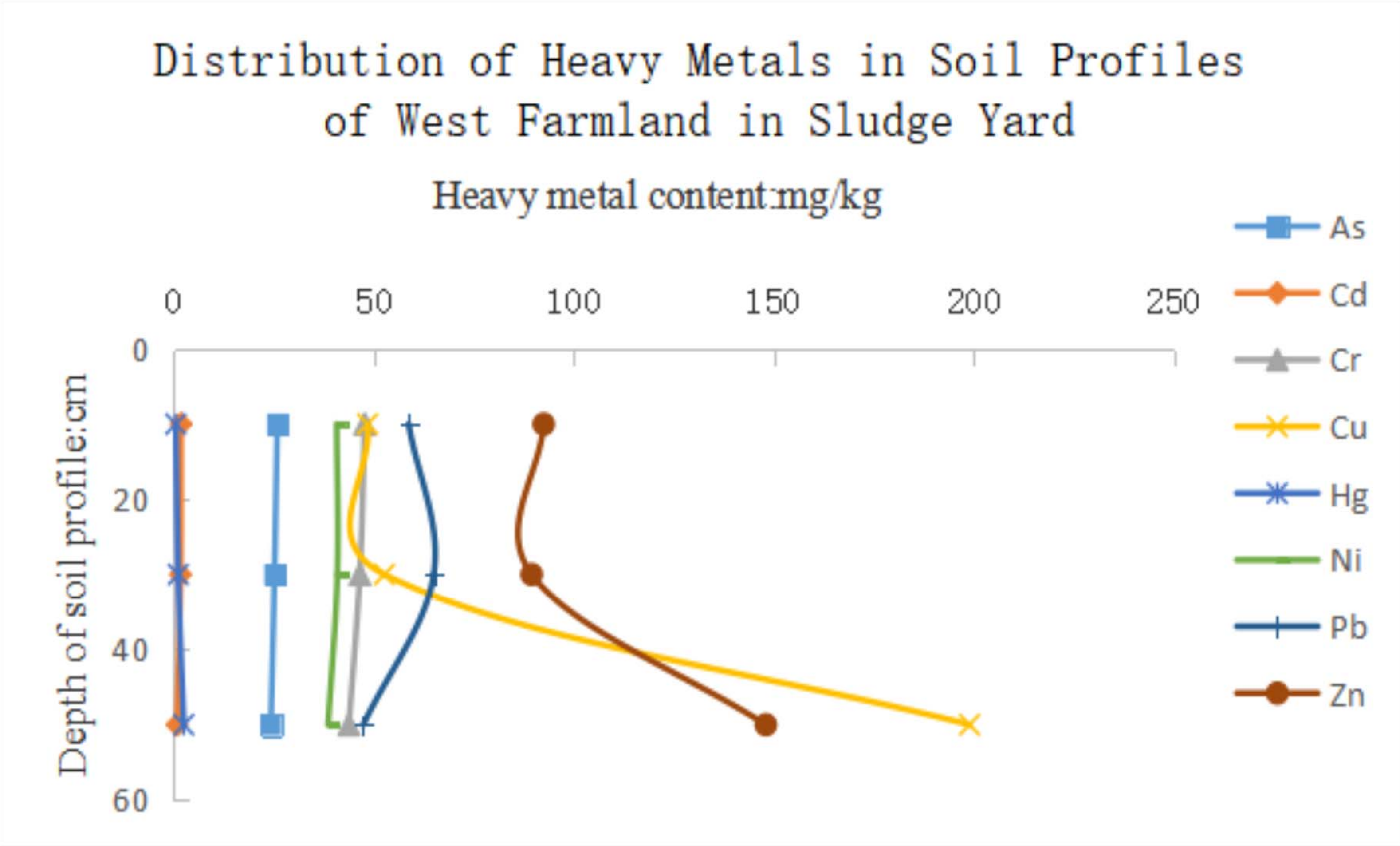
Comparison of Heavy Metals in Sludge with Related Standards



	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Measured value of sludge	67.05	2.10	47.26	178.99	2.23	36.11	46.97	358.05
Agricultural Grade A	30	3	500	500	3	100	300	1500
Agricultural Grade B	75	15	1000	1500	15	200	1000	3000
Landscaping	75	20	1000	1500	15	200	1000	4000
Mixed landfill and Sludge quality	75	20	1000	1500	25	200	1000	4000


Heavy metal content of the soil profile distribution of the sludge dumps
Heavy metal content:mg/kg
0
20
40
60
80
100
120
Depth of soil profile:cm
0
20
40
60
80
100
As
Cd
Cr
Cu
Hg
Ni
Pb
Zn



Distribution of Heavy Metals in Soil Profiles of West Farmland in Sludge Yard
Heavy metal content:mg/kg
Depth of soil profile:cm
0
50
100
150
200
250
0
20
40
60
As
Cd
Cr
Cu
Hg
Ni
Pb
Zn

Main Treatment Methods of Sludge

1、Traditional Disposal Methods and Disadvantages of Sludge

A、Landfill disposal

embezzlement of land, soil and groundwater pollution

B、Incineration

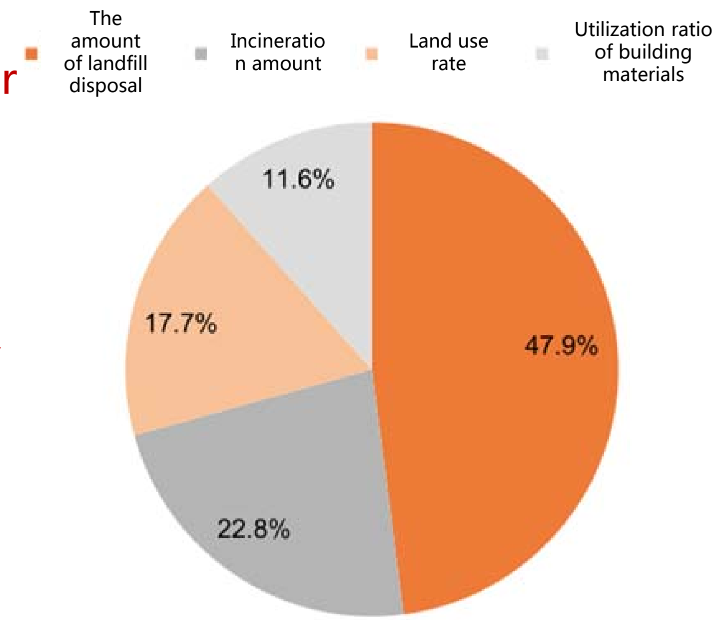
high energy consumption, large investment, air pollution (acid gas, fly ash)

C、Land use (untreated)

heavy metal pollution, plant toxicity, pathogen transmission, odor

D、Making building materials

low product quality, substandard



2、Aerobic composting process for sludge treatment

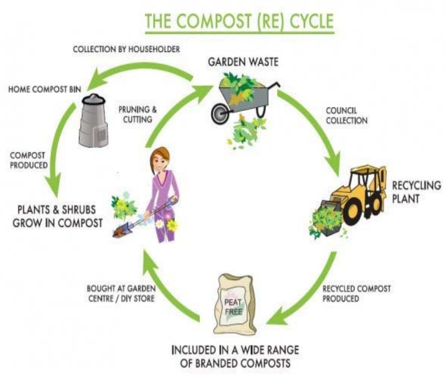
★ Aerobic composting: Under aerobic conditions, aerobic bacteria absorb, oxidize, and decompose the waste. Through their own life activities, microorganisms oxidize a portion of absorbed organic matter to simple inorganic substances, at the same time, the energy needed for the growth of microorganisms is released, the other part of the organism is synthesized into new cytoplasm, so the microbial growth and reproduction,produce more organisms.

