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Livestock waste treatment systems of the future：A challenge to environmental quality, food safety and sustainability

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- **Nutrient content and environmental pollution of livestock manure**
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Livestock Farming Status in China

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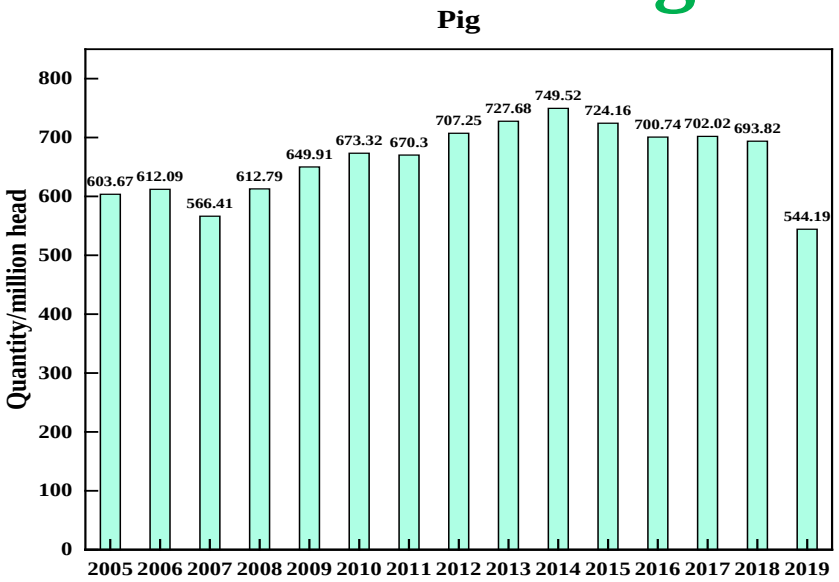
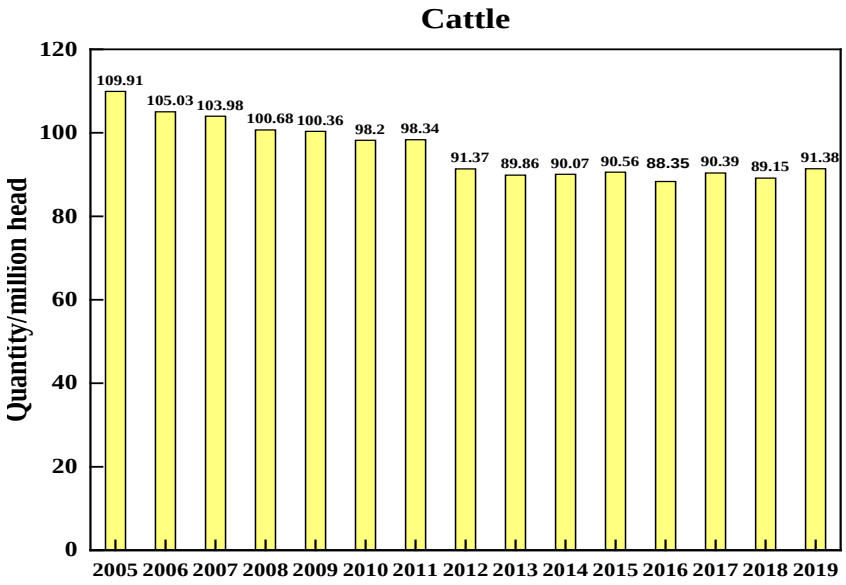
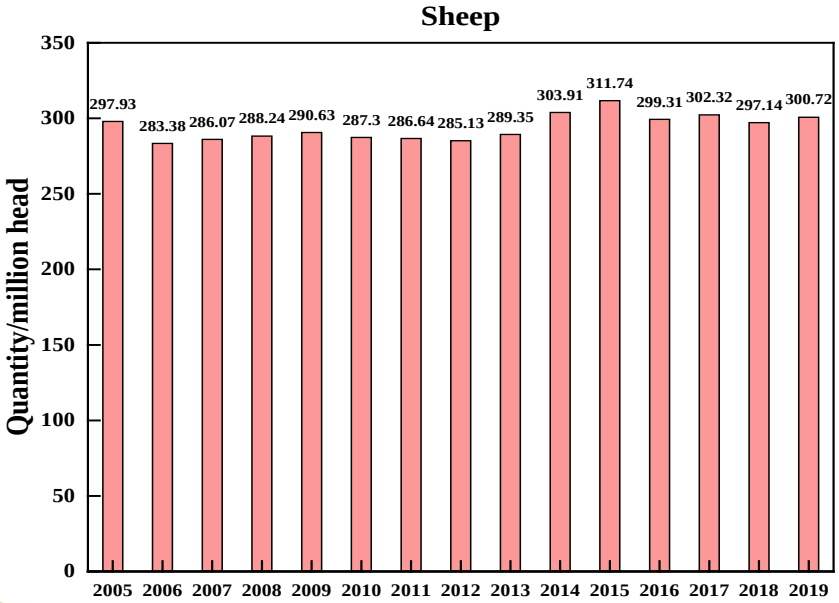
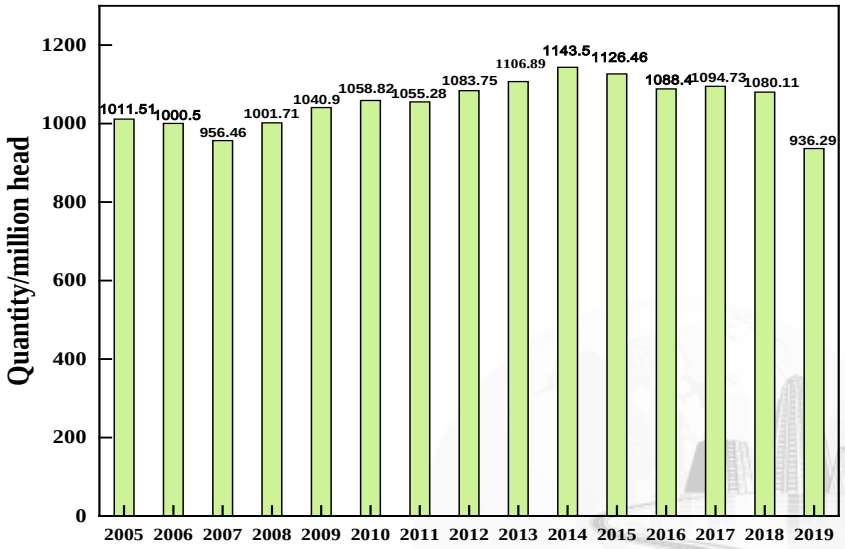








Source: China Statistical Yearbook (based on slaughter)

Livestock Farming Status in China

Livestock Farming Status in China

With rapid development of the livestock industry, the production of manure increased year by year.

In 2019, the amounts of livestock manure is about 3.8 billion ton.

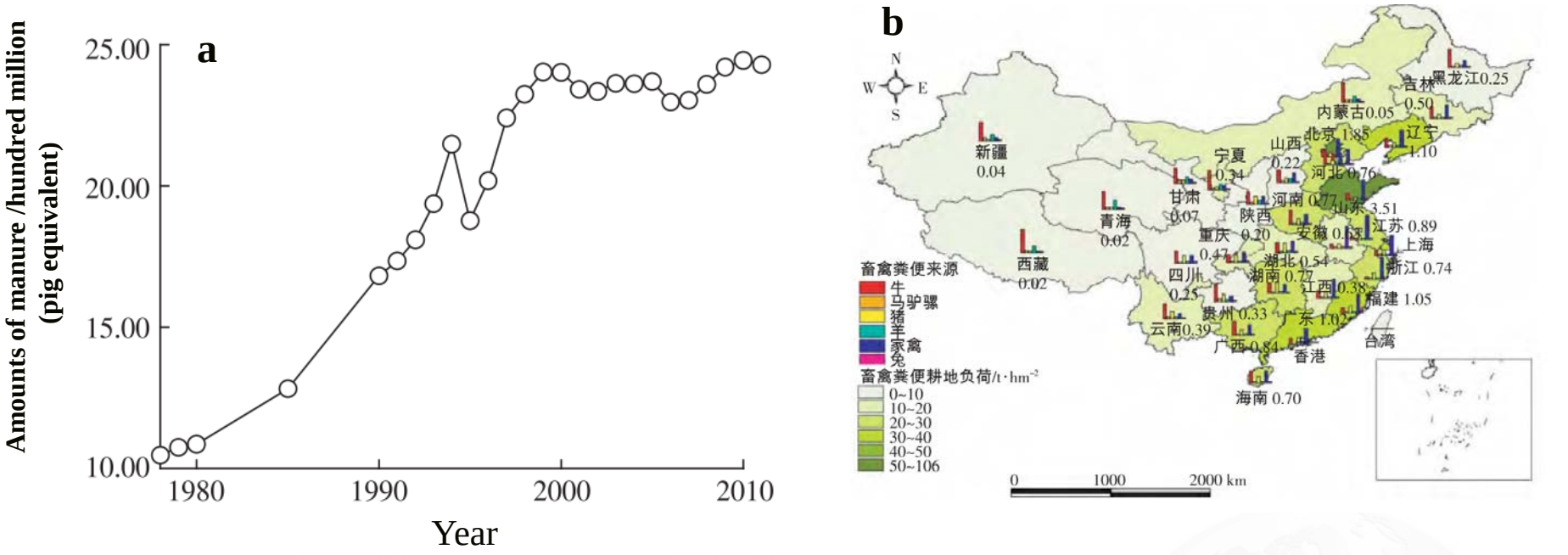


Fig. Amounts (a) of livestock manure in China during 1978 to 2011, and cropland load of manures in 2011 (b)

Source: Zhu et al., 2014.

