沼氣工程發展與沼液沼渣利用與處理

BIOGAS PLANTS DEVELOPMENT AND THE UTILIZATION / POST-TREATMENT OF THE DIGESTATES

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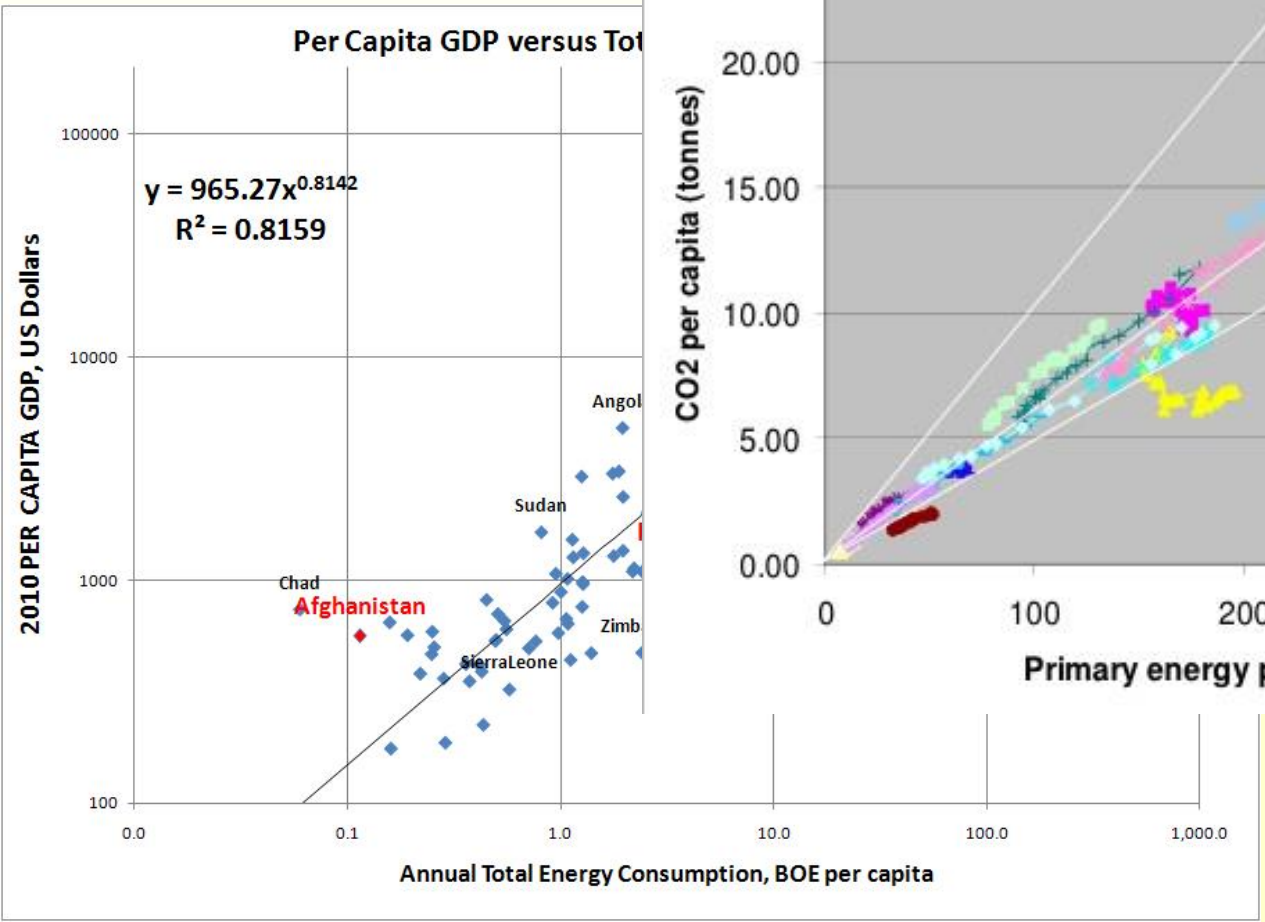
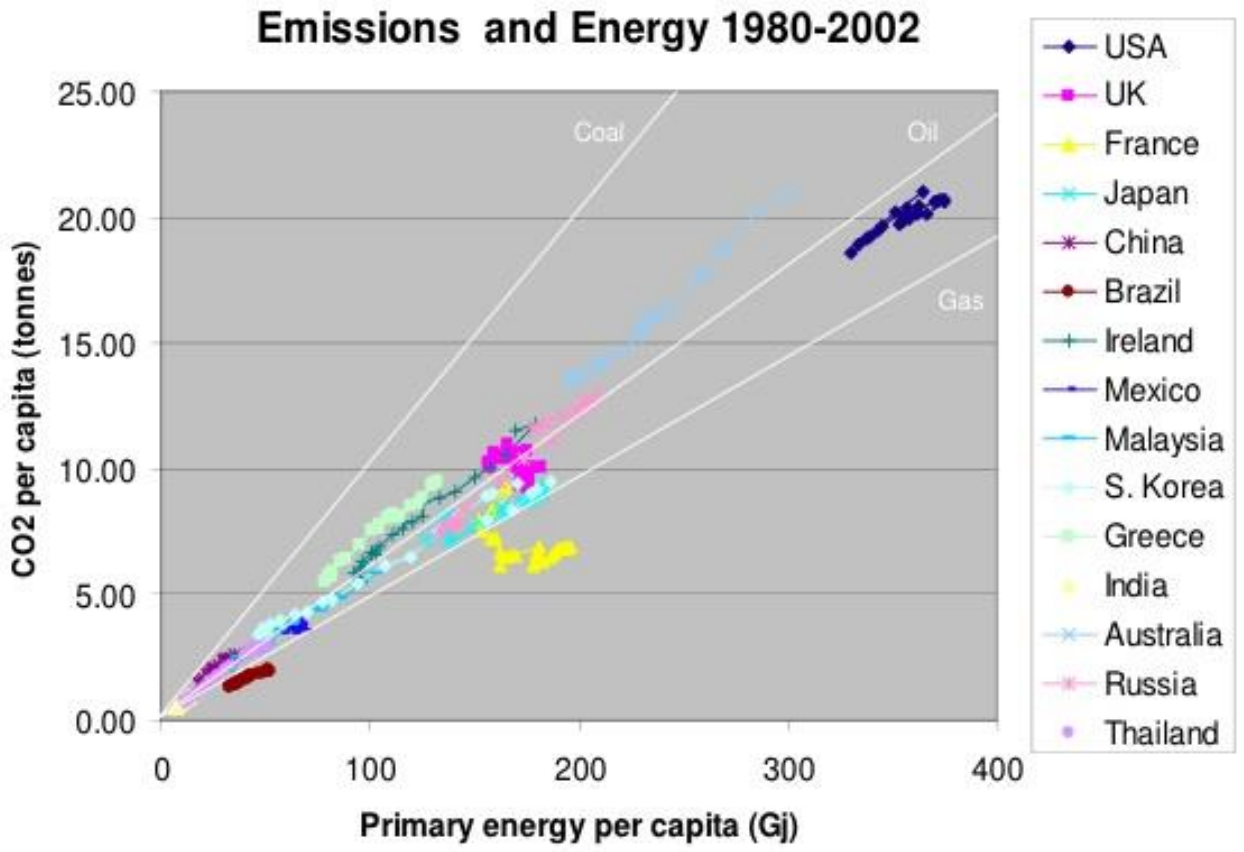
7. 東方智慧，和則雙贏

能源與環保是社會發展的基礎
ENERGY/ENVIR. FOR DEVELOPMENT





沼氣工程：環保優先？

BIOGAS PLANTS: ENVPROTECT 1？

	類別Waste	數量,億噸/年, Amount (×10^8 tons/a)	
1	畜禽糞便 Livestock manure	31.6	濕基, wet
2	農作物秸稈 Crops residue	6.89	濕基, wet

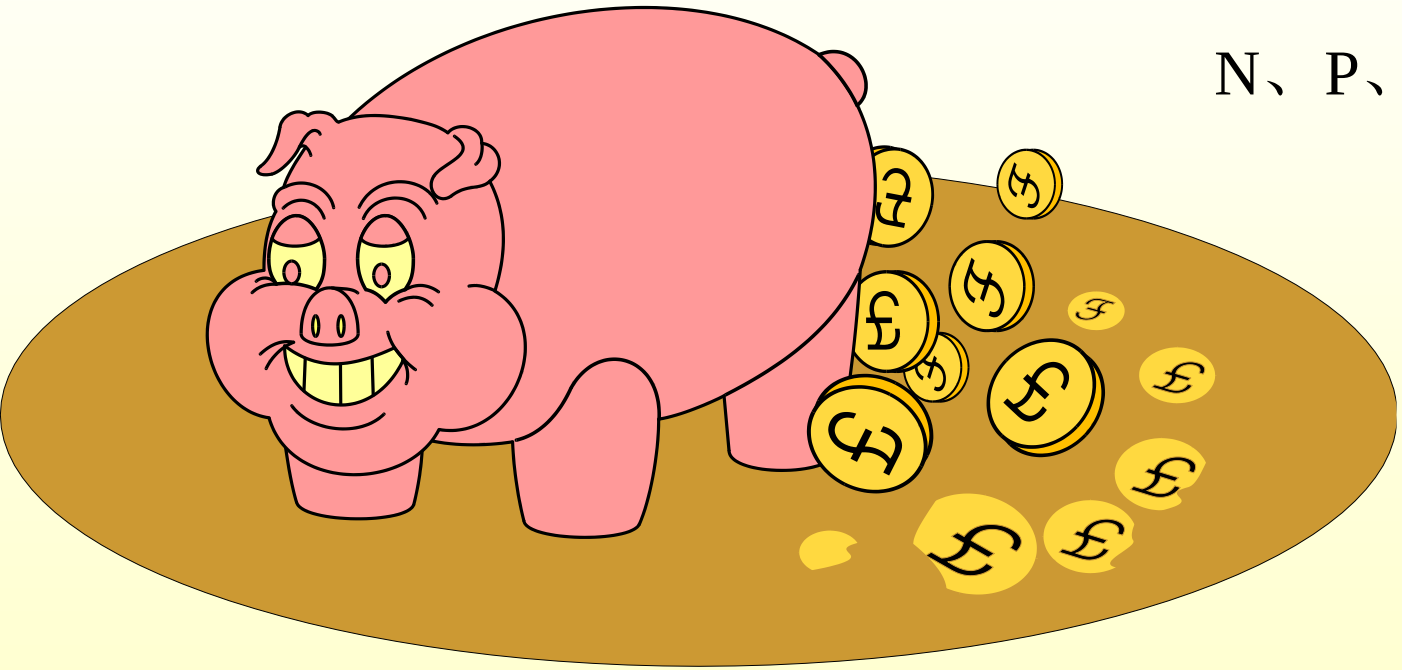



城市生物質燃氣聯盟統計資料,2009
Statistical Data from the 'Alliance on Technological Innovation of Urban Biomass Gas Industry',2009