Sludge

Aerobic composting

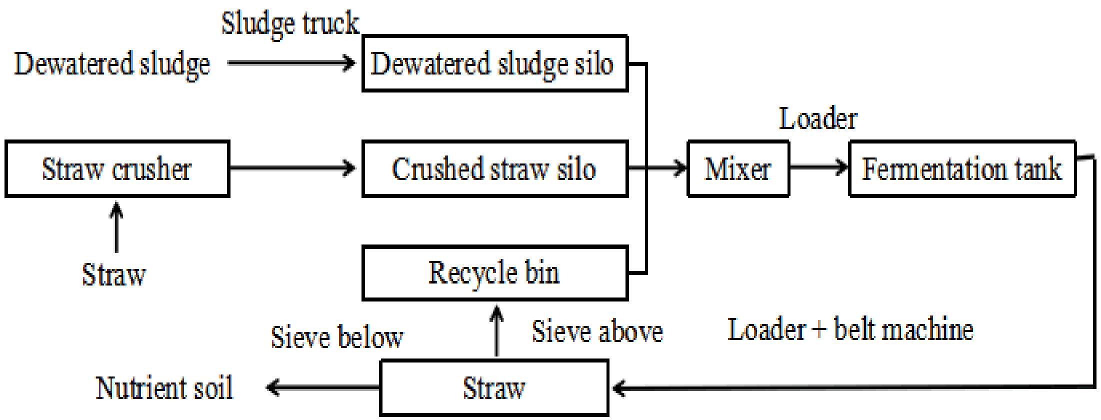
Organic Fertilizer

Application



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



Composting process

Composting Processing Equipment





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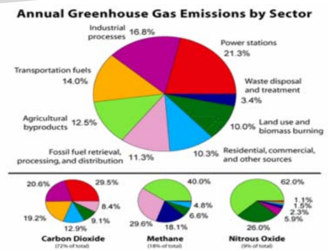
Disadvantages and Improvement of Sludge Composting

1、Disadvantages of traditional composting



- Greenhouse gases and volatile organic compounds emissions

  VFA、 CH_4、N_2O （Greenhouse effect）

- Ammonia volatilization

  NH_3 （Nitrogen loss and Lower quality）

Composting without biochar (Control)

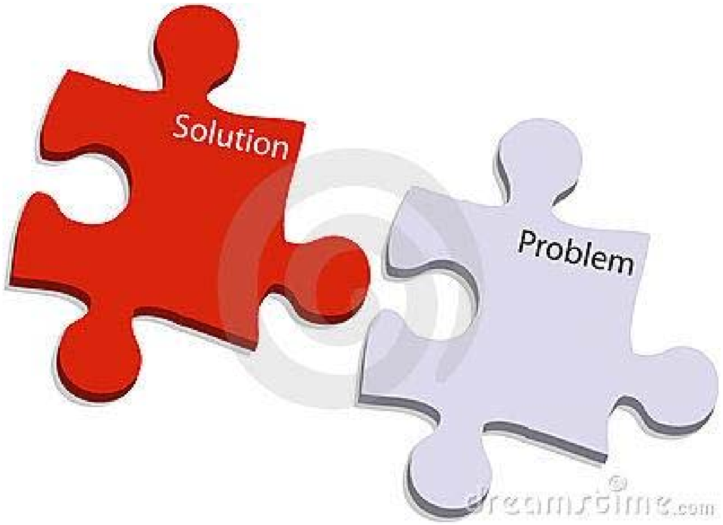
- High activity of heavy metals

  Cu、Zn、Pb、Cr、Cd、Hg、As （Soil pollution and Plant poisoning）

- Low degree of humification

  Humus 、Humic acid （Poor quality）

2、Major ways to improve existing composting processes



★ A、Adjust the physical and chemical parameters of composting：

adjust C/N、water content and aeration rate

★ B、Add exogenous additives：

microbial additives, mineral additives and chemical additives

★ C、Biological treatment：

Earthworms

Methodology

1

Formulation of starting mixture

(Biosolids+WS+ additives)

2

Mixing of additives:

Biochar : 0, 2, 4, 6, 8, 12 and 18% (dry weight basis)

3

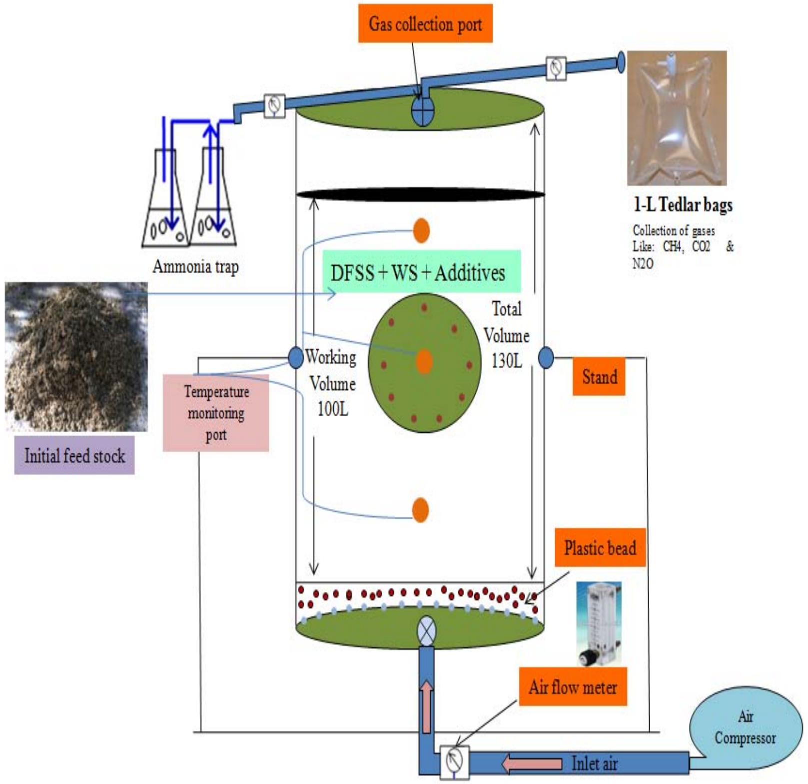
Monitored the gaseous emission, temperature, pH, moisture, C/N ratio, NH_4^+ -N, during 0, 3, 7, 10, 14, 21, 28 and 42 days of the composting period.