Nutrient and Pollutant Contents in Livestock Manure

A. The nutrient contents in livestock manure

Category	N(%)	P_2O_5(%)	K_2O(%)	Cu(mg/kg)	Zn(mg/kg)
Pig Manure	0.2~3.50	0.39~3.05	0.94~3.65	12.1~1742	40.5~2287
Cattle Manure	0.32~3.13	0.22~2.74	0.20~3.75	8.9~437.2	31.3~634.7
Chicken Manure	0.60~4.85	0.39~4.75	0.59~4.63	16.8~736.5	38.8~1017
Sheep Manure	0.25~2.08	0.35~1.72	0.89~3.00	13.1~47.9	30.2~161.1

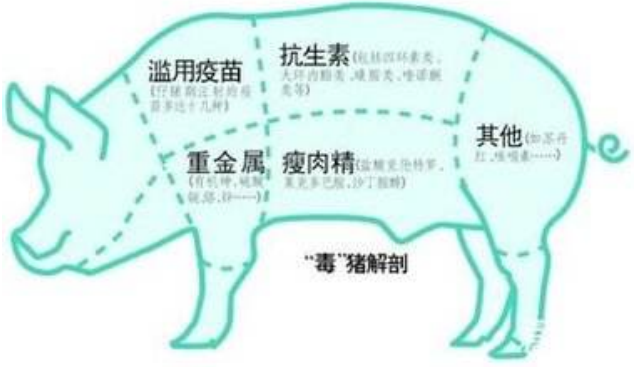
Source (Li et al., 2009)

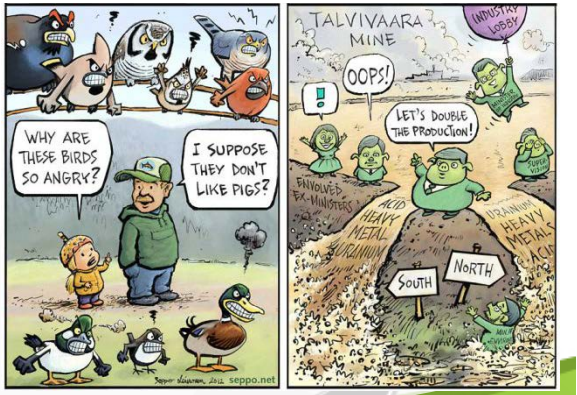
B. Heavy metals contents in livestock manure

Unit: (mg/kg)

Category	Cd	Pb	Cr	As	Hg	Ni
Pig Manure	0.06~2.75	0.71~16.02	0.20~116.20	0.54~88.97	0~0.13	4.03~20.45
Chicken Manure	0.04~1.48	0.92~26.94	0.60~42.75	0.57~66.99	0~0.12	7.44~15.08
Cattle Manure	0.10~1.67	2.11~23.61	0.05~29.04	0.42~5.95	0~0.11	3.73~19.15

Source (Jia et al., 2016)

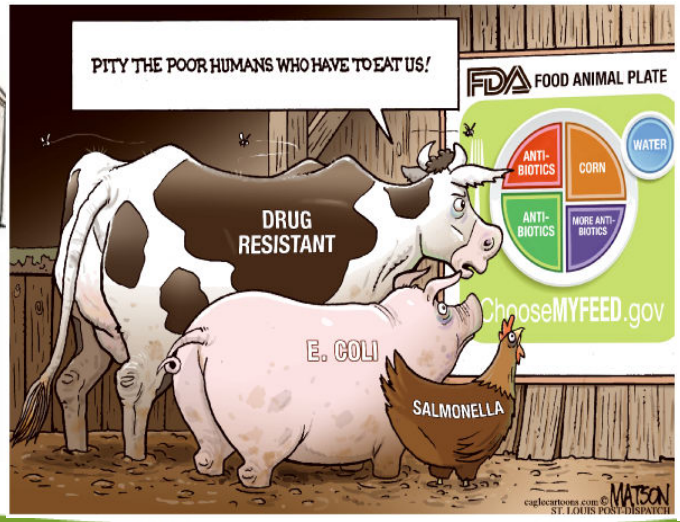


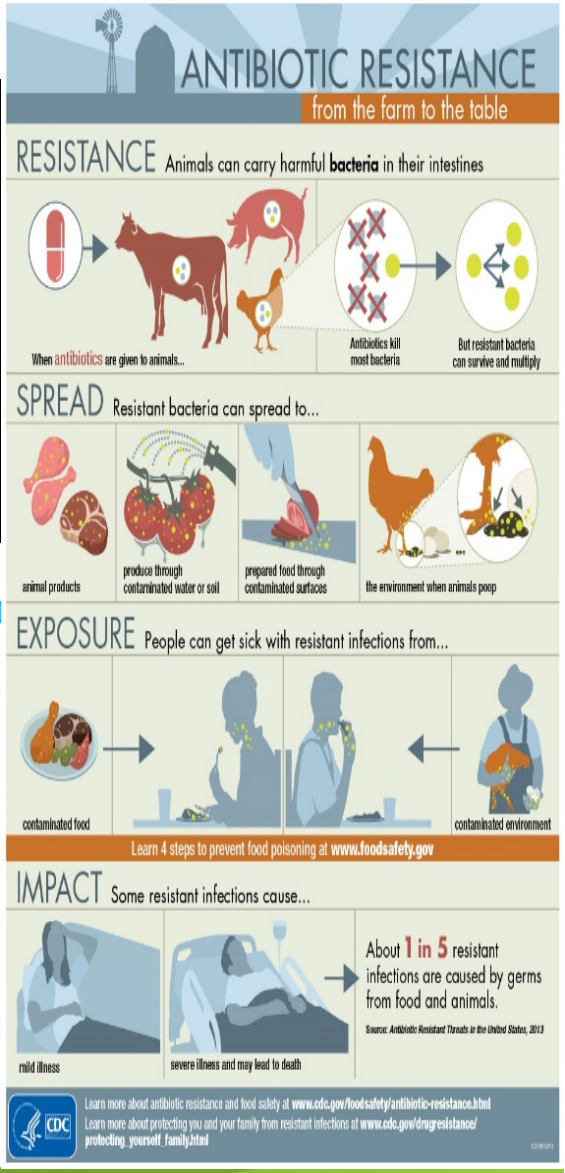


C. Antibiotic contents in pig and chicken manure

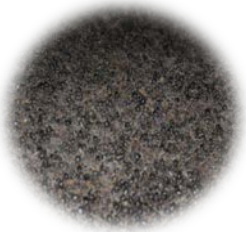
Parameter (mg/kg)	Tetracycline TTC (四环素)	Oxytetracycline OTC（土霉素）	Aureomycin CTC （金霉素）
Pig Manure	0.4~78.57	0~524.4	0~124.8
Chicken manure	0~14.56	0~23.43	0~121.78

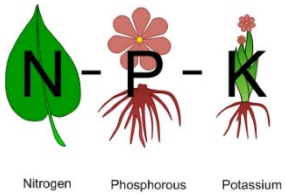
Source (Wang et al., 201





Environmental Pollutions of Livestock Manure





Pathogens

Heavy metals

Antibiotic and resistance gene

Discharge

Air pollution
(**Obnoxious gas**)

Water contamination
(Eutrophication)

Soil pollution
(Heavy metals、resistance gens)

Food safety
(Heavy metals)

Causing bacterial disease

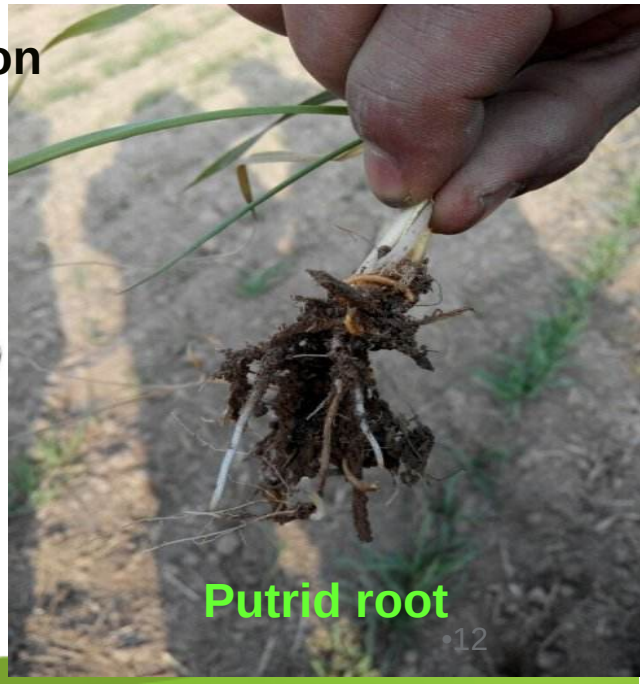

odor


Soil pollution

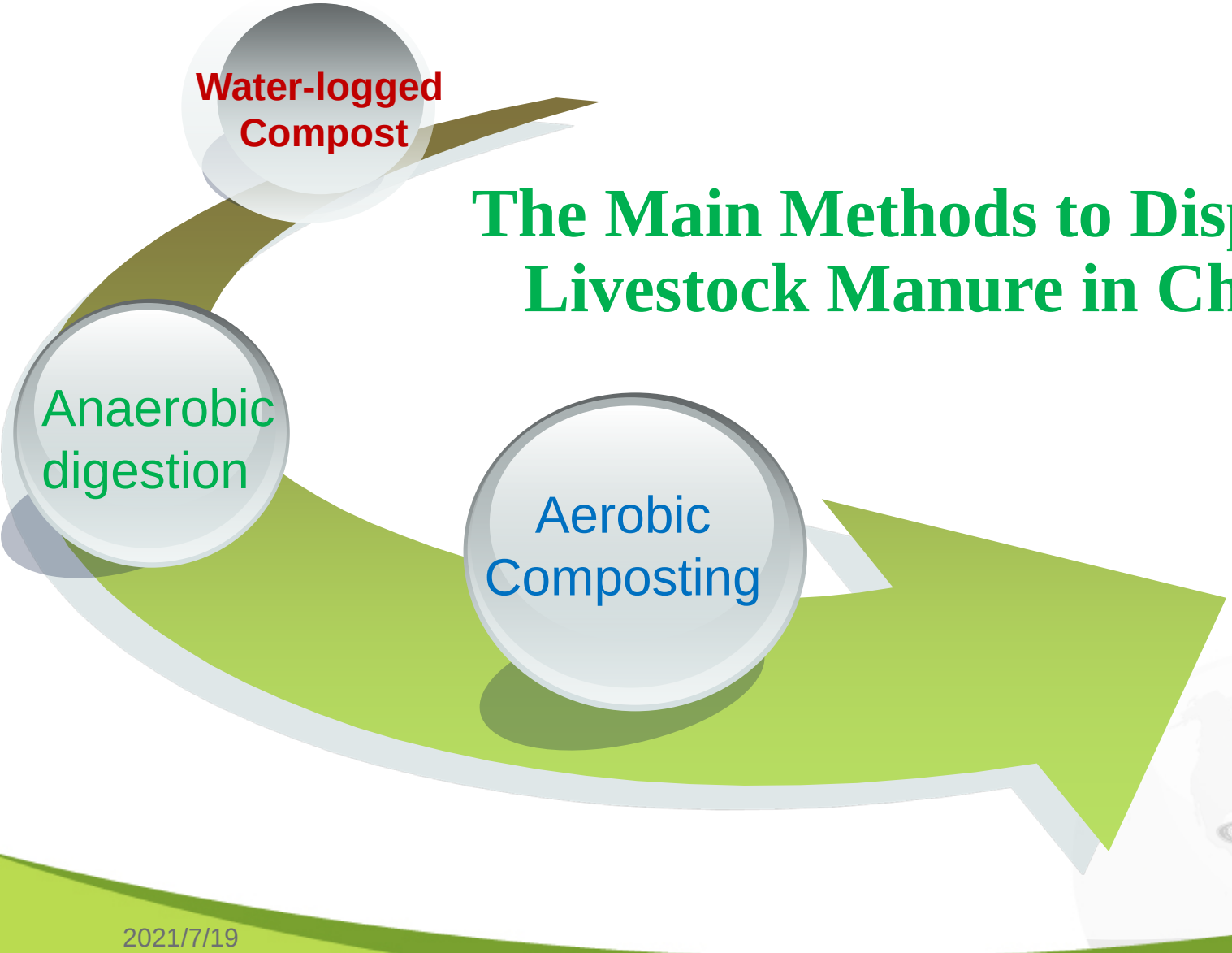

Water pollution


Harm Plant Growth

Food contamination



The Main Methods to Dispose Livestock Manure in China

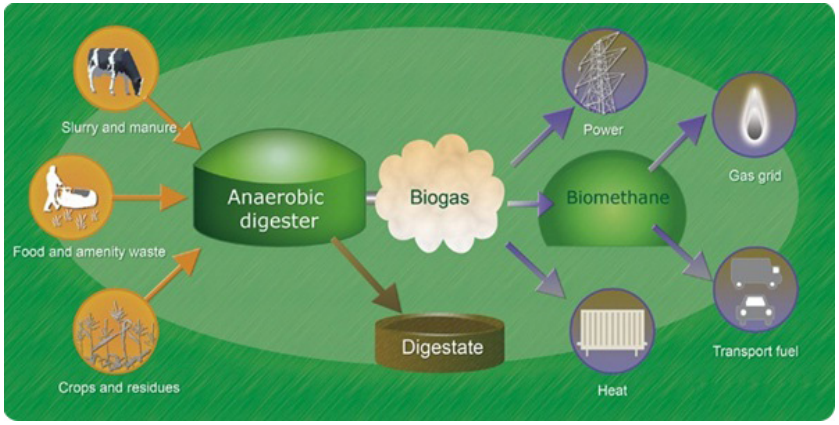


Water-logged Compost of livestock manure has been used in China for thousands of years. In last decades, it is accepted as a traditional economical and effective manure disposal method.