2010年大陸畜禽養殖COD、NH3排放分別達1184萬噸、65萬噸，占大陸排放總量的45%、25%，占農業源排放量的95%、79%。

到2020年大陸農業基本實現畜禽糞汙資源化利用，病死畜禽全部實現無害化處理；基本實現農作物秸稈資源化利用，秸稈露天焚燒現象得到有效控制。

換個角度看污染
HOW DO WE VIEW WASTES



N、P、K---Nutrients肥料

C--- Energy能源

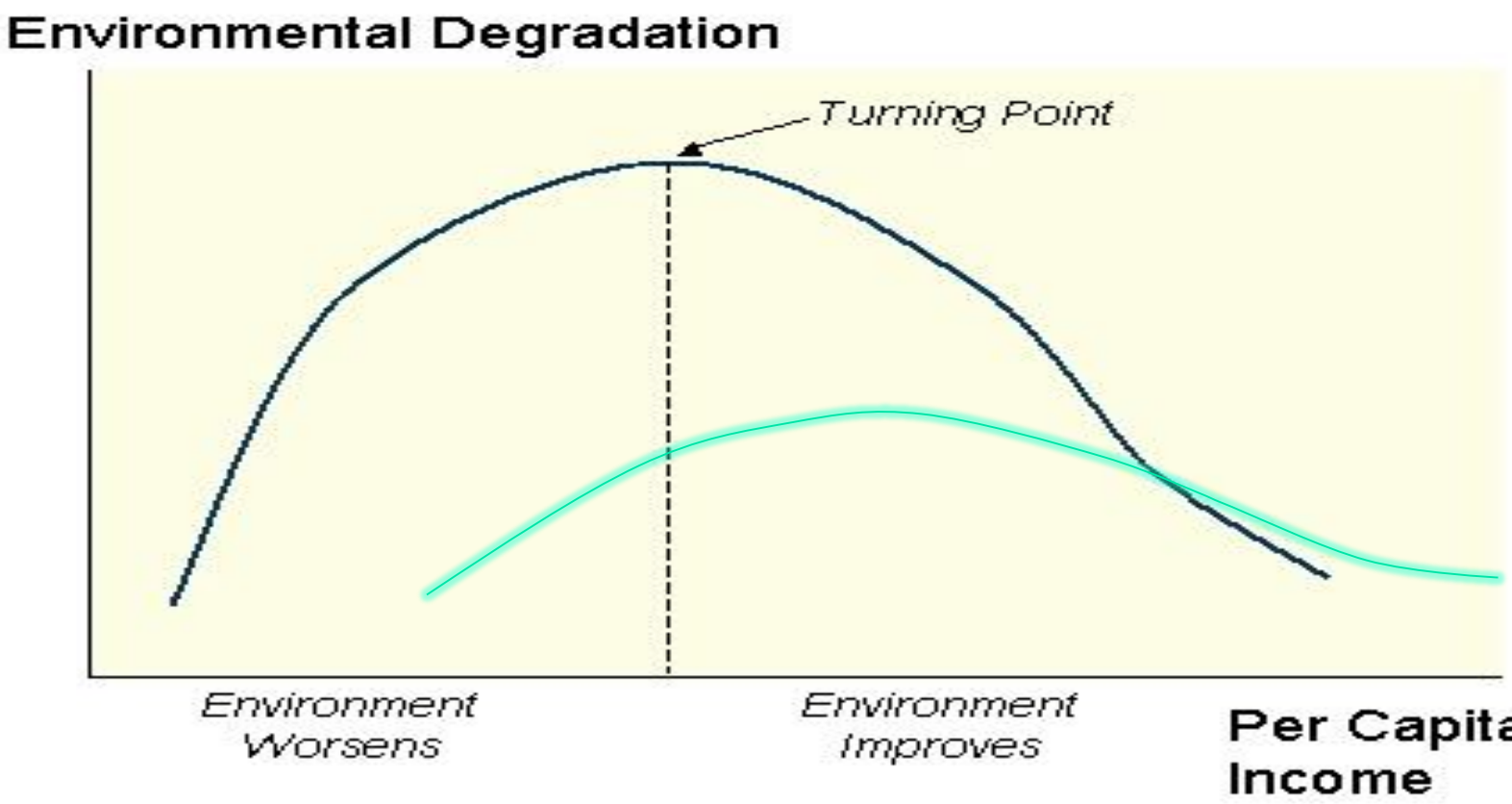
H-O---Water水

All are Renewable

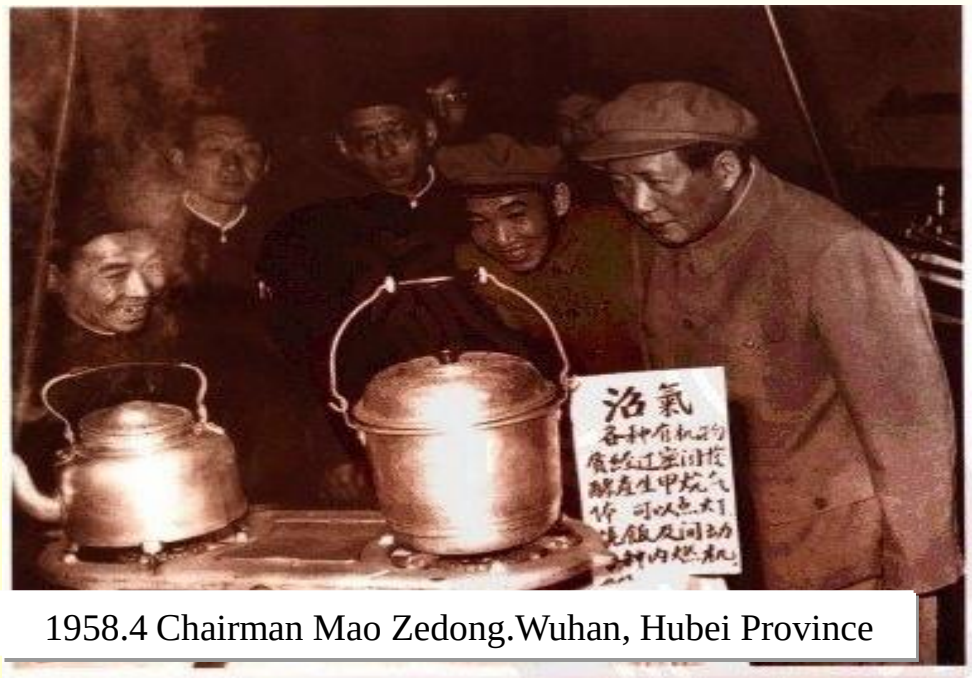
ReNEW

環境保護-必須的選擇
ENVIRONMENTAL PROTECTION- A MUST

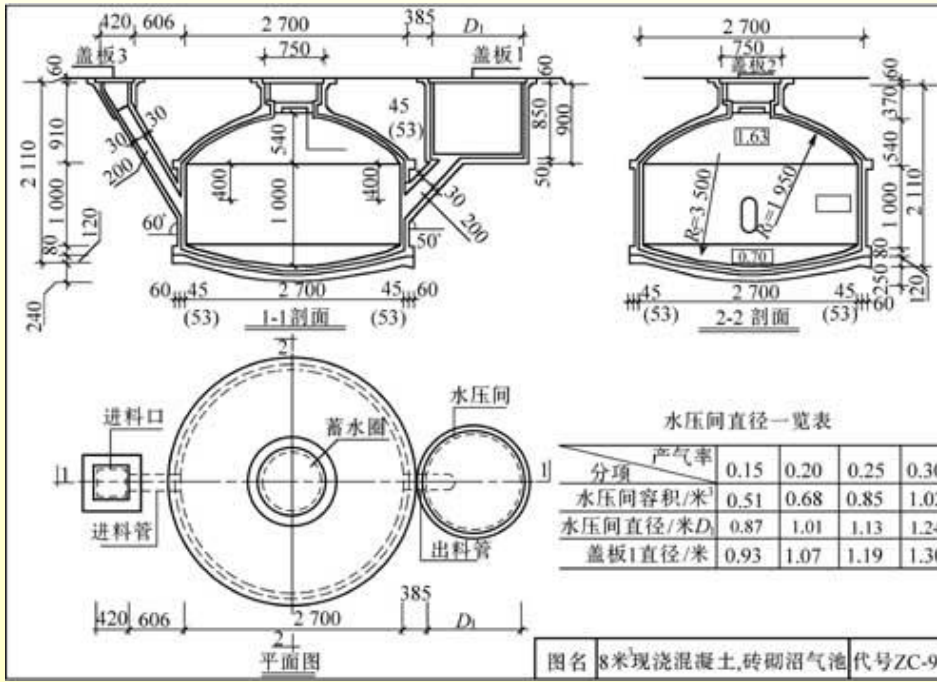
The environmental Kuznets curve



沼氣工程發展與沼液沼渣利用的意義
BIOGAS PLANTS DEVELOPMENT AND THE CHALLENGE OF DIGESTATES



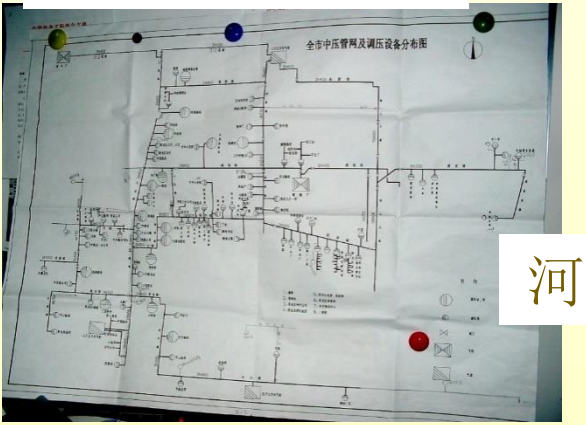
1958.4 Chairman Mao Zedong.Wuhan, Hubei Province