4

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

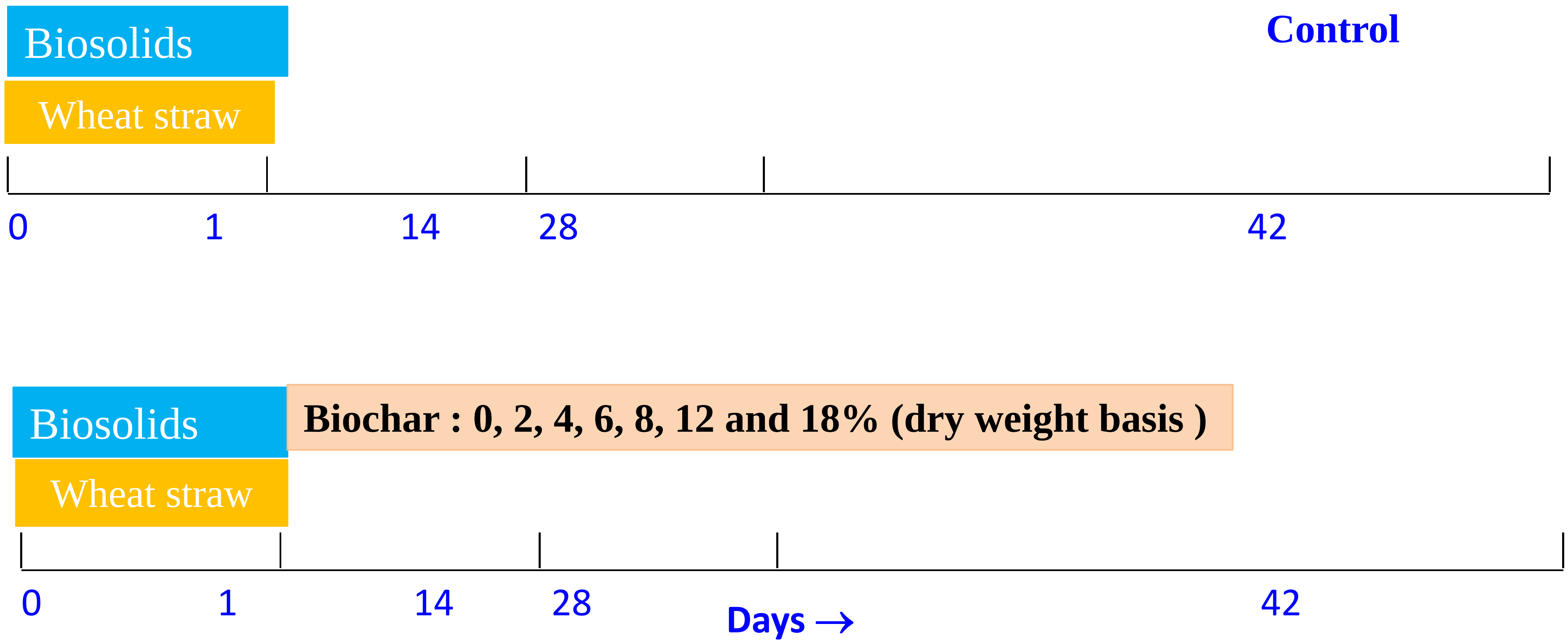
Collection of Sewage sludge and mixing with bulking agents

Flow diagram of composter



0.35 L $h^{-1}kg^{-1}$

Treatments & Substrate addition



Dewatered fresh sewage sludge (DFSS) or Biosolids and wheat straw mixed 1:1 ratio on dry weight basis, while additives added on SS dry weight basis; Day 0: 50-60% moisture content

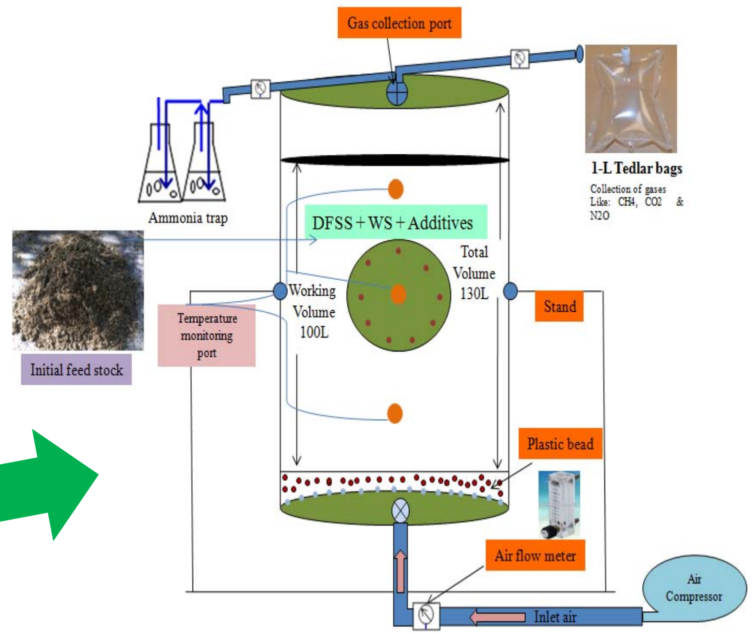
Bulk density of the compost mass in the reactor was determined to estimate the compost weight in the reactor ; Continuous thermophilic (55 ºC)

Flow Diagram of Composting Process

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

Biochar : 0, 2, 4, 6, 8, 12 and 18% (dry weight basis)

In vessel -130-L Composter



0.35 L h kg

Composting without additives (Control)