However, the amount of manure used in land exceeds its carrying capacity, which not only affects the normal growth of plants, but also reduces production and causes numerous environmental and health hazard.

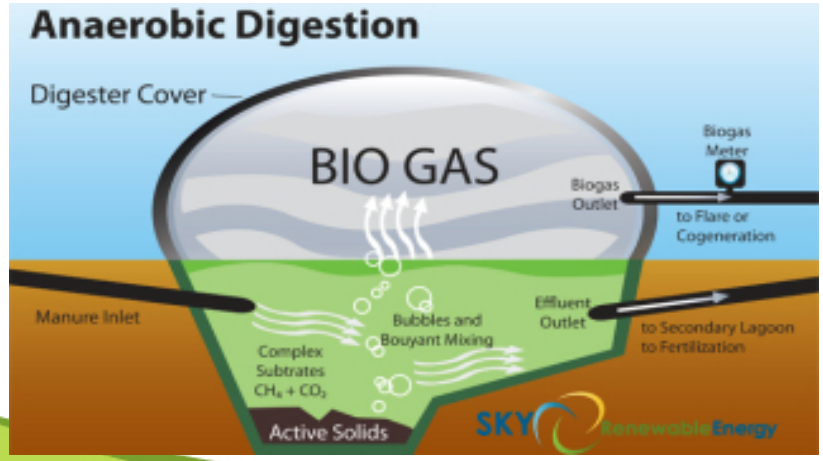
In China, anaerobic digestion and composting are the two major methods to dispose and recycle the livestock manure.

Anaerobic digestion is a biological process that produces a gas principally composed of methane (CH_4) and carbon dioxide (CO_2) otherwise known as biogas.



Advantage

1. Bio-energy (CH_4)
2. Fertilizer (biogas slurry and residue)
3. Harmless and clean



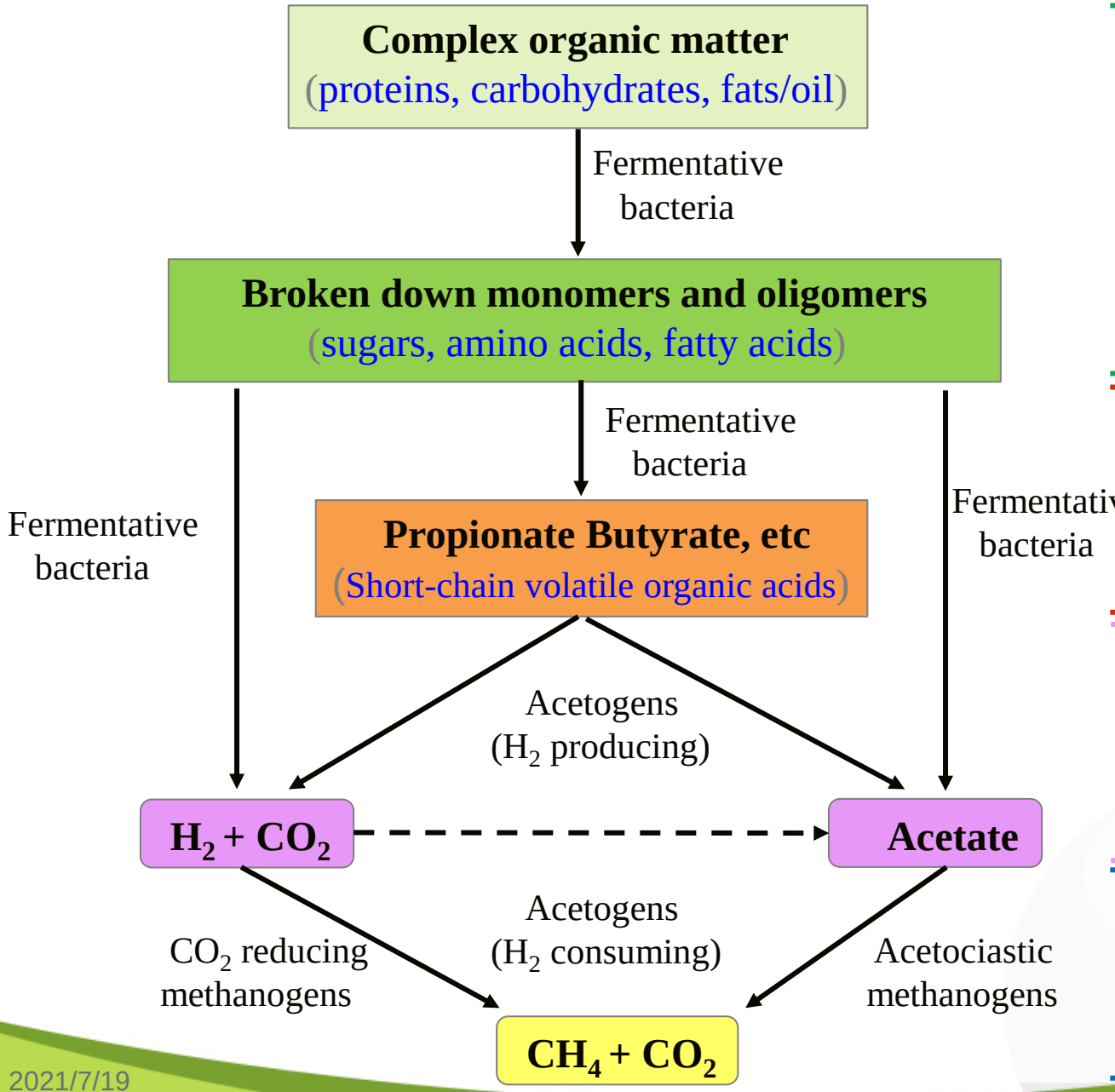
Disadvantage

1. High investment
2. Strict requirements

(O_2, pH, temperature, and season)