沼氣工程提供城市燃氣

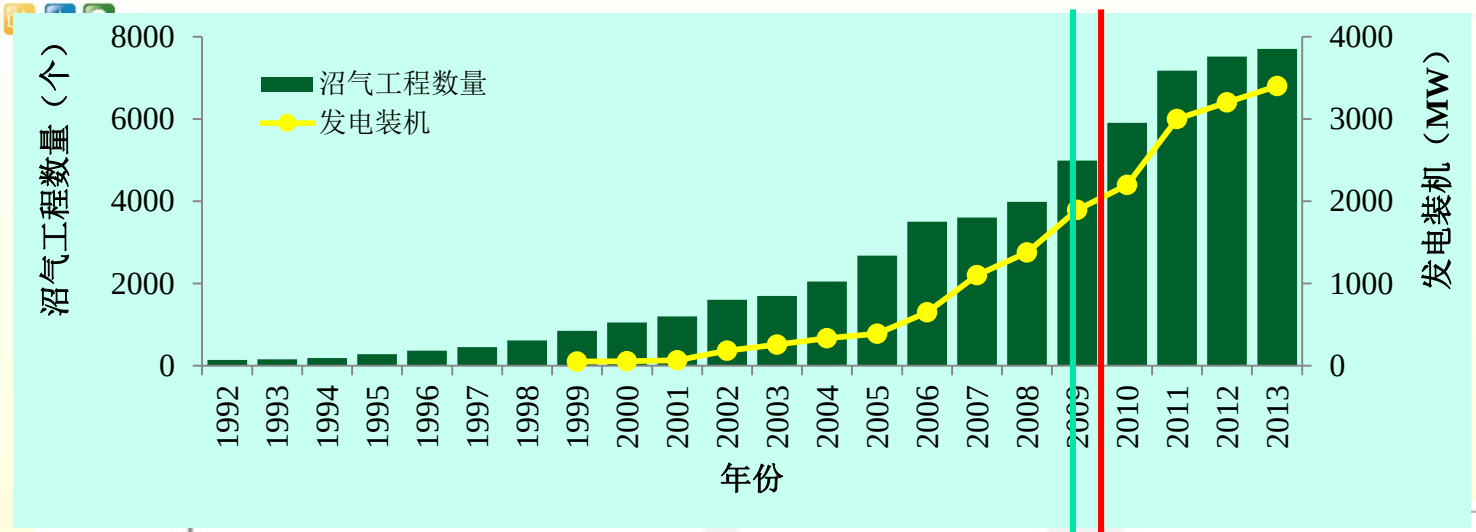
BIOGAS AS BIOMETHANE

歐洲案例



河南南陽

國際原油價格與德國沼氣工程
PETROPRICE AND BPS

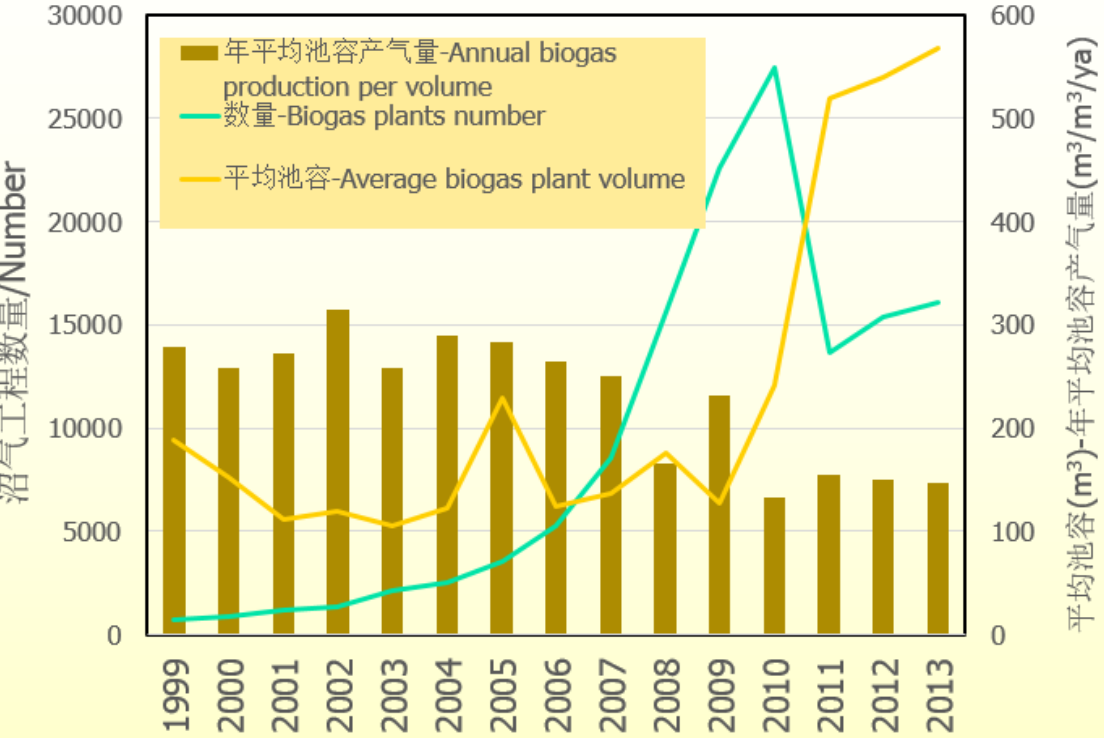


沼氣工程的作用
THE ROLE OF BIOGAS PLANTS

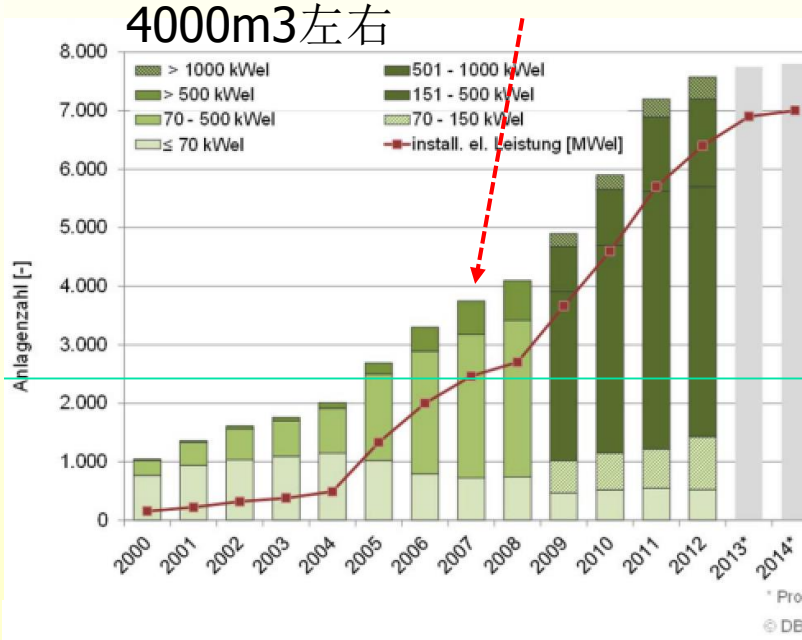
環保價值
不可或缺

能源價值
或隱或現

沼氣工程：量大，水準有待提高
BPs: Big Number, Quality Question



以1.8kWh/m3沼氣發電，平均每天工作22h全年工作，單個沼氣工程怕平均產氣量4000m3左右



中國農村統計年鑒（2000-2008）；中國農業統計資料（2010-2013）
2009年中國戶用沼氣和沼氣工程發展現狀分析，中國科學院青島生物能源與過程研究所

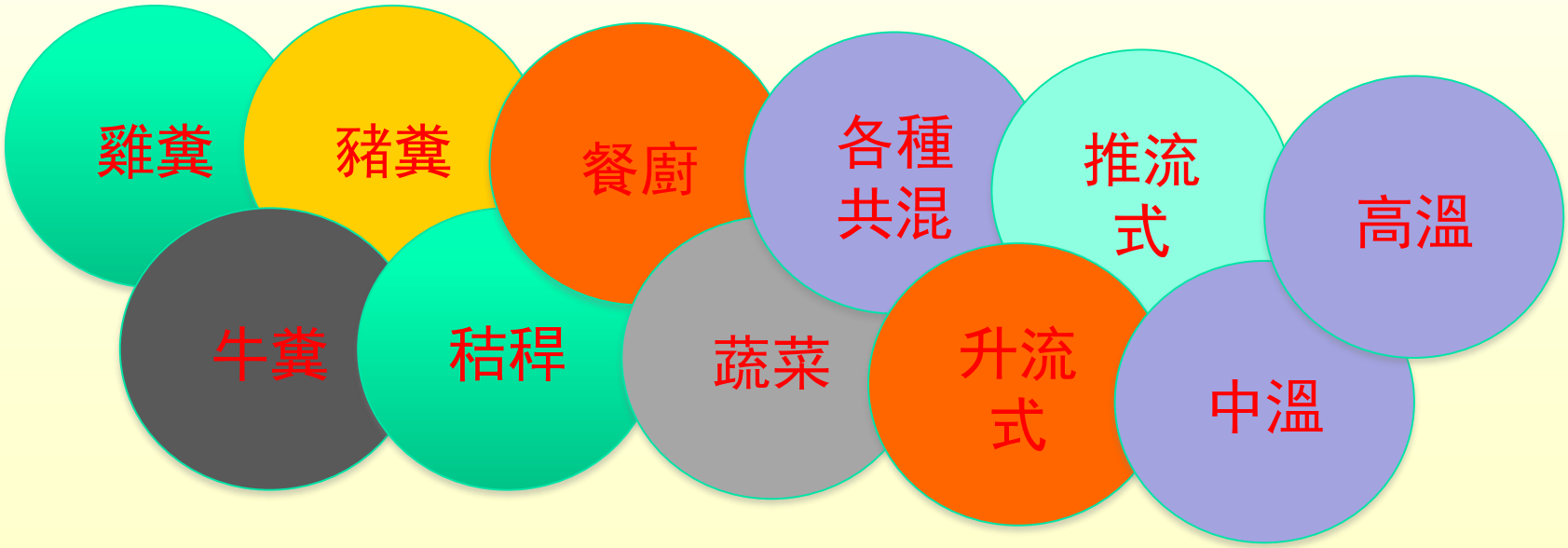
沼液沼渣難題
DIGESTATES: ONE BOTTLE-NECK CONSTRAINTS FOR BIOGAS DEVELOPMENT