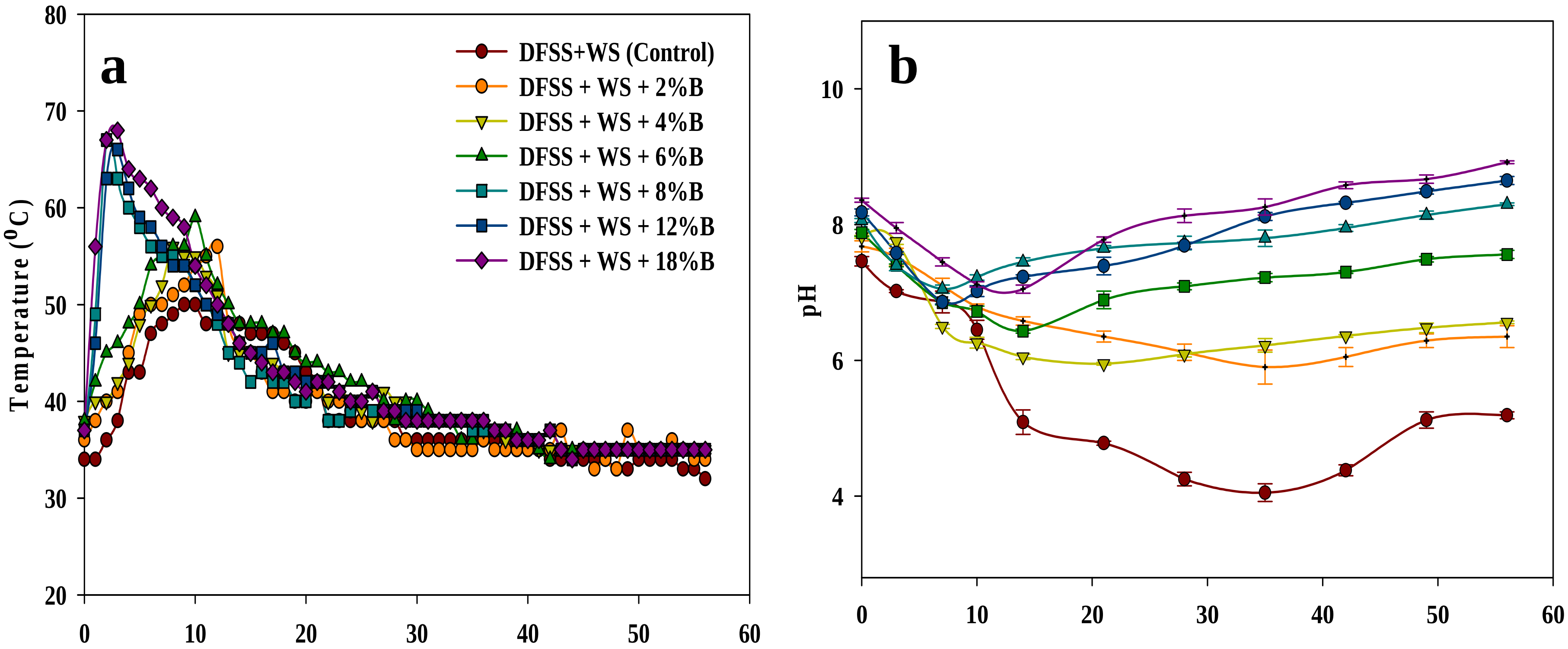
Composting with additives

Initial Properties of Mixing Ratio

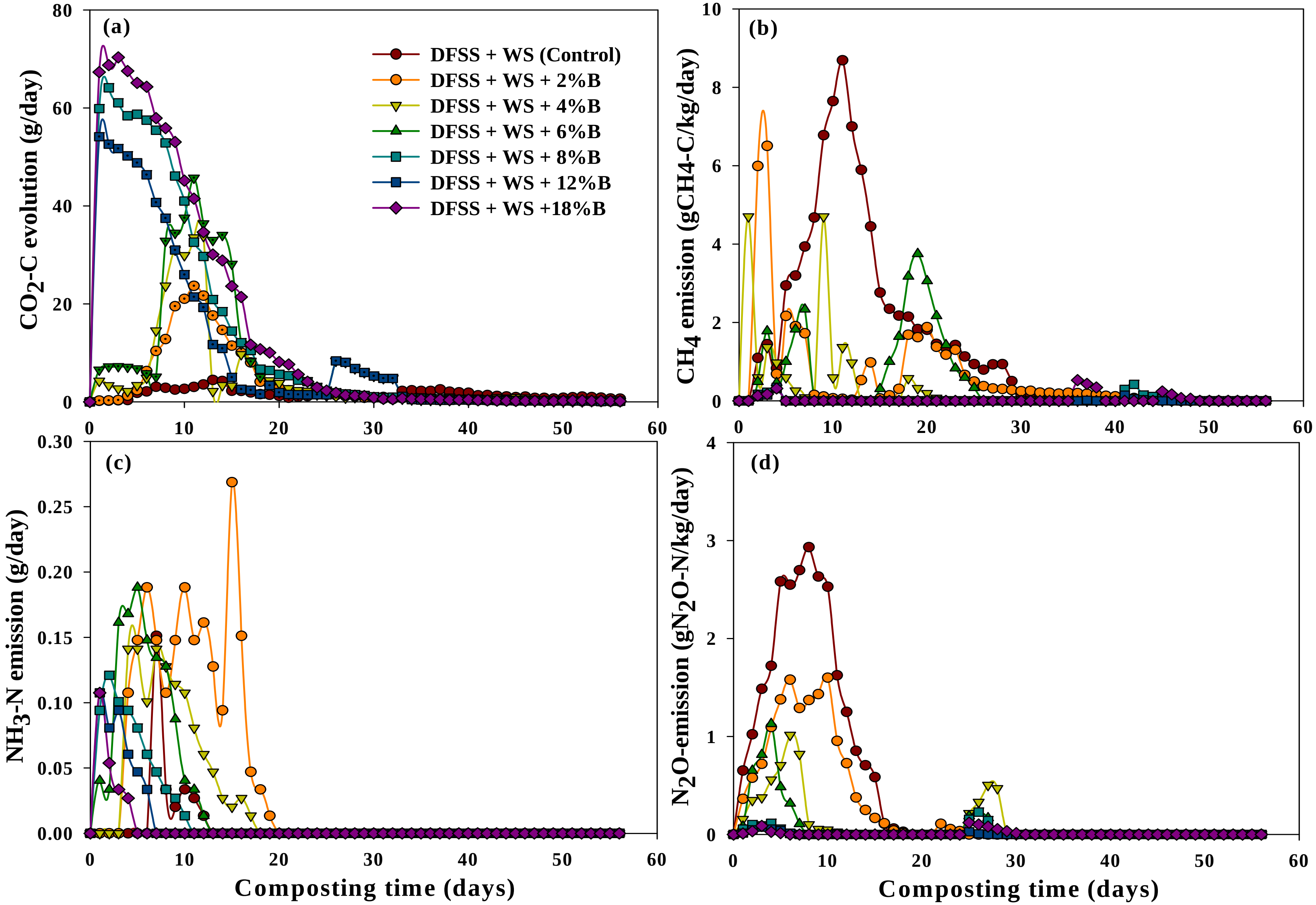
Parameters	DFSS	WS	Biochar	Mix
Moisture content (%)	81.24±1.85	10.43±0.20	2.42±0.50	56.23±1.45
pH (solid:water = 1:5)	7.27±0.04	4.93±0.14	8.78±0.10	8.12± 0.05
EC (mS cm^{-1}) (Solid: water = 1:5)	5.10±0.16	0.71±0.03	0.98 ±0.03	3.05± 0.03
Total organic matter (%)	79.28±2.18	97.86±2.74	96.23±2.84	93.63± 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)