3. Low efficiency of CH_4 production

The Process of Anaerobic Digestion



Phase 1 Hydrolysis

Phase 2 Acidogenesis

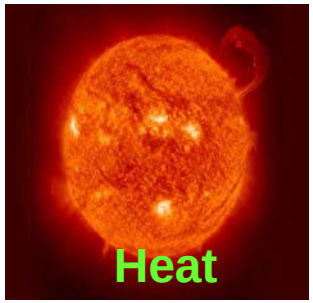
Phase 3 Acetogenesis

Phase 4 Methanogenesis

Livestock manure

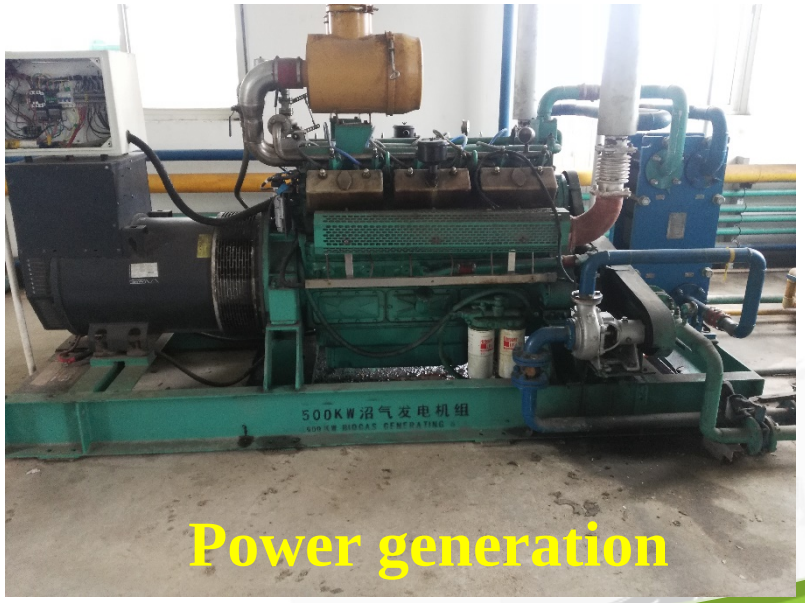
Anaerobic digestion

Biogas



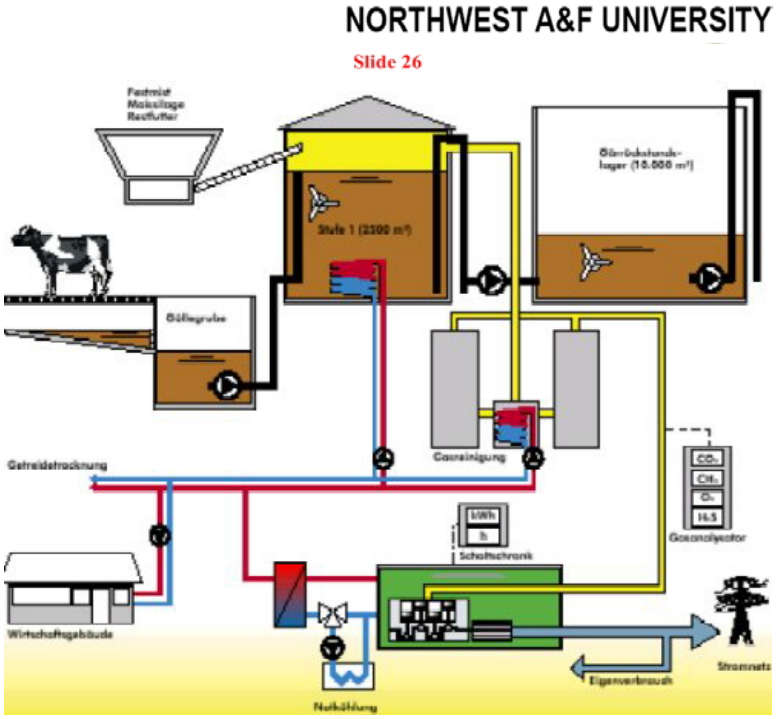
Biogas utilization

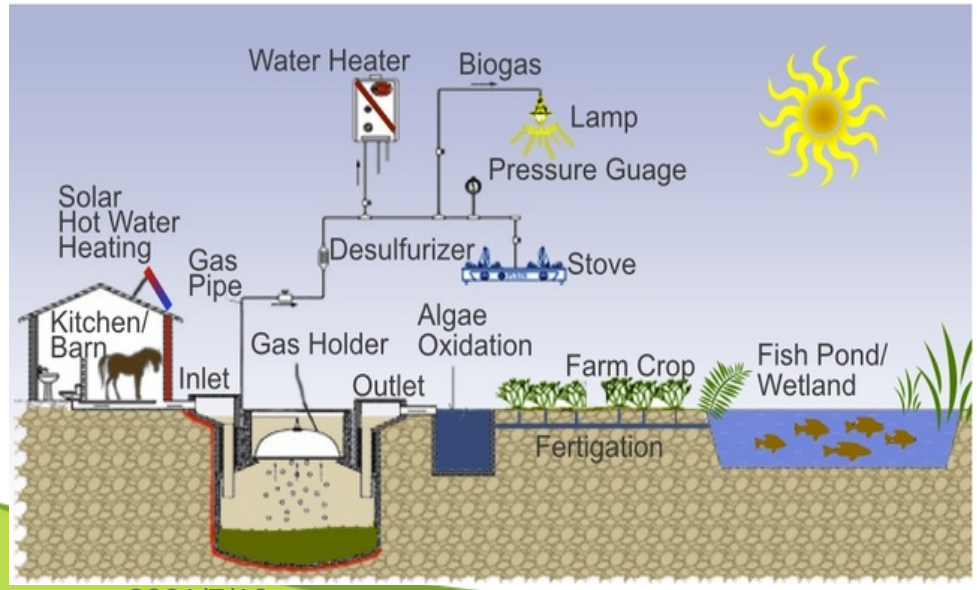
Anaerobic residue utilization

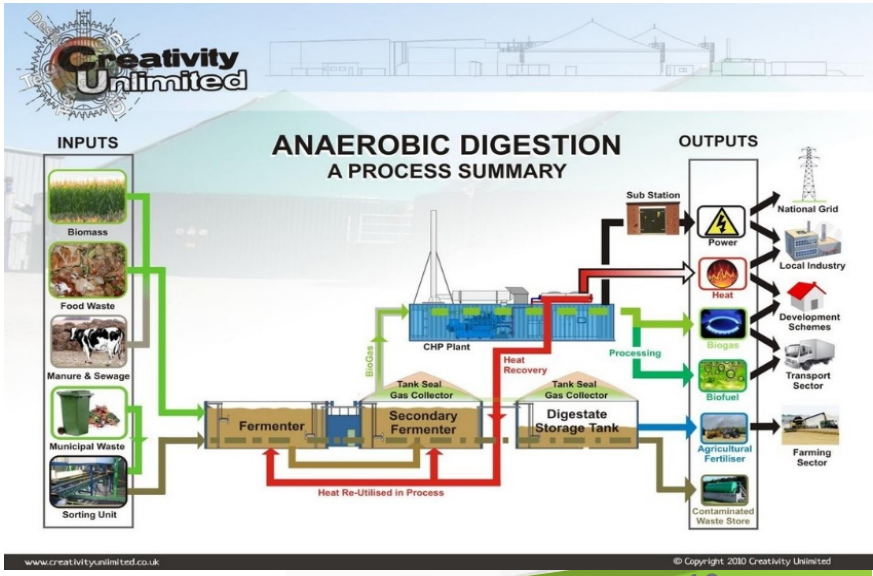


Power generation


沼气发电工艺流程图
贮气柜
沼气
热水罐
入国家电网
电能
发电机组
热水
沼气锅炉
净化水箱
运粪车
猪粪
猪粪猪尿混合物
集水池
匀浆池
厌氧发酵罐
沼液暂存池
沼液中转池
猪尿


NORTHWEST A&F UNIVERSITY
Slide 26
Gärrückstands-lager (12.000 m³)
Stufe 1 (2100 m³)
Güllegrube
Gasreinigung
Getreidetrocknung
Schaltschrank
Gasanalysator
Wirtschaftsgebäude
Eigenverbrauch
Stromnetz
Notkühlung


Water Heater
Biogas
Lamp
Pressure Guage
Solar Hot Water Heating
Gas Pipe
Desulfurizer
Stove
Kitchen/ Barn
Inlet
Gas Holder
Algae Oxidation
Outlet
Farm Crop
Fish Pond/ Wetland
Fertigation


Creativity Unlimited
INPUTS
ANAEROBIC DIGESTION
A PROCESS SUMMARY
OUTPUTS
Biomass
Food Waste
Manure & Sewage
Municipal Waste
Sorting Unit
Fermenter
Secondary Fermenter
Digestate Storage Tank
CHP Plant
Tank Seal Gas Collector
Heat Recovery
Biogas
Processing
Heat Re-Utilised in Process
Sub Station
Power
Heat
Biofuel
Agricultural Fertiliser
Contaminated Waste Store
National Grid
Local Industry
Development Schemes
Transport Sector
Farming Sector
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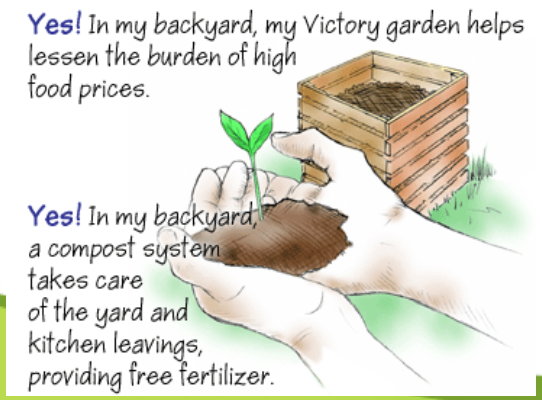
Composting of Livestock manure in China

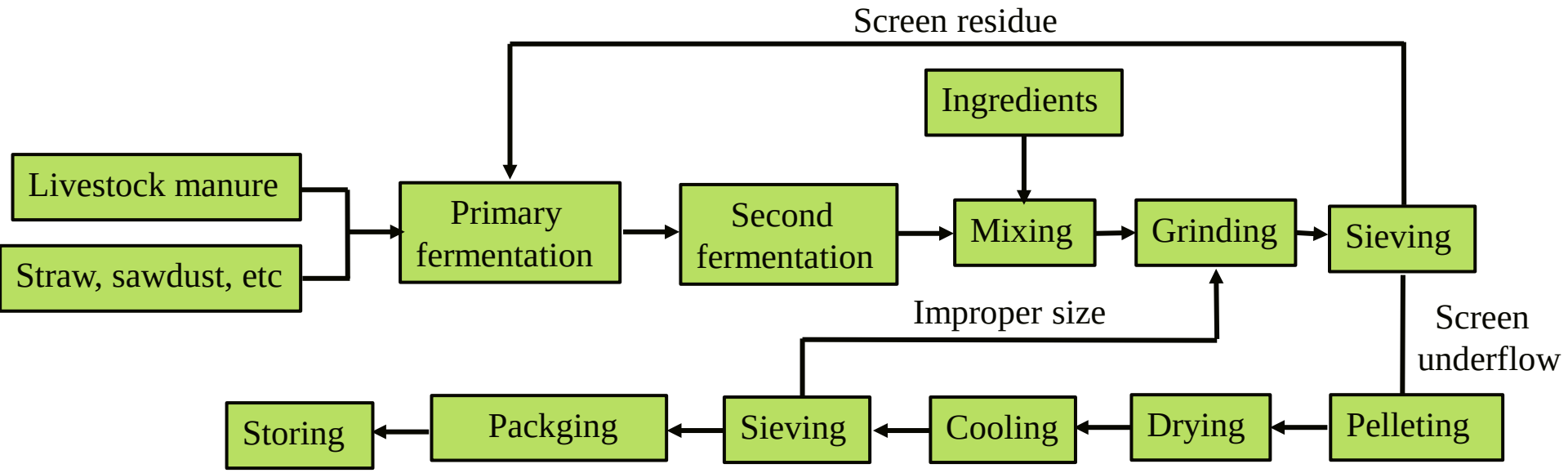
- Composting has been widely accepted as one of the preferred cost-effective methods that converts the organic waste to soil fertilizer or amendment. (**Topic**)

Livestock manure → Composting → compost

With the rapid development of organic agriculture, the market demand of organic fertilizer increased significantly.



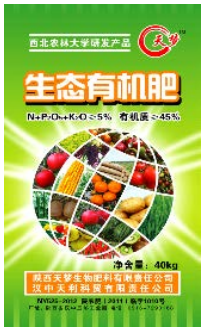
Industrial Composting Process




合力叉车


tang
YIGUO
益果肥业
生态有机肥料


有机肥料


生态有机肥
N+P2O5+K2O≥5%
有机质≥45%
净含量：40kg


高活性有机肥
N+P2O5+K2O≥5%
有机质≥45%
净含量：40kg


净重：40kg
陕西省兴平市新起源牧业有限公司


益果有机肥


生物有机肥


国家测土配方项目指定产品
天梦 中国·天禧
BB 肥
N-P2O5-K2O 总养分≥57%
19-19-19
陕西天梦生物肥料有限责任公司


BB肥料
净含量：40kg
陕西天梦生物肥料有限责任公司


水渭益果有机肥
苹果示范园
测土配方 精准施肥


玉米专用肥


天梦BB肥
大田型
陕西天梦生物肥料有限责任公司


天利有机肥


净含量：40kg
陕西省兴平市新起源牧业有限公司

The Standard of Organic Fertilizer in China

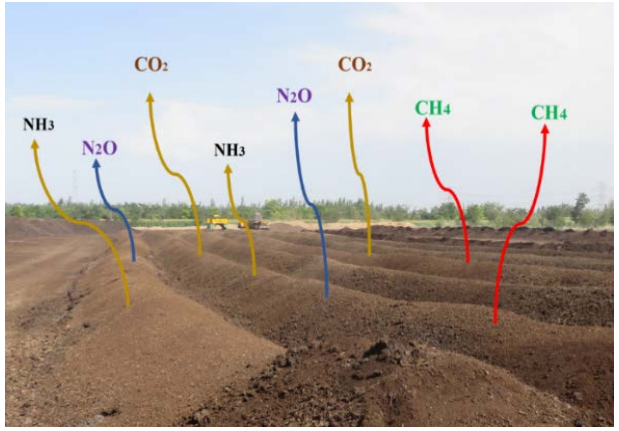
Item	Index
Organic matter (based on dry basis) %	≥30%
Total nutrient ($N+P_2O_5+K_2O$)	≥4%
Moisture content (based on wet basis)%	≤30%
pH	5.5~8.5
GI	≥70%
As (based on dry basis)	≤15mg/kg
Hg (based on dry basis)	≤2mg/kg
Pb (based on dry basis)	≤50mg/kg
Cd (based on dry basis)	≤3mg/kg
Cr (based on dry basis)	≤150mg/kg