1. 養殖場規劃缺乏切實可行的環境影響評價和環境污染控制方案；
2. 大量沼液廢水的產生，無法像歐美一樣在周邊農田得以消納；
3. 在沼液迴圈、減量和達標排放方面，國際上沒有可以借鑒的技術答案；
4. 缺乏對沼液的深層認識和可以信賴的資料（養分、重金屬、激素等）；
5. 沼液農田利用規範不明，有規不依現象嚴重；沼液沼渣農田施用的環境影響缺乏評估；
6. 農業源污染剛剛得到社會重視，仍難以被農業源污染業主所接受。

原料不同，沼液成分不同

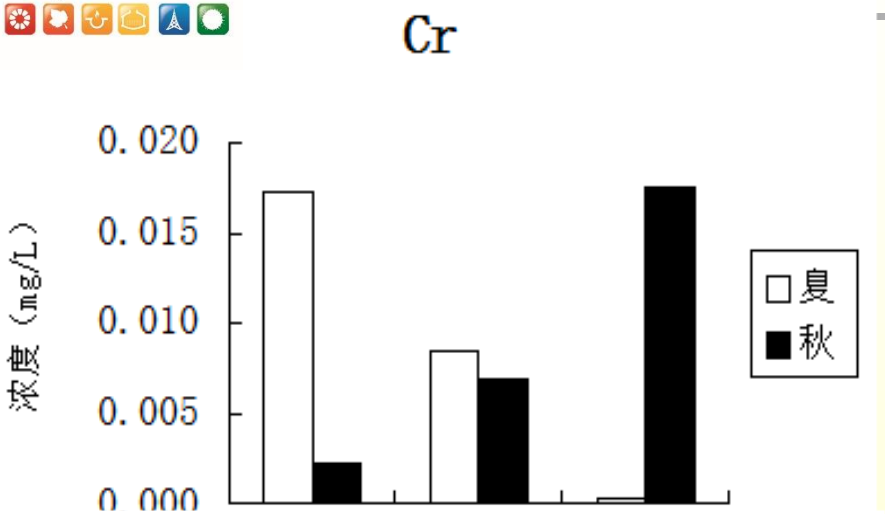
DIGESTATES COMPOSITION VS FEEDSTOCKS

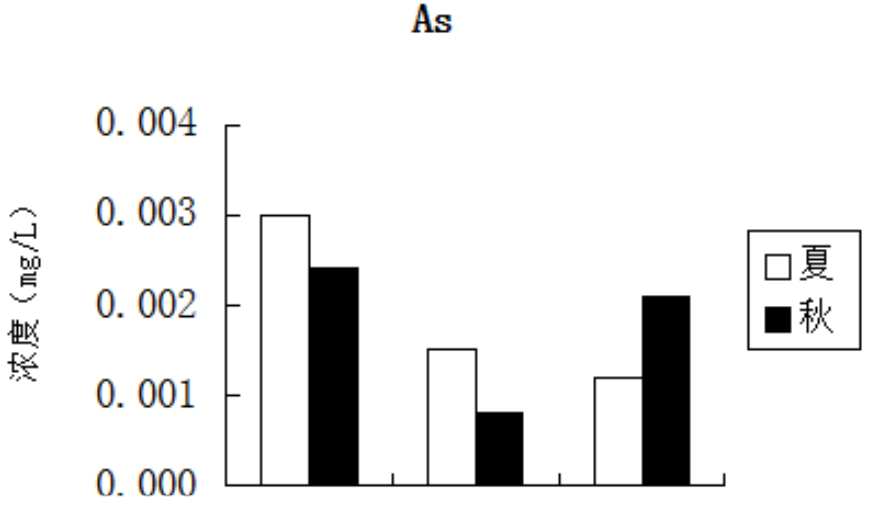
作物學雖給出了多種不同作物對營養含量的需求，但不同發酵原料（含共混）、發酵工藝、季節條件下產生沼液的養分含量差異較大，缺乏共性圖譜。

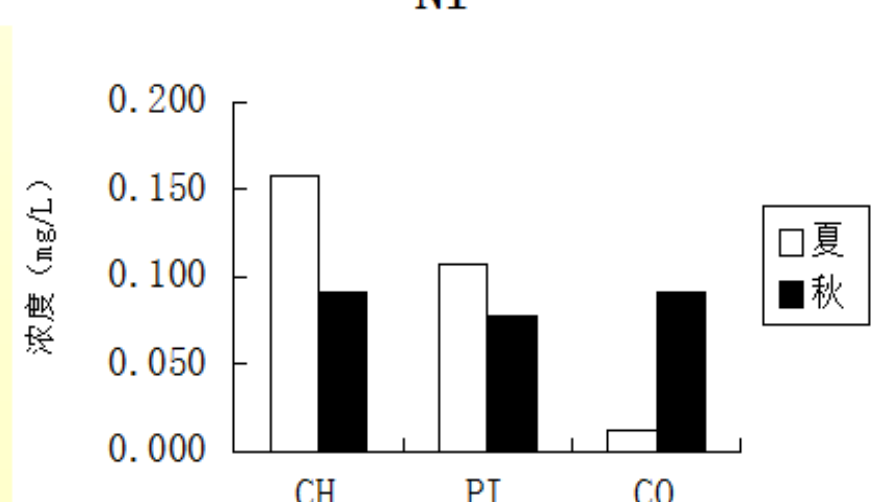


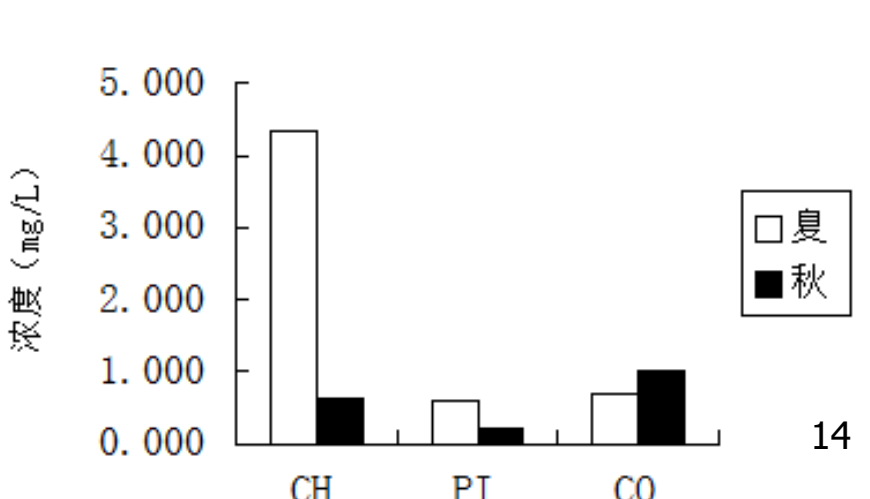
重金屬累積風險

HEAVY METALS ACCUMULATION RISK









沼液如何儲存

HOW TO STORE THE DIGESTAT

Photo 5: Covered digestate storage tank

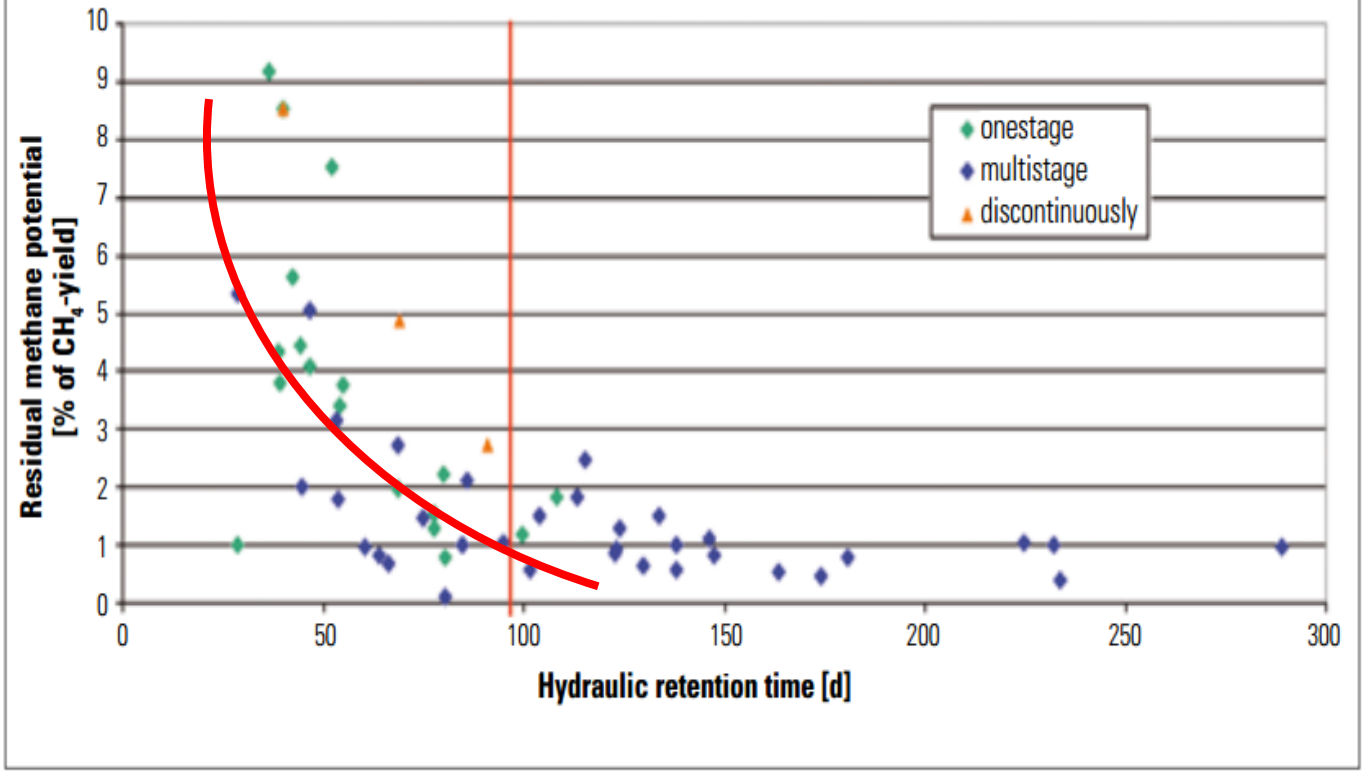


Figure 2: Losses of methane from digestate stores (Weiland, 2009)

In European countries with a developed biogas sector (e.g. Germany, Denmark and Austria) there are now**financial incentives to establish covered digestate stores**, with the main objective of reducing emissions.