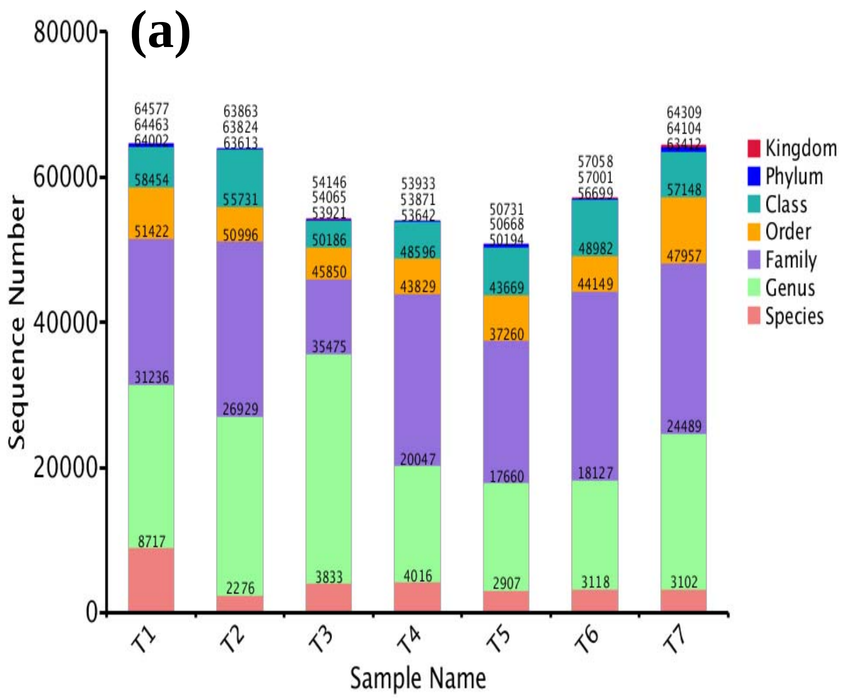
Changes temperature and pH during composting