Source: NY525-2021

Challenges composting industry in China

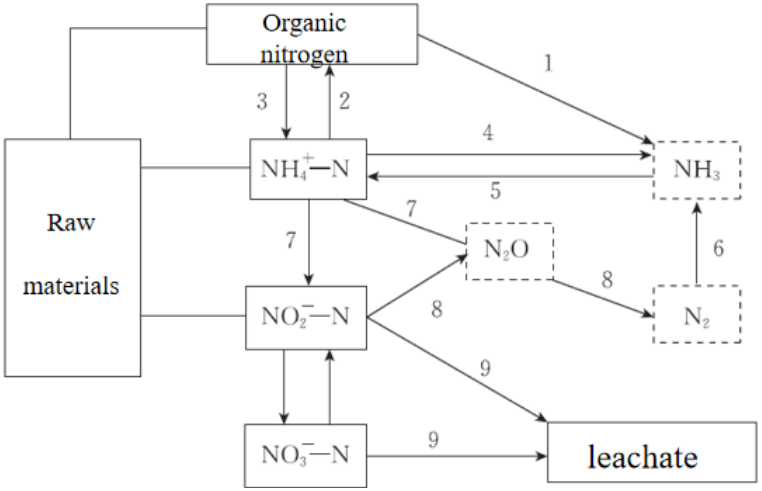
- **Greenhouse gases emission**

  CH_4、N_2O



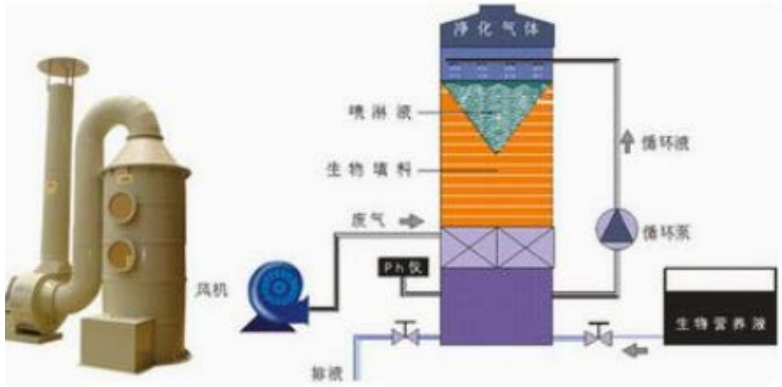
- **Loss of nitrogen**

  NH_3



The transformation of nitrogen during composting.

1. ammoniation 2. Solid hold 3. Mineralization 4. Volatilization
5. Dissolution 6. Nitrogen fixation 7. Nitrification 8. Denitrification
9. Eluviation

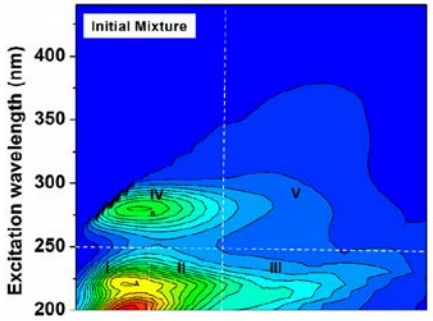


High bioavailability of heavy metals

Cu、Zn

Low degree of humification

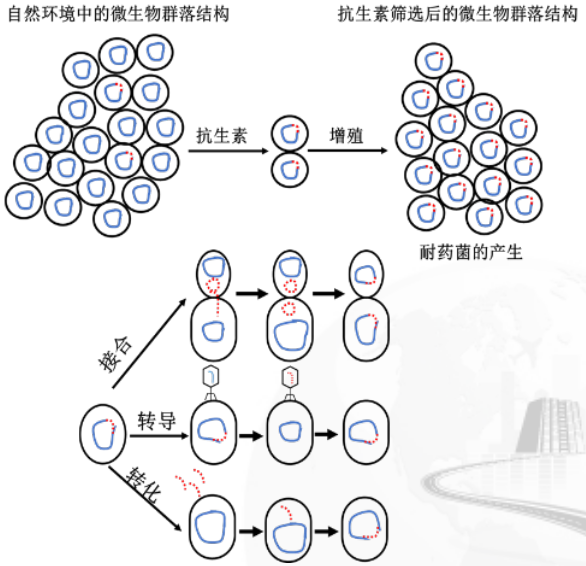
Humus 、Humic acid



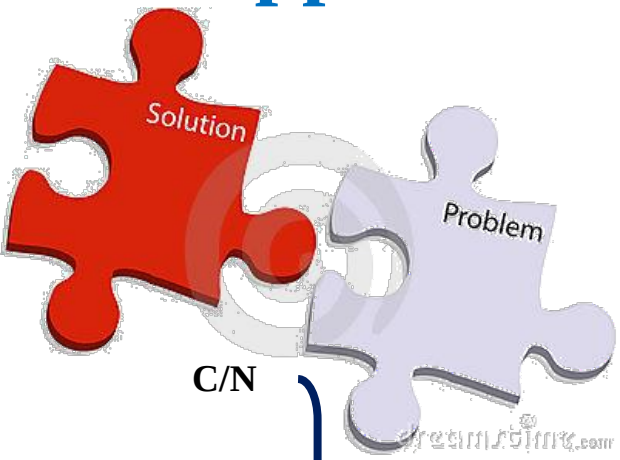
Resistance gene transmission

Antibiotics resistance gene

Heavy metal resistance gene



Opportunities for the composting industry



C/N

Moisture

Porosity

Aeration rate

Improved method

Adjust | **Additives** | **Improving method**

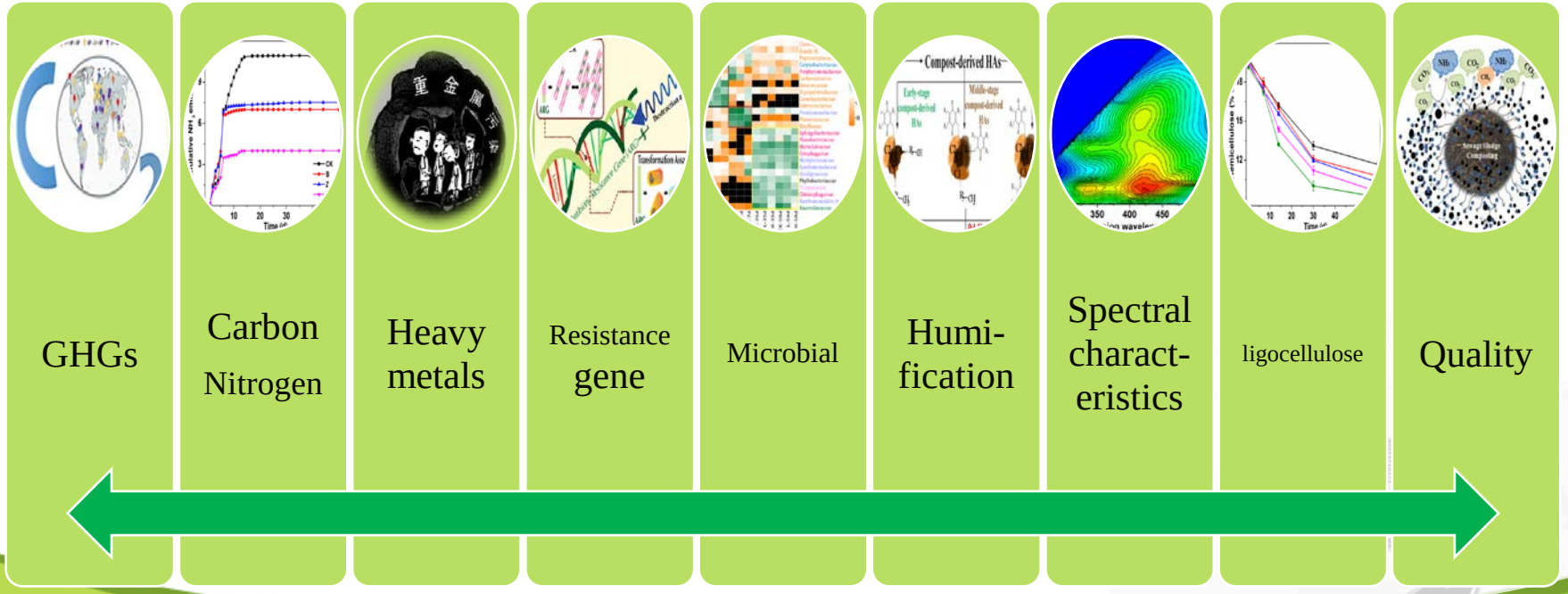
Microbial | **Mineral** | **Chemical**

Fly ash Lime Zeolite Biochar Bentonite Clay Struvite

Attempts of our group in clean composting

Our group is committed to improving the technical problems in the composting process through external additive auxiliary technology, and researching and developing new composting additive improvement technologies from the aspects of additive screening, application dosage and combination ratio.

Including：



Related results published by our group

Manure

Bulking agents

or

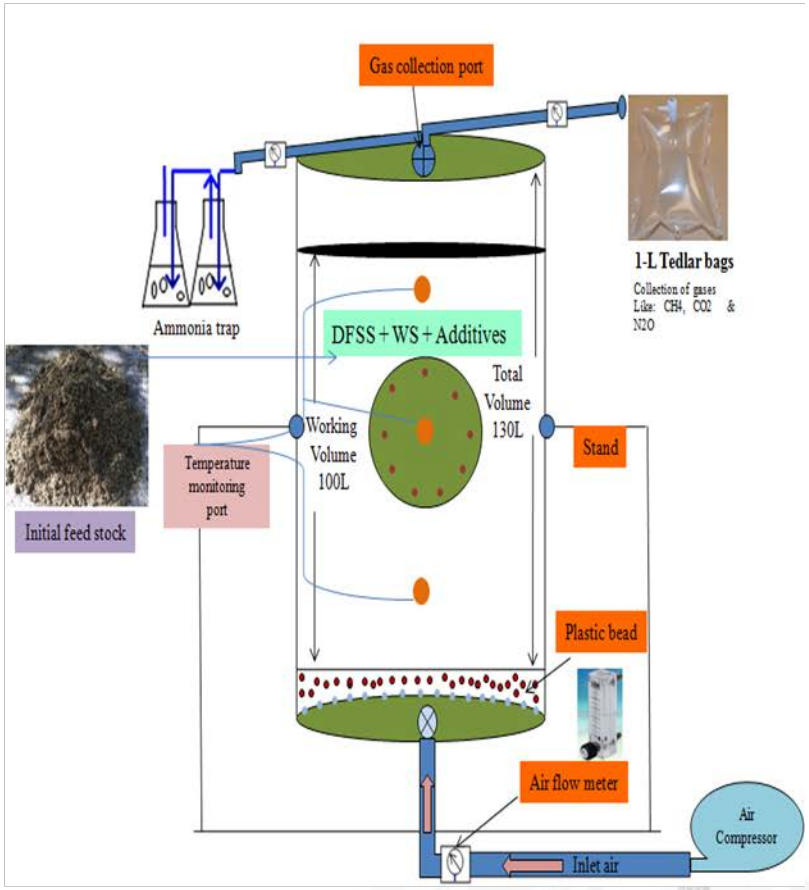
Additives

Mixing

Material filled

Composting

Matured compost


Gas collection port
1-L Tedlar bags
Collection of gases
Like: CH4, CO2 & N2O
Ammonia trap
DFSS + WS + Additives
Total Volume 130L
Working Volume 100L
Stand
Temperature monitoring port
Initial feed stock
Plastic bead
Air flow meter
Air Compressor
Inlet air