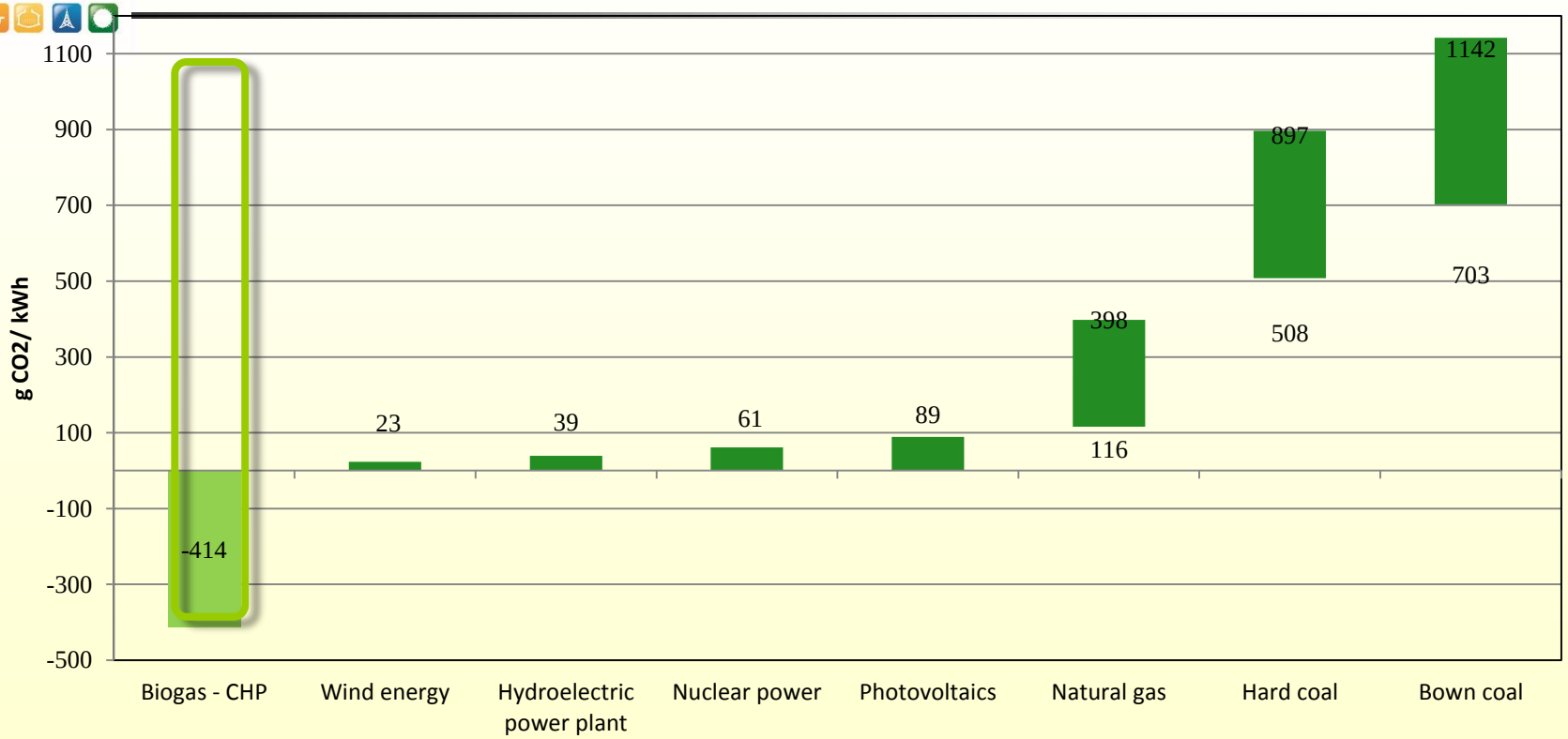
Weiland, P. (2009). Biogas – Messprogramm I 61 Biogasanlagen im Verlich. Erstellt durch Johann Heinrich von Thunen-Institut (VTI), Gulzow, Germany

長途輸送和農田施用機械：經濟性與可行性

LONG-DISTANCE TRANSPORTATION/LARGE SCALE LAND APPLICATION MACHINE

沼氣工程是負碳技術

BP-CARBON NEGTIVE

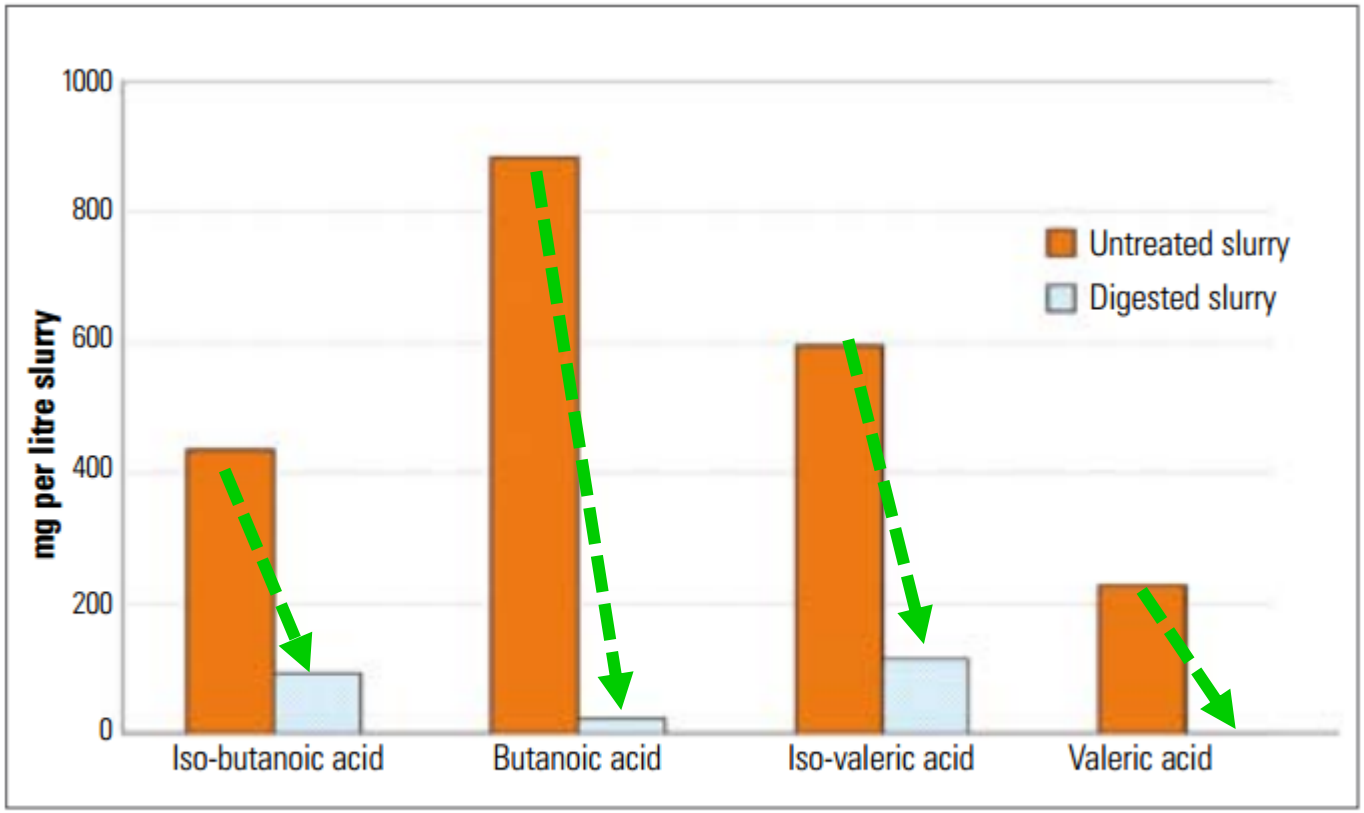


Specific CO_2 Emission Associated with Energy Generation

Resource: Poeschl M, S Ward & P Owende. 2010. Prospects for expanded biogas utilization in Germany.*Renewable & Sustainable Energy Reviews*: In Review