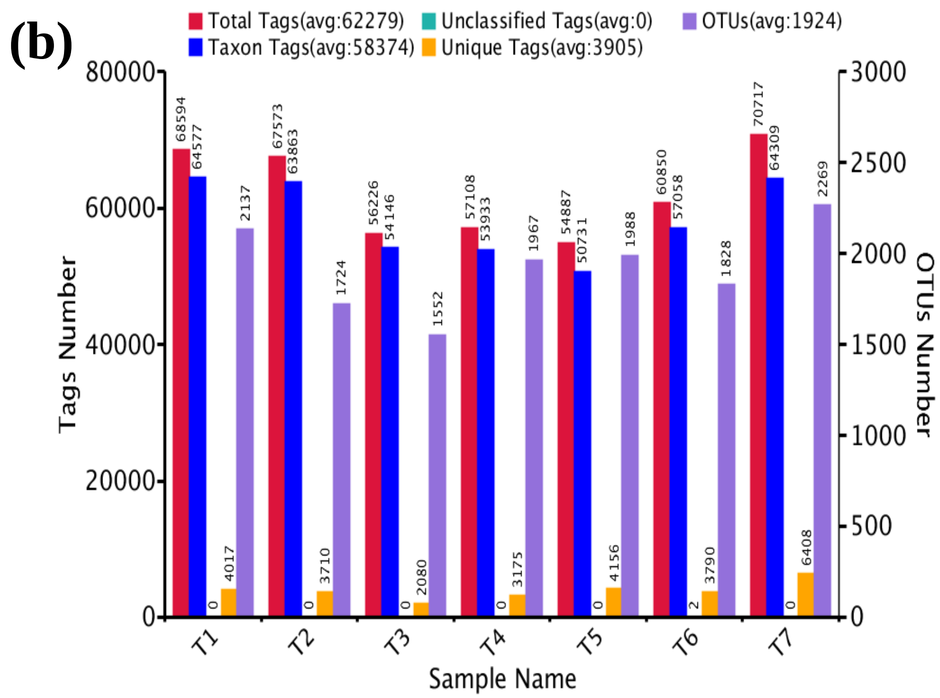


Gaseous emission

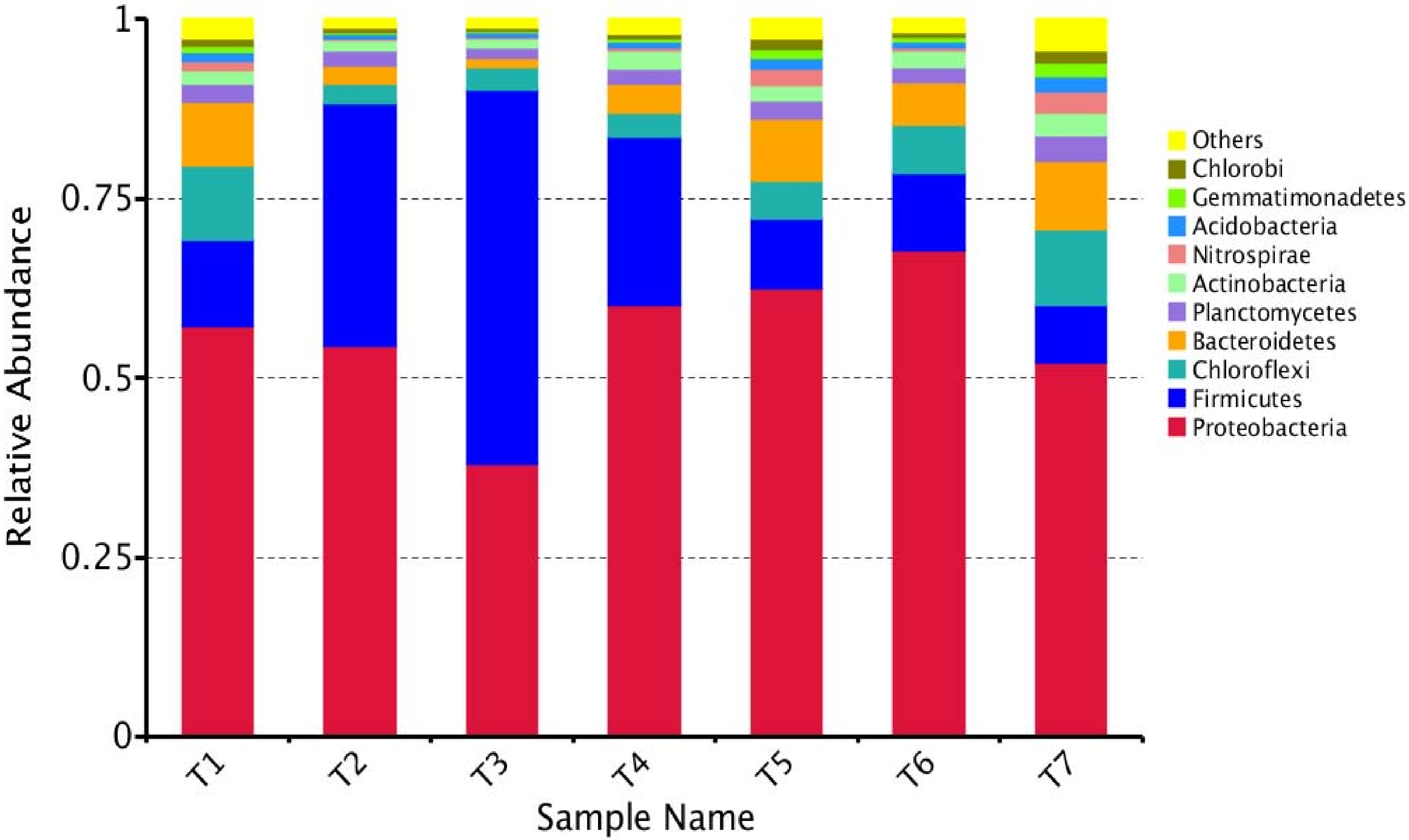


16SRNA technology for microbial dynamics

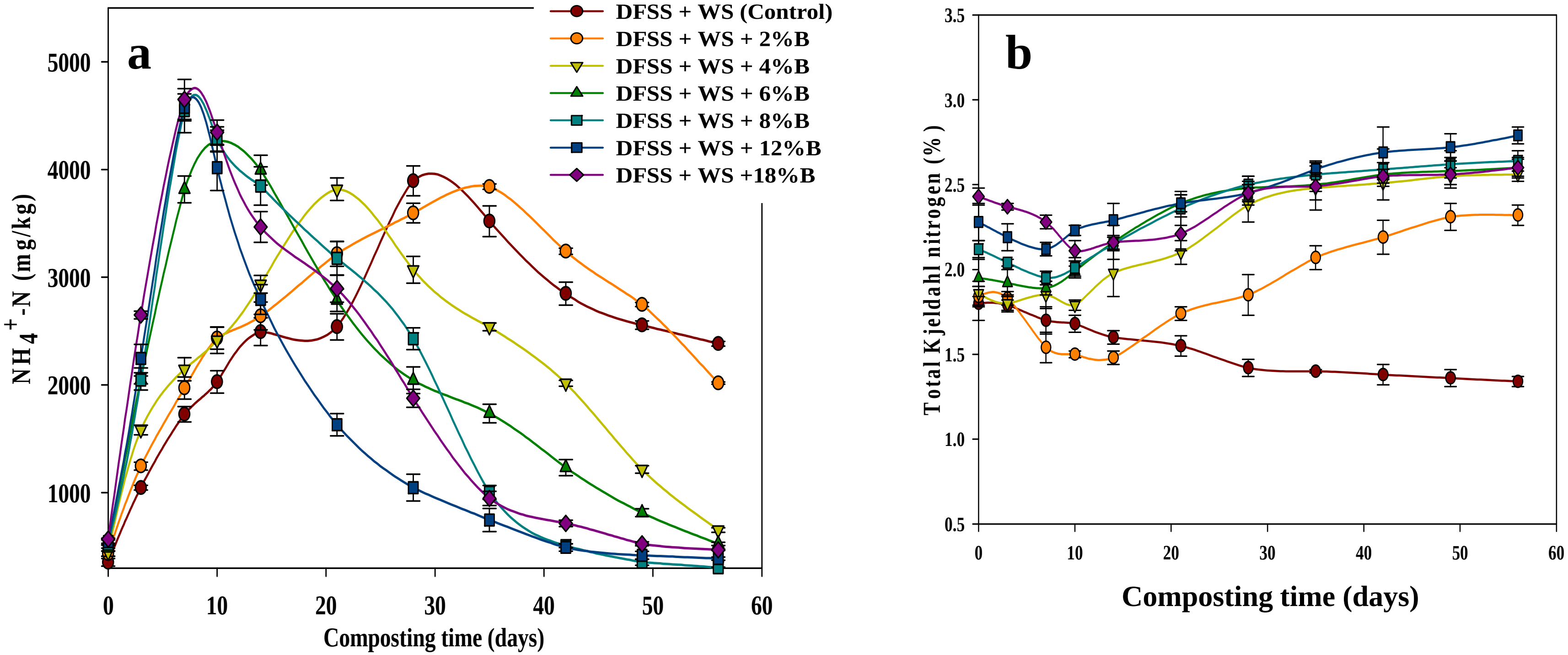




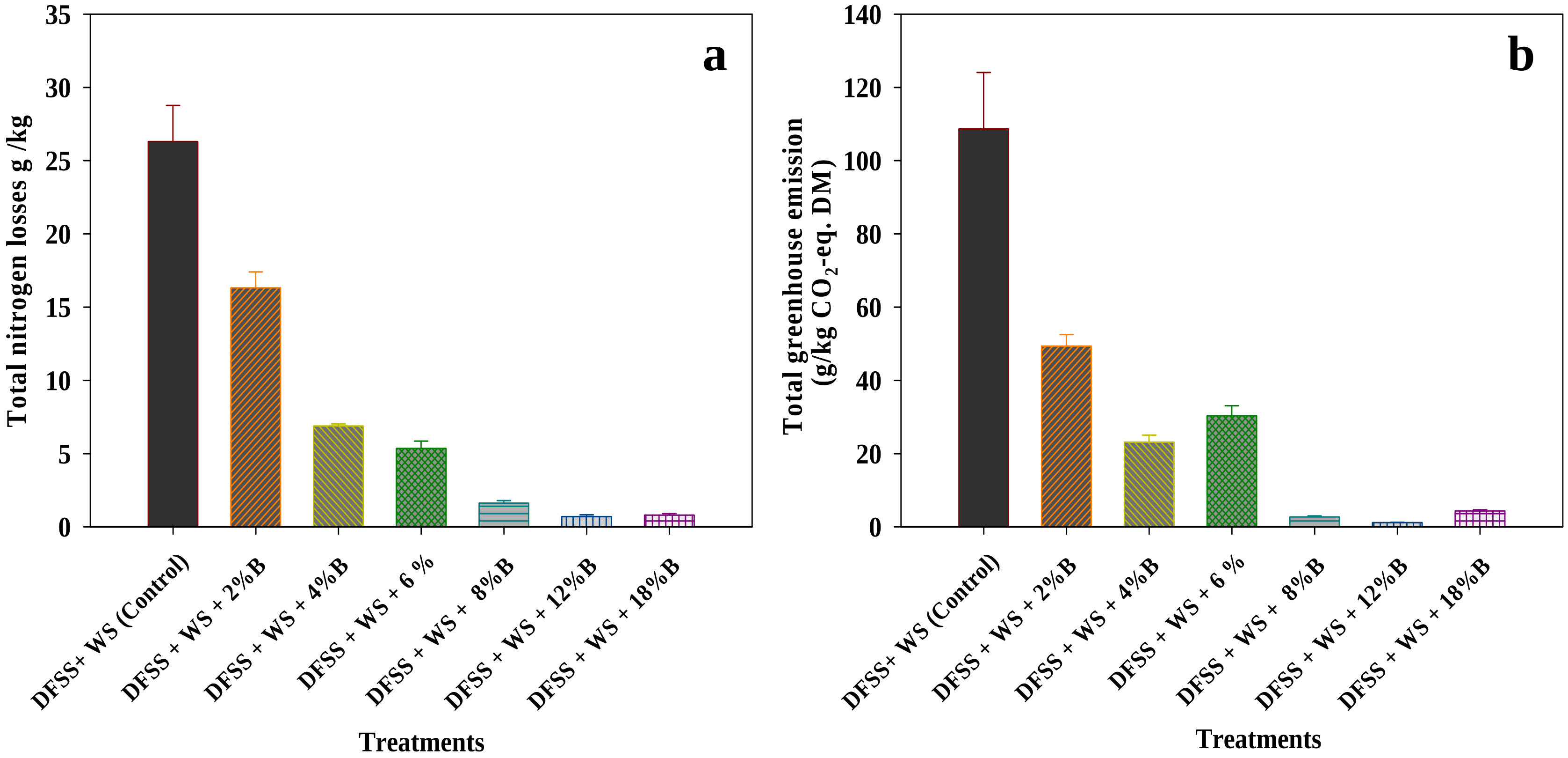
The relative abundance of the dominant bacterial taxonomic groups separated using total 16S rDNA gene sequences