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

1. Effect of biochar, zeolite and their mixtures on organic mater transformation and nitrogen conservation of pig manure composting (Wang et al., 2017; Bioresource Technology)

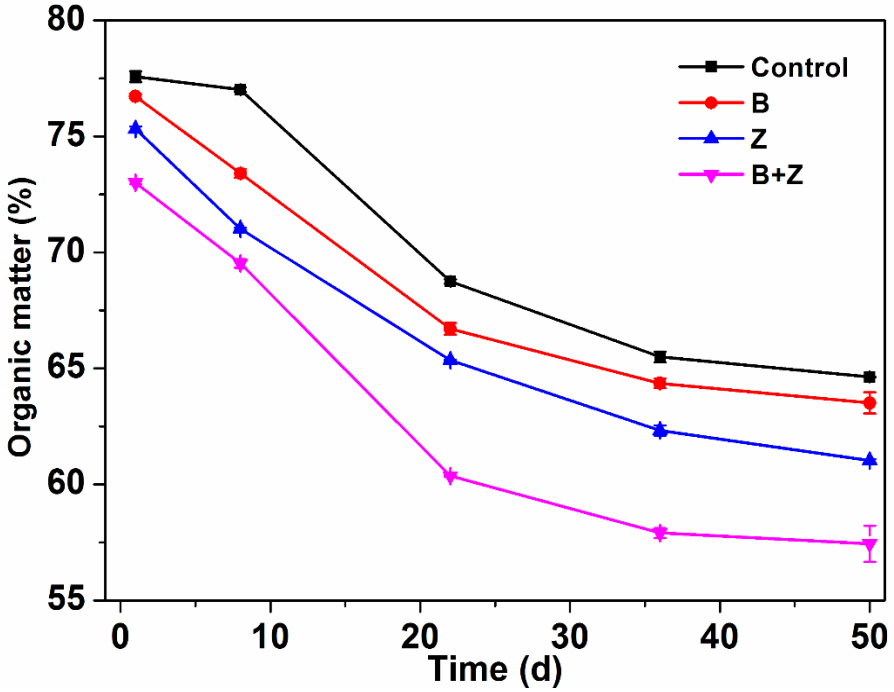
Pig manure

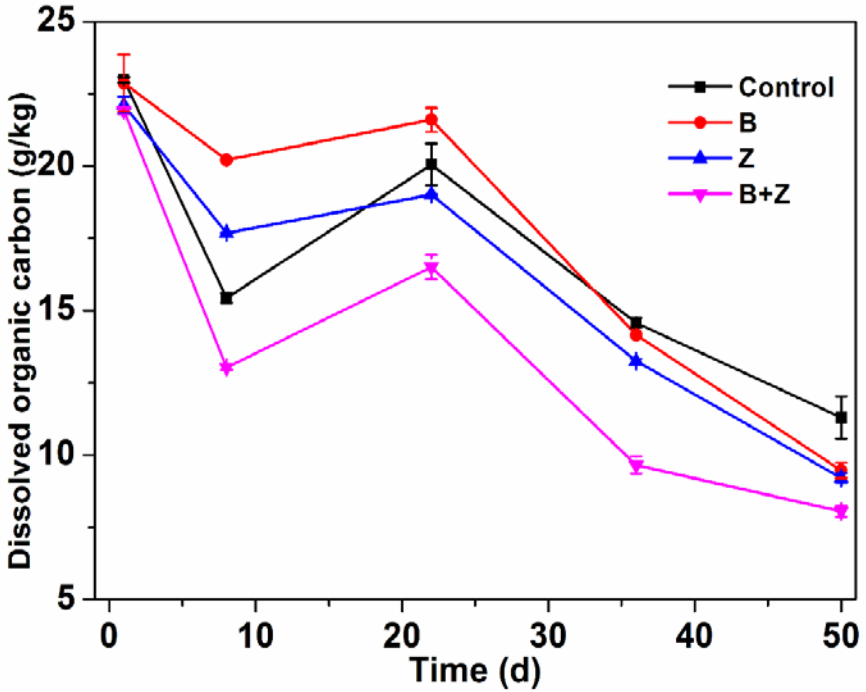
Wheat straw

Biochar (B)

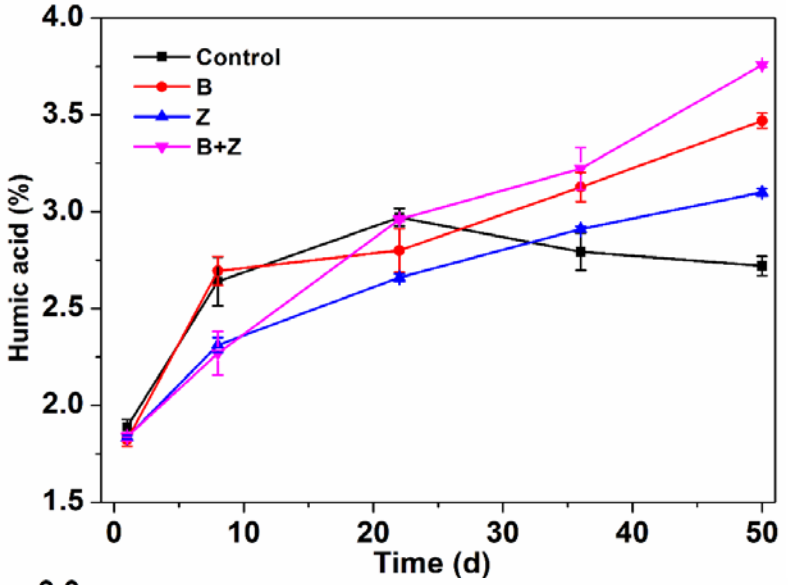
Zeolite (Z)

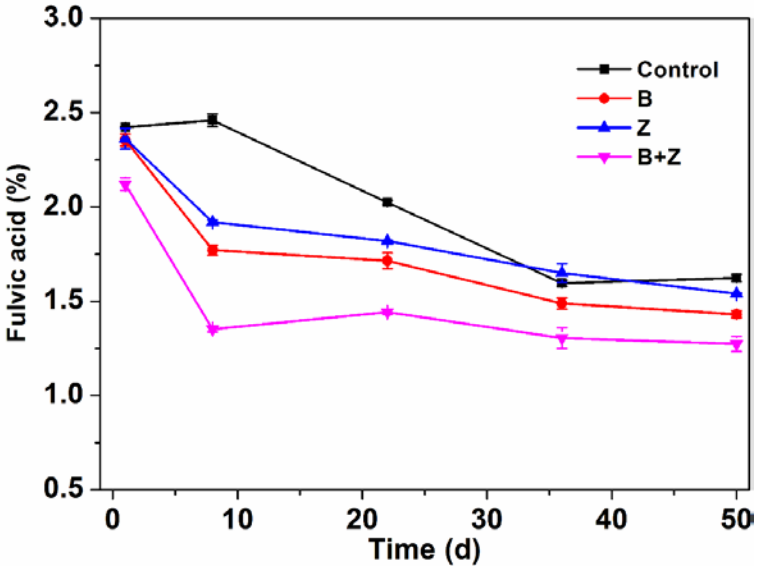
Combined(B+Z)

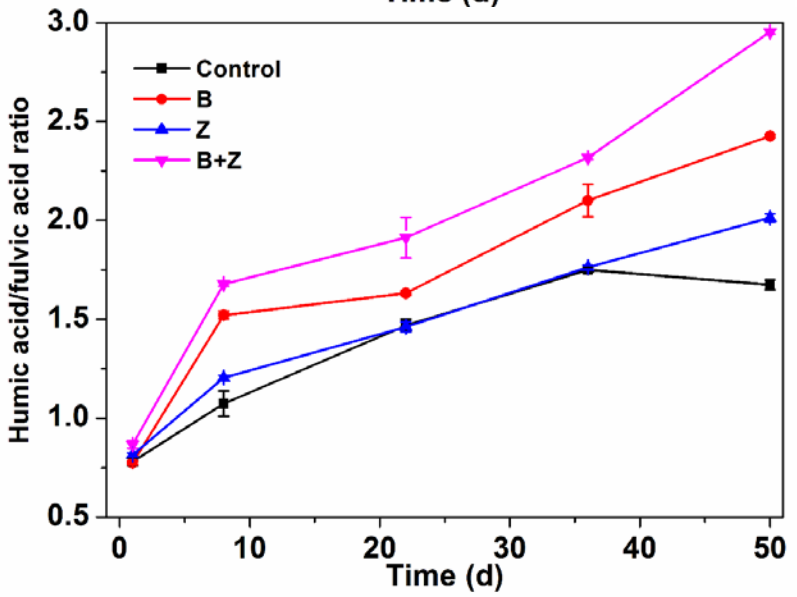




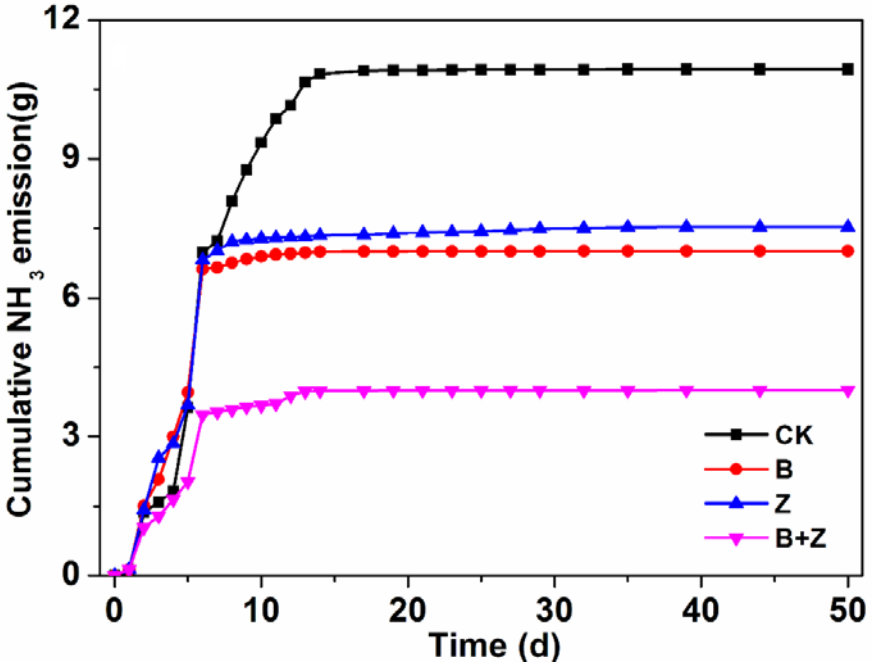
Biochar, zeolite and their combination can promote the degradation and stabilization of organic matter, and the combined treatment efficiency is the best**(OM 15.57% , DOC 60.04%).**







Biochar, zeolite and their combination can promote the humification process of compost, and the combination treatment had a significant effect on the formation of humic acid.