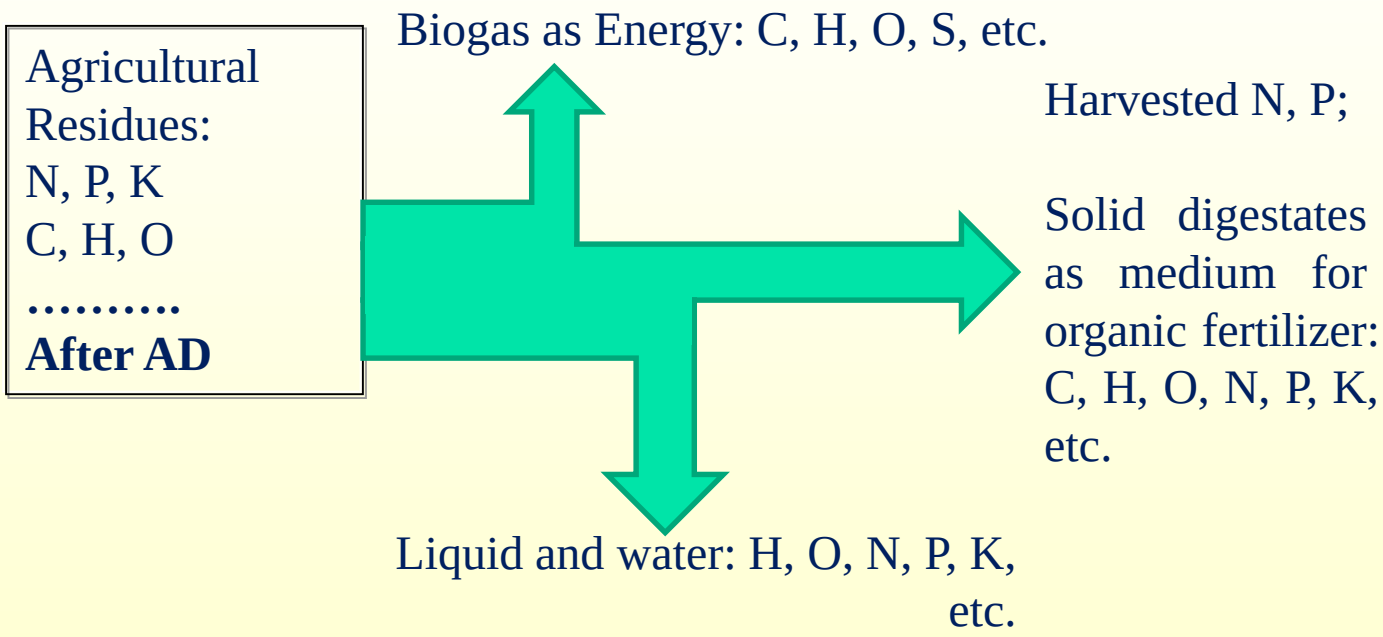
厭氧發酵大大降低畜禽糞汙的臭味

UNPLEASANT ODOUR GREAT REDUCTION BY AD



Figures 3: Concentration of volatile fatty acids in untreated slurry and digested slurry (Hansen *et al.*, 2004)

通過沼氣工程對有機廢物的多層及利用
MULTI-USE OF ORGANIC RESIDUES IN AD



N, P, K---**N**utrients肥料C---**E**nergy能源H-O---**W**ater水
All are**Re**newable
ReNEW

沼液沼渣迴圈利用的意義
ADVANTAGES OF DIGESTATES RECYCLING

1. 沼液中含有豐富的動植物尤其是植物生長激素，沼液沼渣的農田施用可以帶來意想不到的效果：提高植物抗逆能力、提高產量和品質；
2. 沼液中含有NPK等植物所需的營養元素和微量元素，它們來自植物，由返回大地，形成物質的良性迴圈；
3. 尤其是P是不可再生的生命必須的營養成分；但是如果不回收，集中進入水體則會導致富營養化；
4. 沼液沼渣的循化利用降低外排廢水的處理成本，減少對水資源、肥料資源的消耗。

沼液沼渣利用的國際進展
INTERNATIONAL EXPERIENCES OF DIGESTATES UTILIZATION/RECYCLING

In all casesenvironmental problem can be minimised by avoiding the application of digestate (or any fertilisers) in periods with low plant uptake or high rainfall.

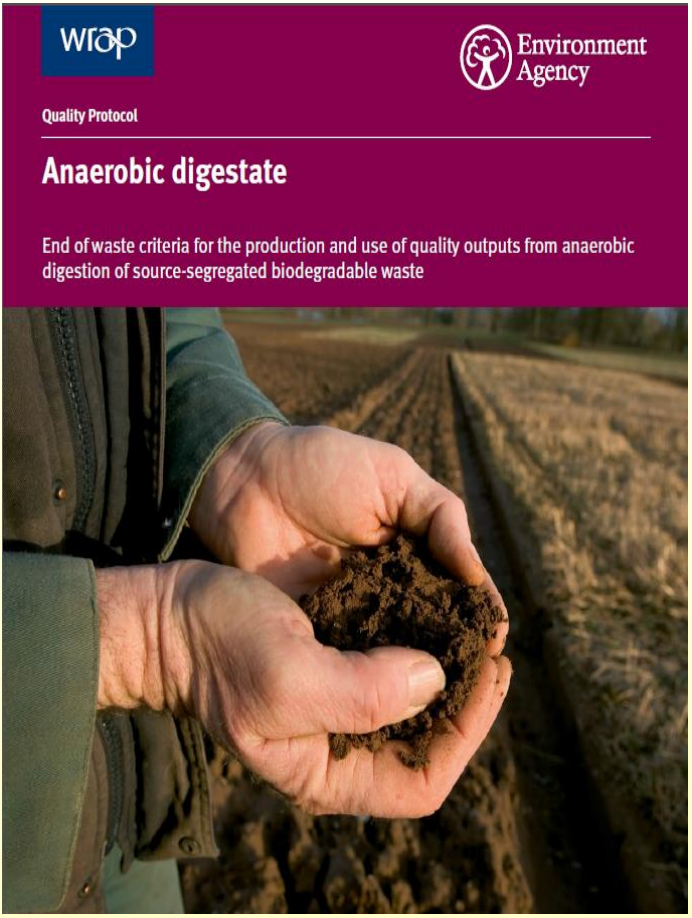
各國對沼液農田施用量、儲存時間、施用時間規定

Table 9: Examples of national limits regulating nitrogen loading on farmland, required storage capacity for digestate, and its spreading season (amended from Nordberg, 1992 and citation in Al Seadi, 2009)

	Maximum nutrient load	Required storage capacity	Compulsory season for spreading
Austria	170 kg N/ha/year	6 months	28 Feb–5 Oct
Denmark	170 kg N/ha /year (cattle) 140 kg N/ha/year (pig)	9 months	1 Feb–harvest
Italy	170–500 kg N/ha/year	90–180 days	1 Feb–1 Dec
Sweden	170 kg N/ha/year (calculated from livestock units per ha)	6–10 months	1 Feb–1 Dec
Northern Ireland	170 kg N/ha/year	4 months	1 Feb–14 Oct
Germany	170 kg N/ha/year	6 month	1 Feb–31 Oct Arable land 1 Feb–14 Nov Grassland

Holm-Nielsen, J. B., Al Seadi, T., Oleskowicz-Popiel, P. The future of anaerobic digestion and biogas utilization. Bioresource Technology, 2009, 100 (22): 5478-5484.
Birkmose, T. S. Nitrogen recovery from organic manures: improved slurry application techniques and treatment-the Danish scenario. Proceedings-International Fertilizer Society. International Fertiliser Society, 2009, 24.

農田施用量
AMOUNT OF APPLICATIO

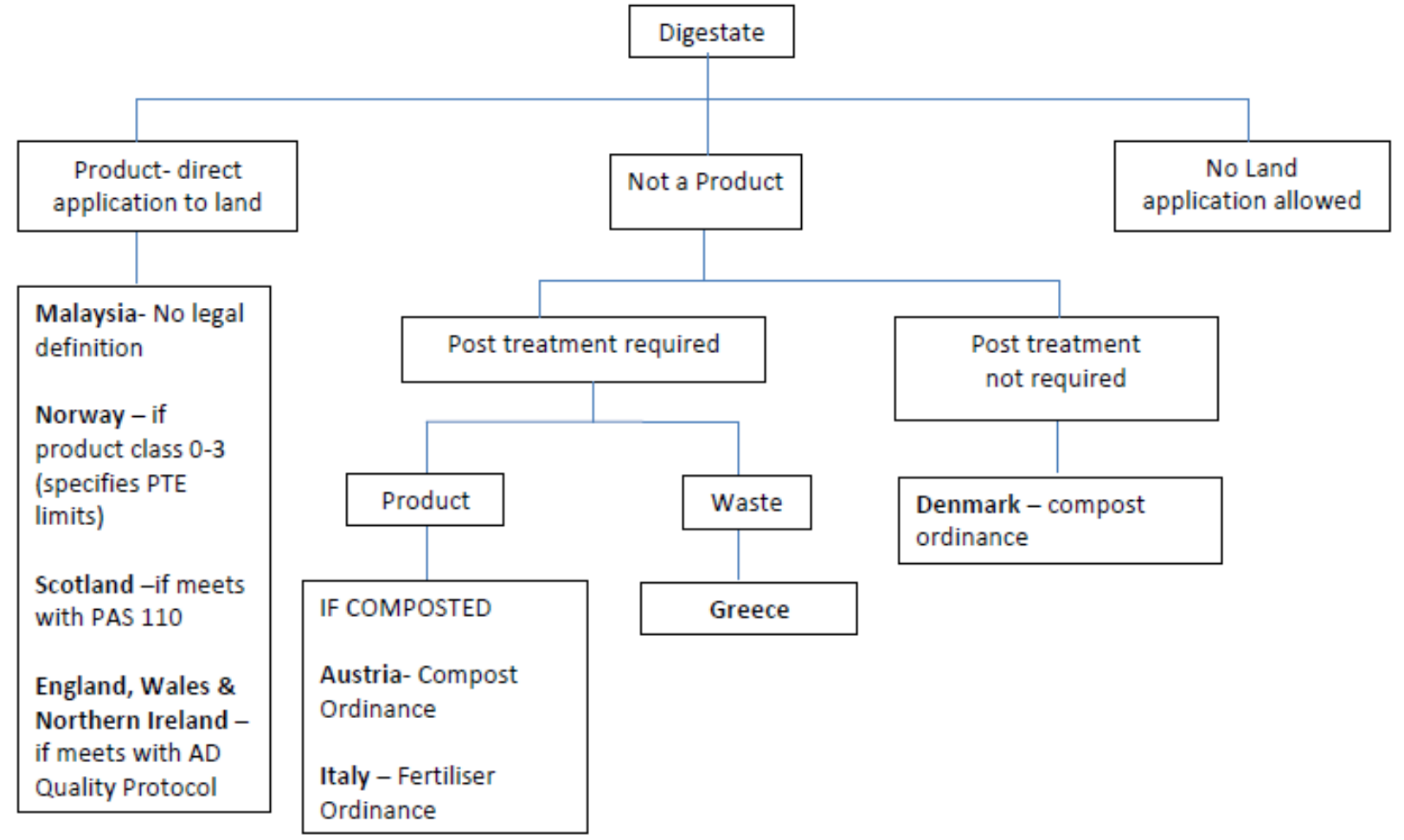


1. UK: Fertiliser recommendations for agricultural and horticultural crops (RB209); available as a computerised version (PLANET); http://www.defra.gov.uk). Also available from Defra is other computer software (MANNER) which predicts the plant availability of manure nitrogen following land application.
2. Canada: Nutrient Management Workbook. <http://www.omafra.gov.on.ca/english/nm/ar/workbook/workbk.pdf> accessed 26 January 2010
3. Northern Ireland: Nutrient management planning. <http://www.ruralni.gov.uk/index/environment/countrysidemanagement/nutrient_management_planning.htm> accessed 26 January 2010
4. England: A simple nutrient management plan <http://www.nutrientmanagement.org/> accessed 26 Jan. 2010
5. Good practice in quality management of AD residues, a publication of IEA-Bioenergy, Task 37. <http://www.iea-biogas.net/Dokumente/management-paw3.PDF> accessed 26 January 2010
6. Denmark: Various biogas information <http://www.landbrugsinfo.dk/Tvaerfaglige-emner/Biogasanlaeg/Sider/Engelsk_materiale.aspx>

Is Digestate considered as a "product"?	Is the legal status as a "product" only restricted to some particular input?	Is there any obligation for post-treatment of Digestate through composting?	What are basic requirements for the application of Digestate?	What are the on-going discussions concerning environmental and agricultural issues and benefits pertaining to direct application/post-composting of Digestate?
Under which conditions?	(e.g. farm waste, slurry)		(e.g.: a permit? Communication? What elements must the communication include? Deep injection?)	