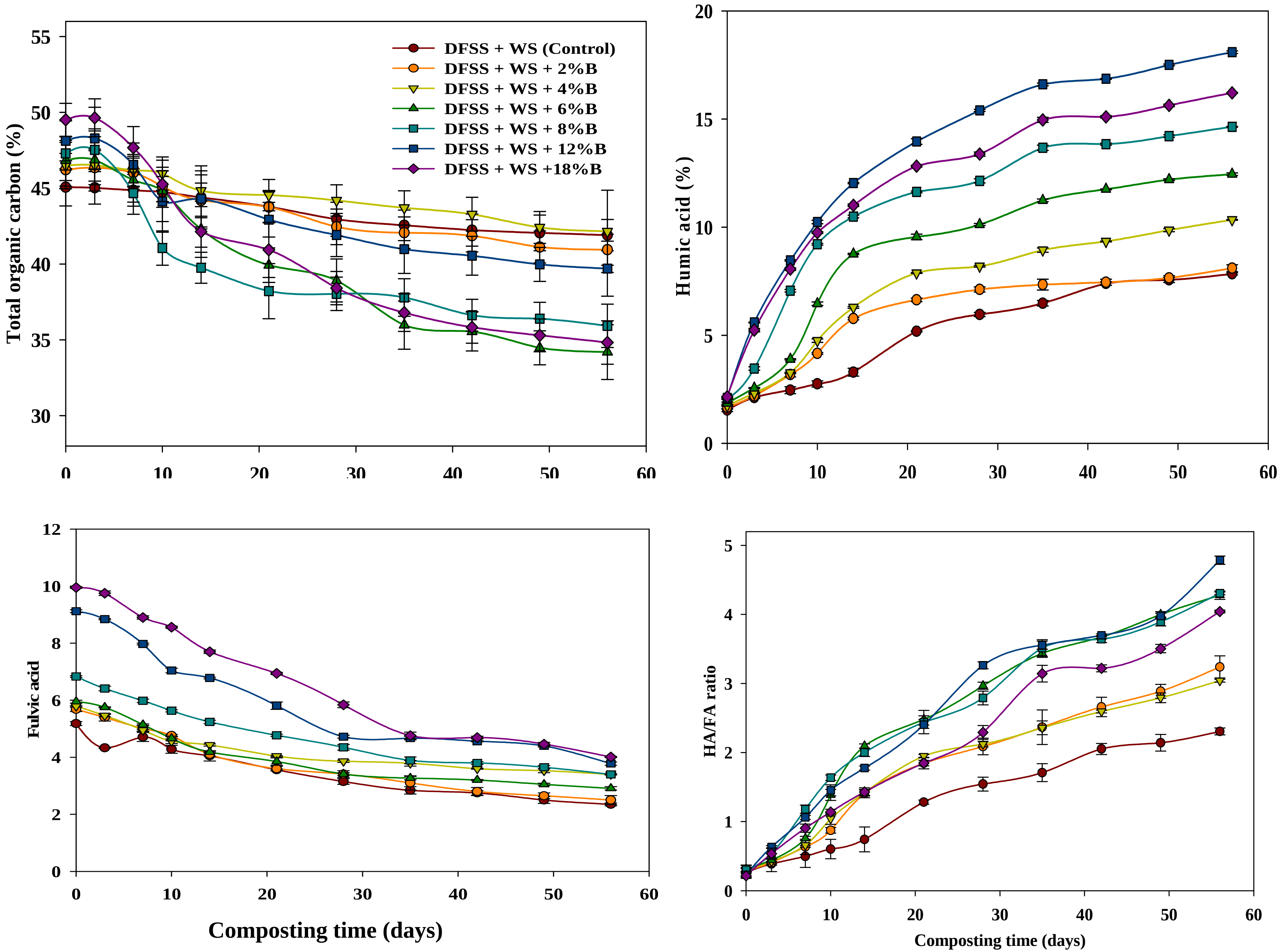
Nitrogen dynamics



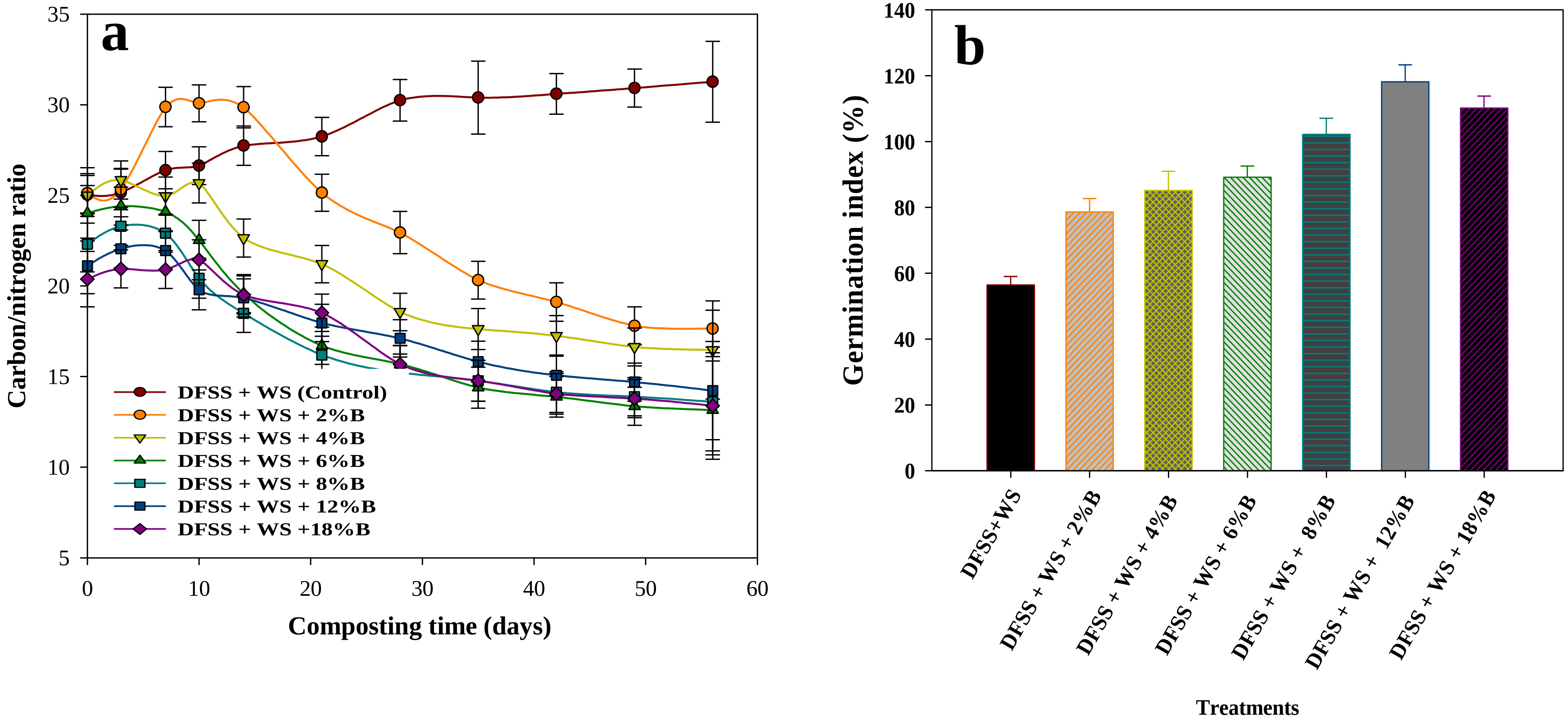
Total greenhouse emission (g/kg CO_2-eq. DM)