31.13%~63.40%

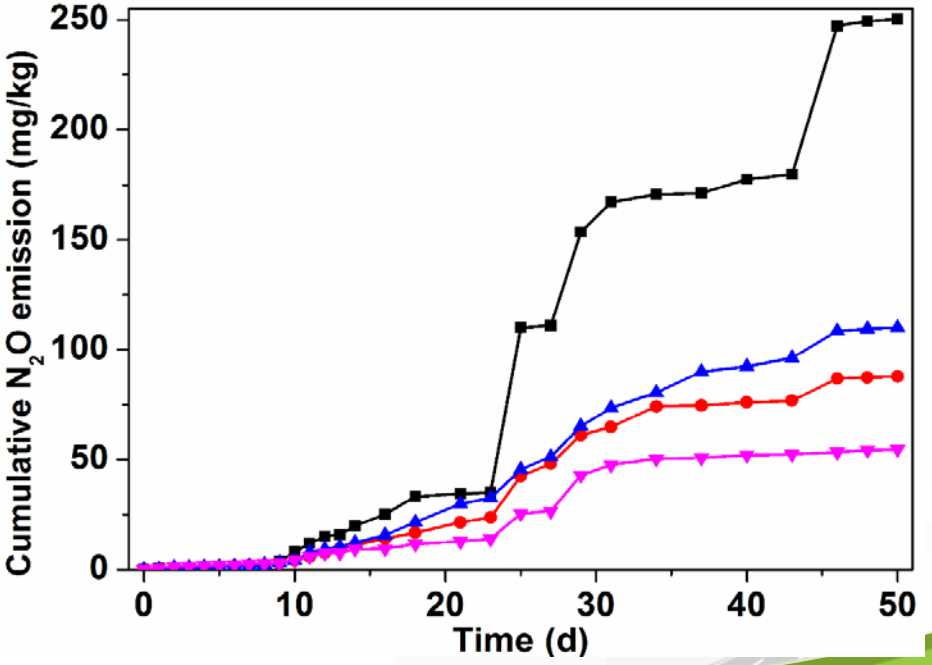
B+Z>B>Z

Compared to the control, the cumulative NH_3 emission in B, Z and B + Z applied was reduced by 35.88%, 31.13% and 63.40%.

56.05%~78.13%

B+Z>B>Z

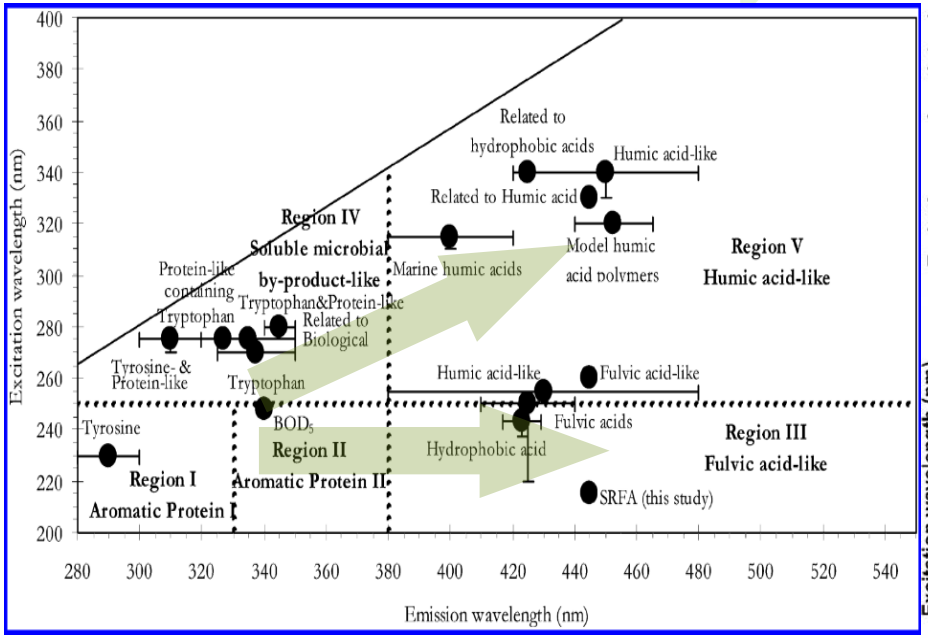
Compared to the control, the cumulative N_2O emission was decreased by 64.91, 56.05 and 78.13% in B, Z and B + Z amended treatments.

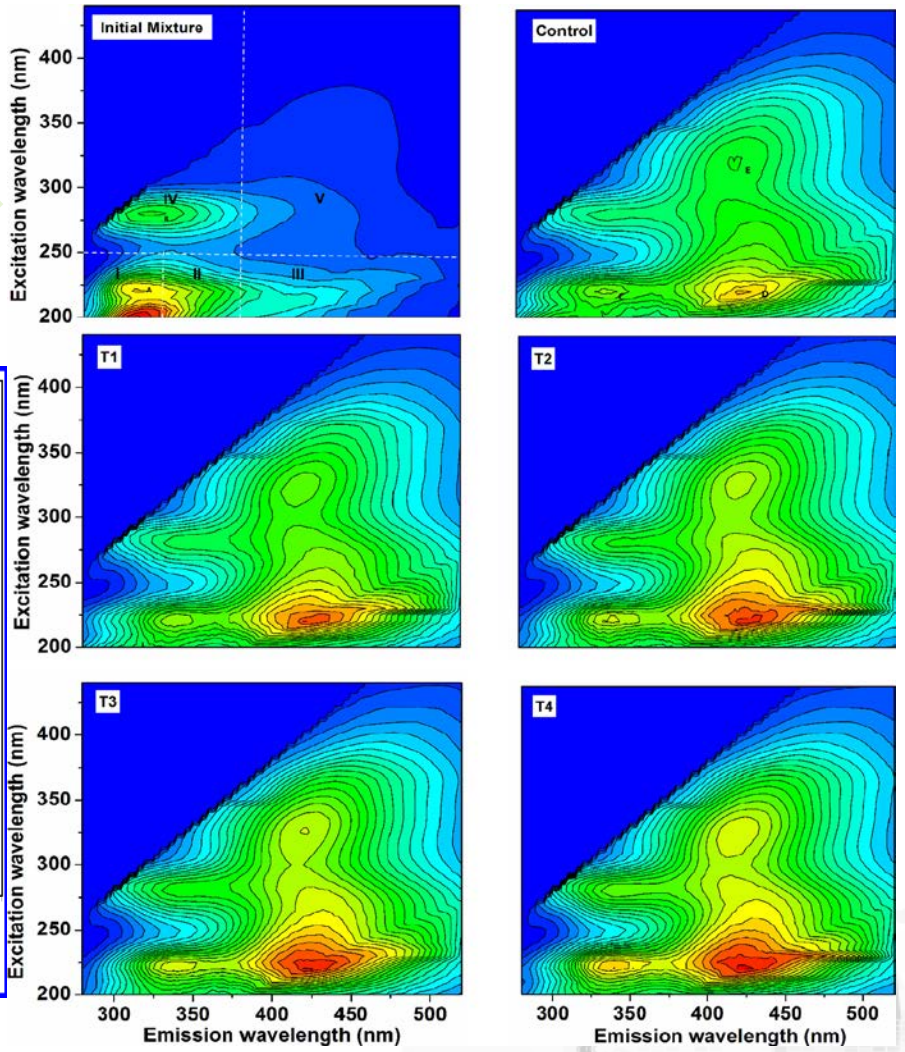


2. Utilization of medical stone to improve the composition and quality of dissolved organic matter and heavy metal passivation in composted pig manure (Wang et al., 2018 Journal of Cleaner Production; Wang et al., 2016 BITE)

Experiment

- Control 0%
- T1 2.5% medical stone
- T2 5% medical stone
- T3 7.5% medical stone
- T4 10% medical stone





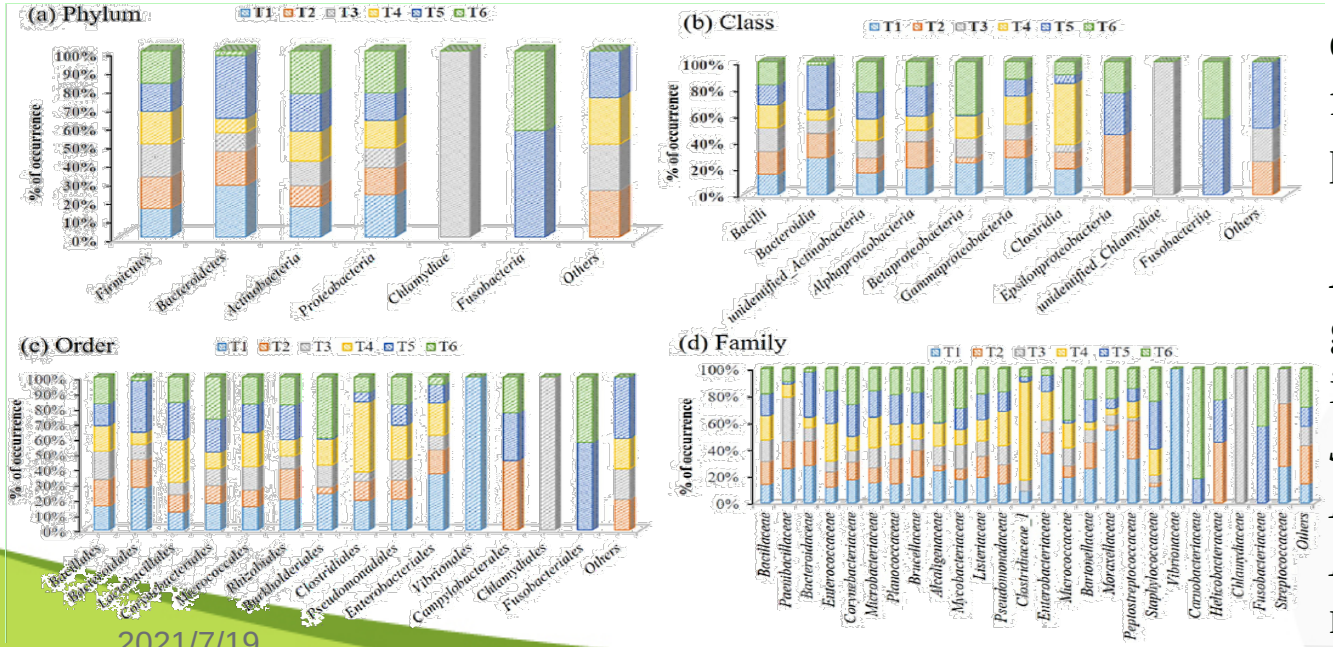
Medical stone amendment could decrease the proportion of aromatic protein-like substrates and promote the stability and humification of compost, especially for 10% medical stone amendment.