沼液沼渣作為肥料？

DIGESTATES AS FERTILIZER PRODUCTS?



FACT SHEET: Requirements for the Treatment and Application of Digestate and Sewage Sludge (Biosolids), International Solid Waste Association.

沼液農田施用機械

DIGESTATES FIELD APPLICATION MACHINE

Splash plate

Injection

Trailing hose

Trailing-shoe

FACT SHEET: Requirements for the Treatment and Application of Digestate and Sewage Sludge (Biosolids), International Solid Waste Association.

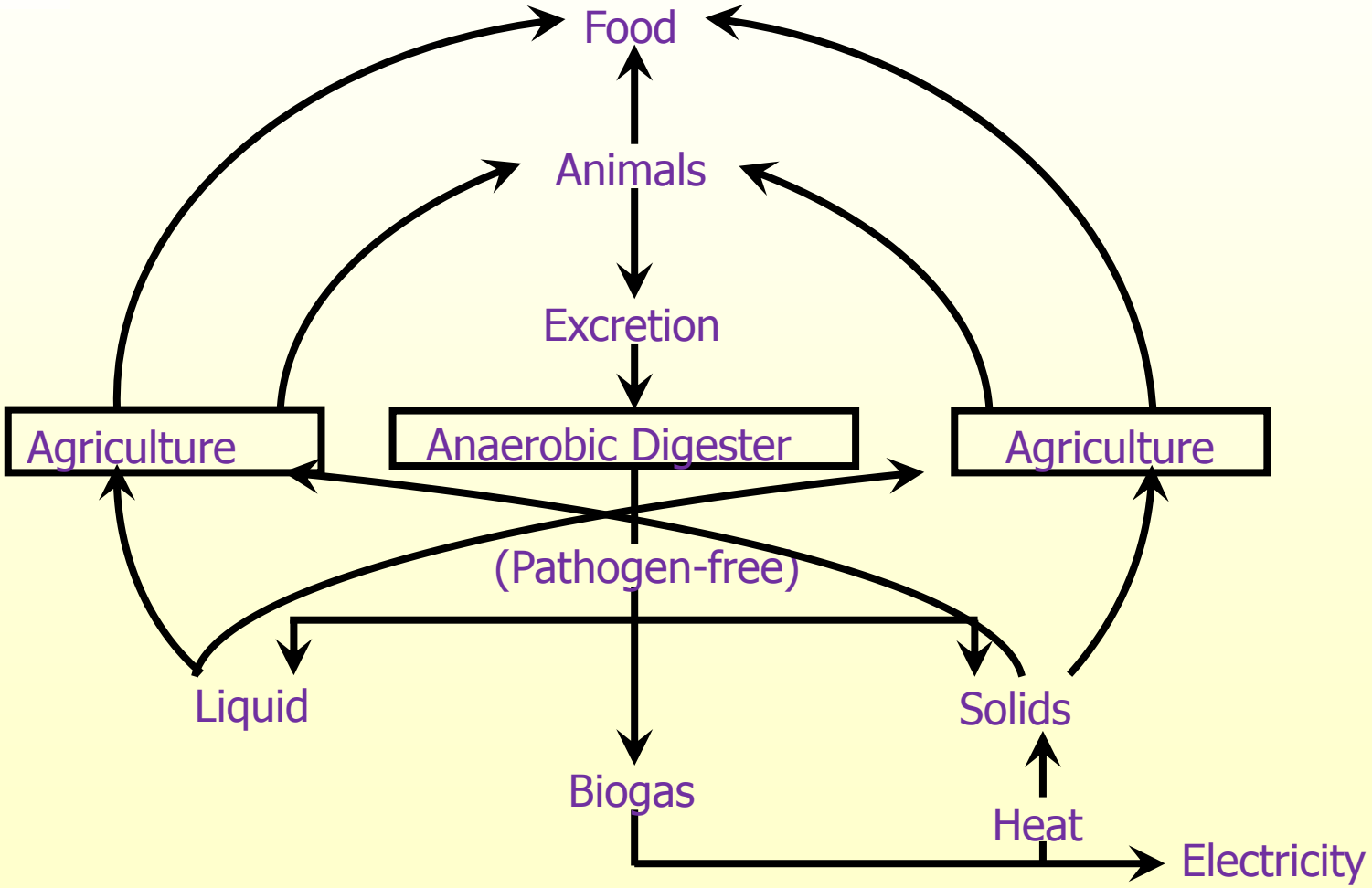
沼液農田施用風險
DIGESTATES FIELD APPLICATION RISK

Table 10: Example from Denmark summarising the characteristics of four digestate and raw slurry application methods (adapted from Birkmose, 2009)

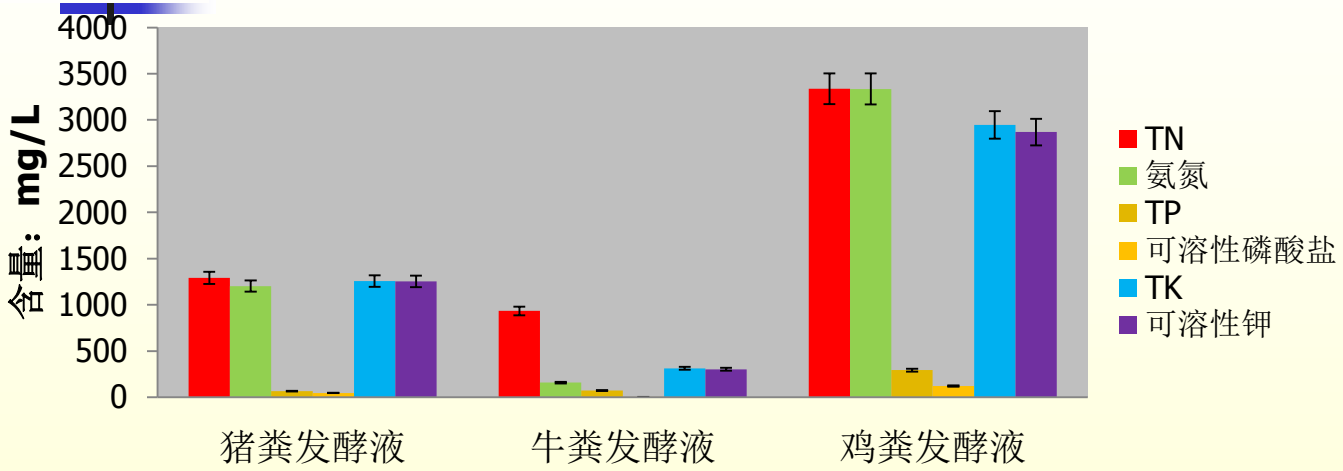
	Trailing hose	Trailing-shoe	Injection	Splash plate
Distribution of slurry	Even	Even	Even	Very uneven
Risk of ammonia volatilization	Medium	Low	Low or none	High
Risk of contamination of crop	Low	Low	Very low	High
Risk of wind drift	Minimal after application	Minimal after application	No risk	High
Risk of smell	Medium	Low	Very low	High
Spreading capacity	High	Low	Low	High
Working width	12–28 metres	6–12 metres	6–12 metres	6–10 metres
Mechanical damage of crop	None	None	High	None
Cost of application	Medium	Medium	High	Low
Amount of slurry visible	Some	Some	Very little	Most

FACT SHEET: Requirements for the Treatment and Application of Digestate and Sewage Sludge (Biosolids), International Solid Waste Association.

沼液沼渣利用的國內實踐
DOMESTIC DIGESTATES UTILIZATION/RECYCLING



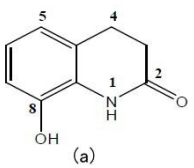
沼液中的養分（N、P、K）
NUTRIENTS IN DIGESTATES

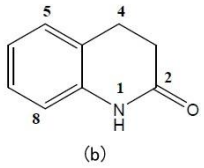


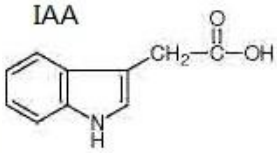
厭氧發酵沼液中含有大量植物生長所需的氮磷鉀等營養成分。

種類(mg/L)	TS（%）	VS（%）	COD	TN	NH_4^+	TP	S-PO_4	TK	S-K
豬糞發酵液 Pig manure based	0.73	0.34	5145	1291.51	1201.83	65.35	45.92	1256.06	1252.81
牛糞發酵液 Cow manure based	0.65	0.38	4050	934.23	157.76	71.67	2.51	312.41	302.08
雞糞發酵液 Chicken manure based	2.21	1.13	13540	3337.88	3335.31	292.35	121.17	2946.27	2868.7
餐廚發酵液 Kitchen based	2-3.5		8500		400-1500	50-100		20-40	