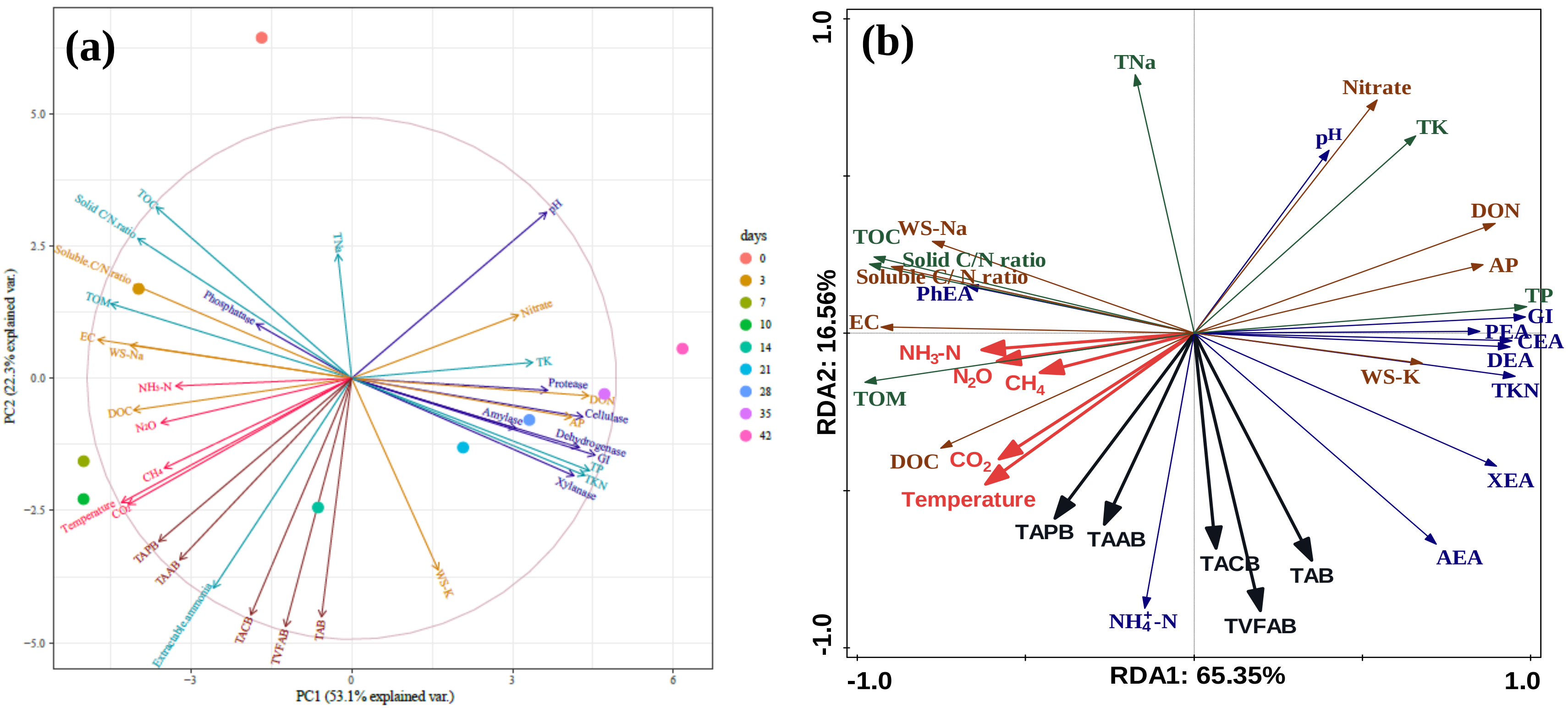
Changes in TOC and humification



Changes in C/N ratio and GI



Principal Component and Redundancy Analysis



Compared the nutrient value between standards and final product after 56 days

Parameter	Standard values		Biochar 12%	Biochar 18%	Control
	HKORC[a]	TMECC[b]/ others			
Ammoniacal-N (mg/kg dw)	< = 700	75-500	305.8 ± 16.6	452.2 ± 13.5	1965±32
CO_2 evolution rate (g C/kg VS/day)	< = 2	2-4	2.43 ± 0.30	3.10±0.18	7.68 ± 0.54
C:N ratio	≤ 25	≤ 25	15.43 ± 1.0	16.13± 0.52	25.59 ± 1.7
pH Value	5.5 - 8.5		7.69 ± 0.02	8.04± 0.13	6.69 ± 0.04
Organic matter (% dw)	> 20	>40[c]	85.55 ± 3.04	84.15 ± 2.63	93.32 ± 2.51
Seed germination index (%)	>=80	80-90	105.4± 5.5	98.27± 3.73	61.69± 4.61
Total nitrogen (as N % dw)	> = 4	-	2.06 ± 0.03	2.58± 0.02	1.45 ± 0.05
Total phosphorous (as P_2O_5 % dw)		-	1.64 ± 0.26	1.81± 0.10	1.38 ± 0.07
Total potassium (as K_2O % dw)		-	1.13 ± 0.18	1.34± 0.06	1.85 ± 0.09
Total N, P, K (% dw)		-	4.83 ± 0.30	5.73± 0.15	4.68 ± 0.13

Conclusions

❖12%Biochar added sewage sludge treatments significantly reduced the CH_4, N_2O and NH_3 emission by 92.85–95.34%, 95.14–97.30% and 58.03–65.17% as compare to control treatments.

❖Furthermore, it was estimated that the 12% biochar could reduce the length of the active phase and enhance the humification with significant 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.

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

Our Composting Experiment Device

Questions?

Thank You…

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