3. An assessment of the persistence of pathogenic bacteria removal in chicken manure compost employing clay as additive via meta-genomic analysis

(Awasthi et al., 2019; Journal of Hazardous Materials)

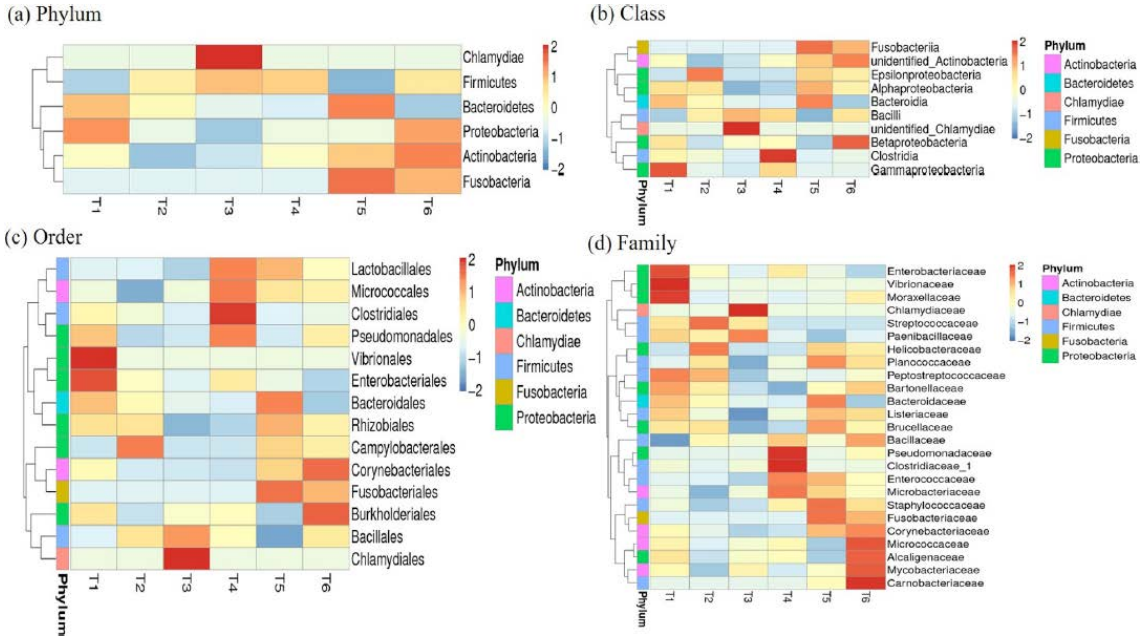
Experiment

- T1 0%
- T2 2% clay
- T3 4% clay
- T4 6% clay
- T5 8% clay
- T6 10% clay

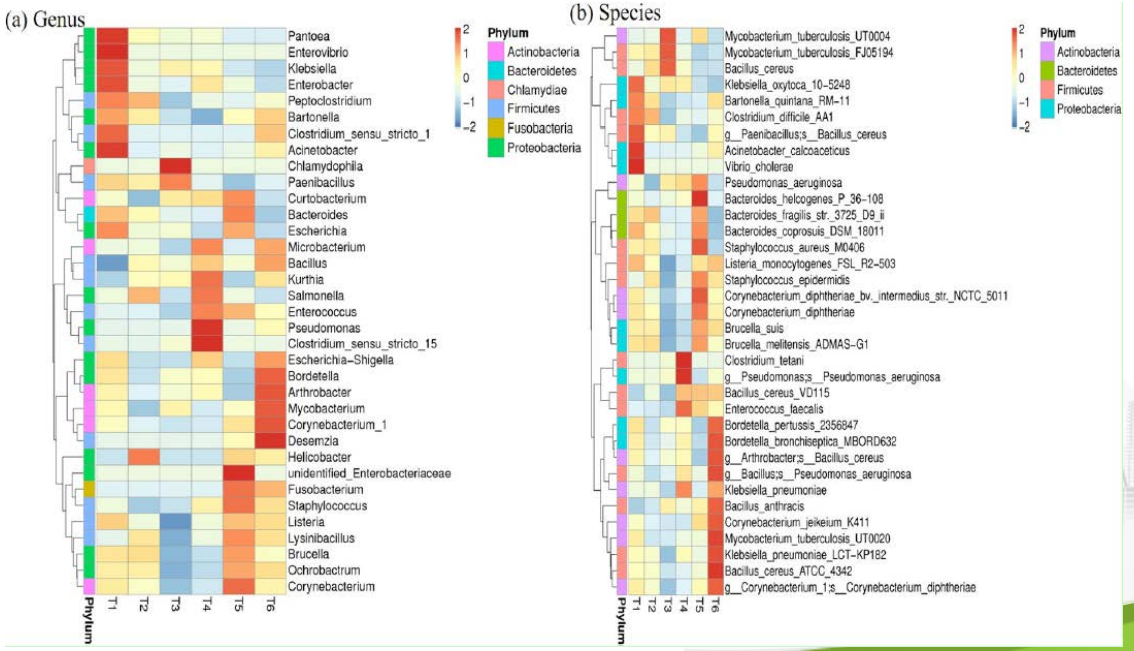


Proteobacteria, ***Firmicutes*** ***Actibobacteria*** and ***Bacteroidetes*** were dominant, as they recorded for 99.05% of the total pathogenic bacteria (PB).

Proteobacteria phyla is group of several PB genera including *Escherichia*, *Salmonella*, *Vibrio*, *Helicobacter, Yersinia and Legionellales*, which were normally -acquired many infectious diseases.



The results showed that 85–87% of pathogenic bacteria relative abundances were significantly reduced in lower dosages of applied clay (T2 and T3).



The Promotion Policy of Organic Fertilizer in China

◆ **Action Plan of Zero Growth in Use of Chemical Fertilizer by 2020,**

March, 2015

◆ **Action Plan on Prevention and Control of Soil Pollution**, May, 2016

◆ **Action Plan on the Fruit, Vegetable and Tea Organic Fertilizer to Replace Chemical Fertilizer**, February, 2017

Common point: 1. Increasing the organic fertilizer utilization

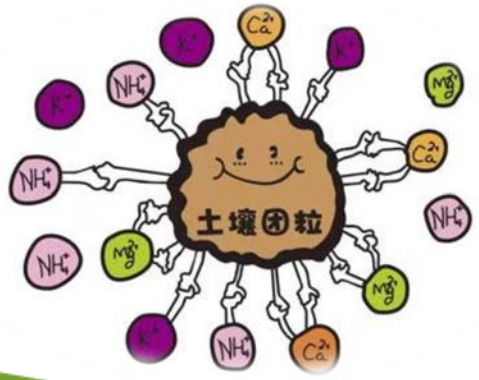
2. Reducing the input of chemical fertilizer

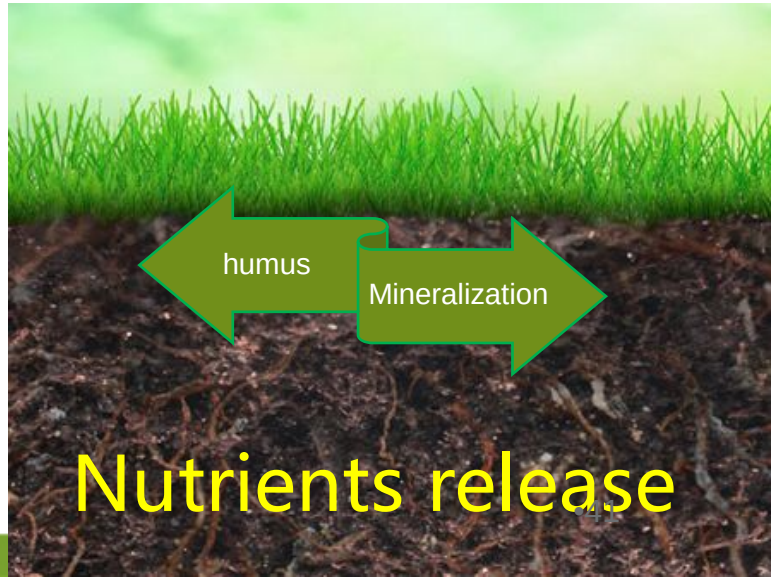
化肥使用零增长：

发展有机

Benefits of Compost Application

- Increase the organic matter content of soil
- Restores soil fertility
- Improve plant growth and health
- Enhance the water-hold capacity of soil
- Promote the activities of microorganism



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苹果示范园
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2


Organic fertilizer application


Chemical fertilizer application

Conclusions

Livestock manure treatments	Disadvantages	Further strategy
Water-logged Composting	heavy metals, odor, pathogen, immature organic matter	Abolish
Anaerobic digestion	High investment, low efficacy of CH_4 production, strict condition	Improve the CH_4 production; Reduce the investment
Composting	NH_3, N_2O, CH_4, heavy metals, low humification	Adjust parameter; Improve the quality

Conclusion

Manure management should properly consider the local conditions

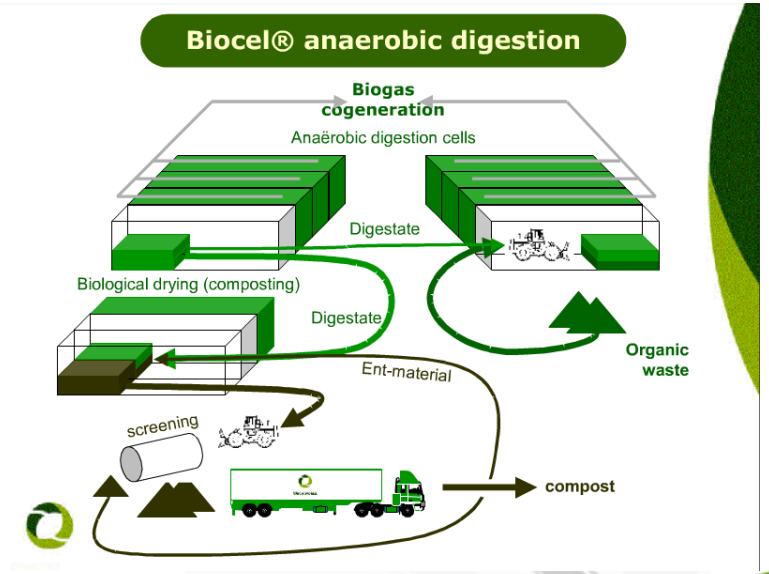
Technology: Composting
Anaerobic Digestion

Government encourage compost utilization and strengthen supervision

- **Policies**
- **Financial**
- **Facilities**

Development the combining technology

- **Anaerobic digestion**
- **Composting**



Questions?

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Thank You…