沼液中的植物激素





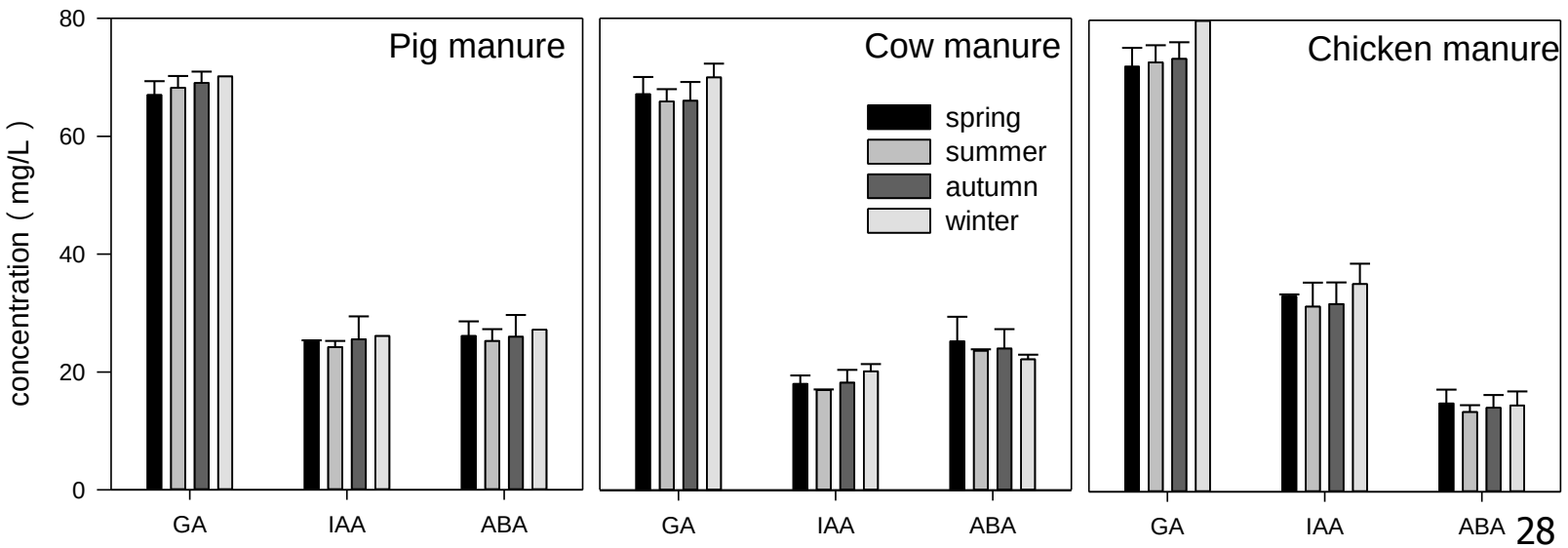


a: 8-羥基-3，4-二氫喹啉-2-酮；b: 3，4-二氫喹啉-2-酮

PLANT-HORMONE IN DIGESTATES

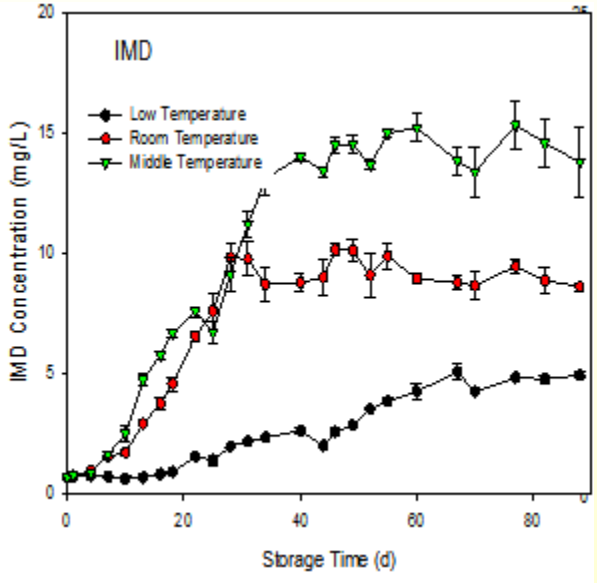
植物激素	雞糞沼液（mg/L）	牛糞沼液（mg/L）	豬糞沼液（mg/L）
赤黴素	72.86±2.93	65.88±2.13	68.24±1.98
吲哚乙酸	31.44±4.06	16.96±0.08	24.25±1.03
脫落酸	13.58±1.14	23.62±0.23	25.27±2.01

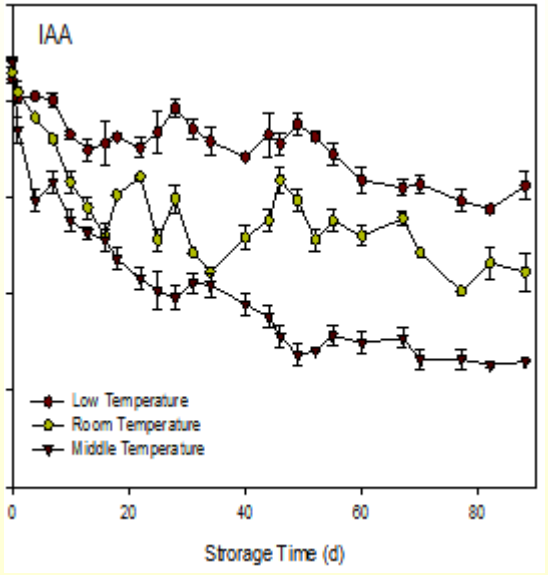
IAA在低濃度(1-10 ng/mL)時促進植物生長，濃度過高對植物有明顯的抑制作用。

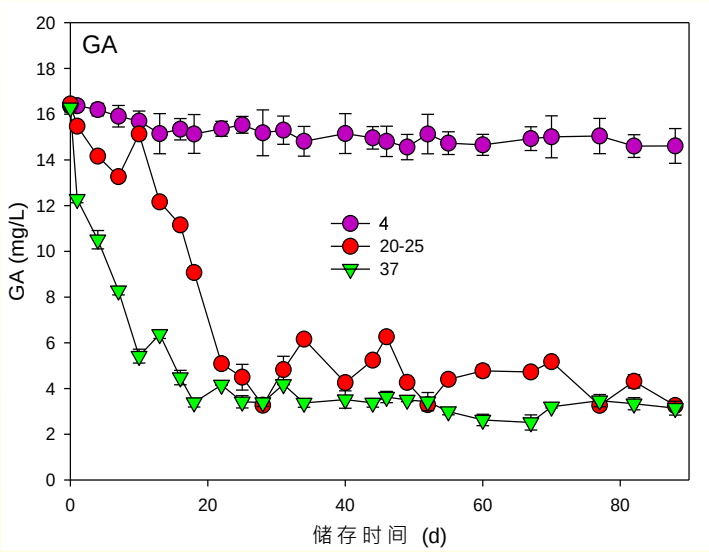


沼液中植物激素在貯存期間的變化

PLANT-HOMONE IN LIQUID DIGESTATES VARIATIONS IN 3 MONTHS STORAGE



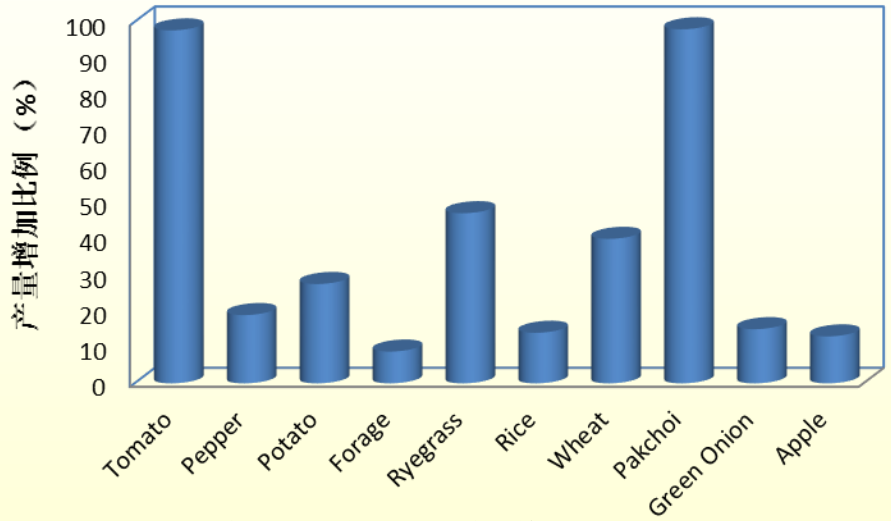




冬季植物激素含量損失5–10%。
春秋季節赤黴素含量約損失75%，吲哚乙酸損失30%。
夏季赤黴素含量約損失75%，吲哚乙酸損失65%。

沼液沼渣增產提質

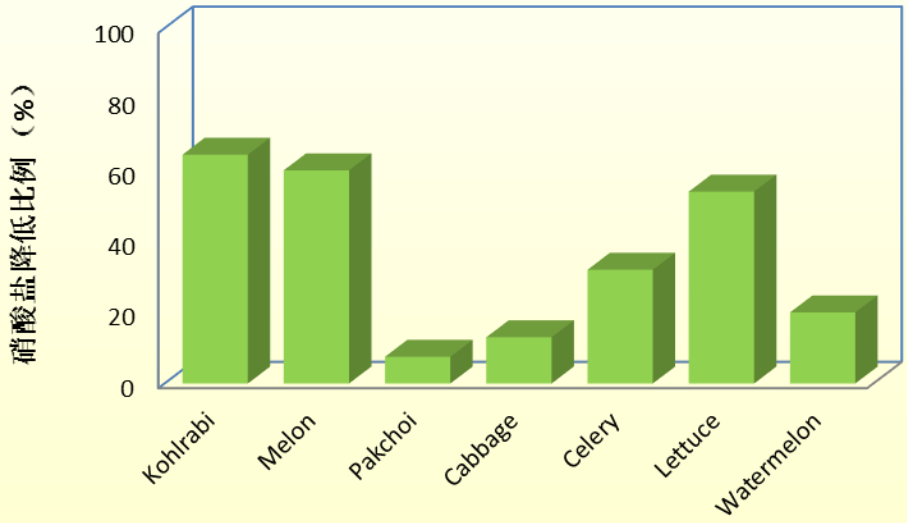
PRODUCTIVITY AND QUALITY ENHANCEMENT BY DIGESTATES APPLICATION



沼渣沼液使用增加作物產量

沼渣沼液的使用還能增加可溶糖、維生素、蛋白質等含量。

沼渣沼液的使用有益於農產品的產量和品質。

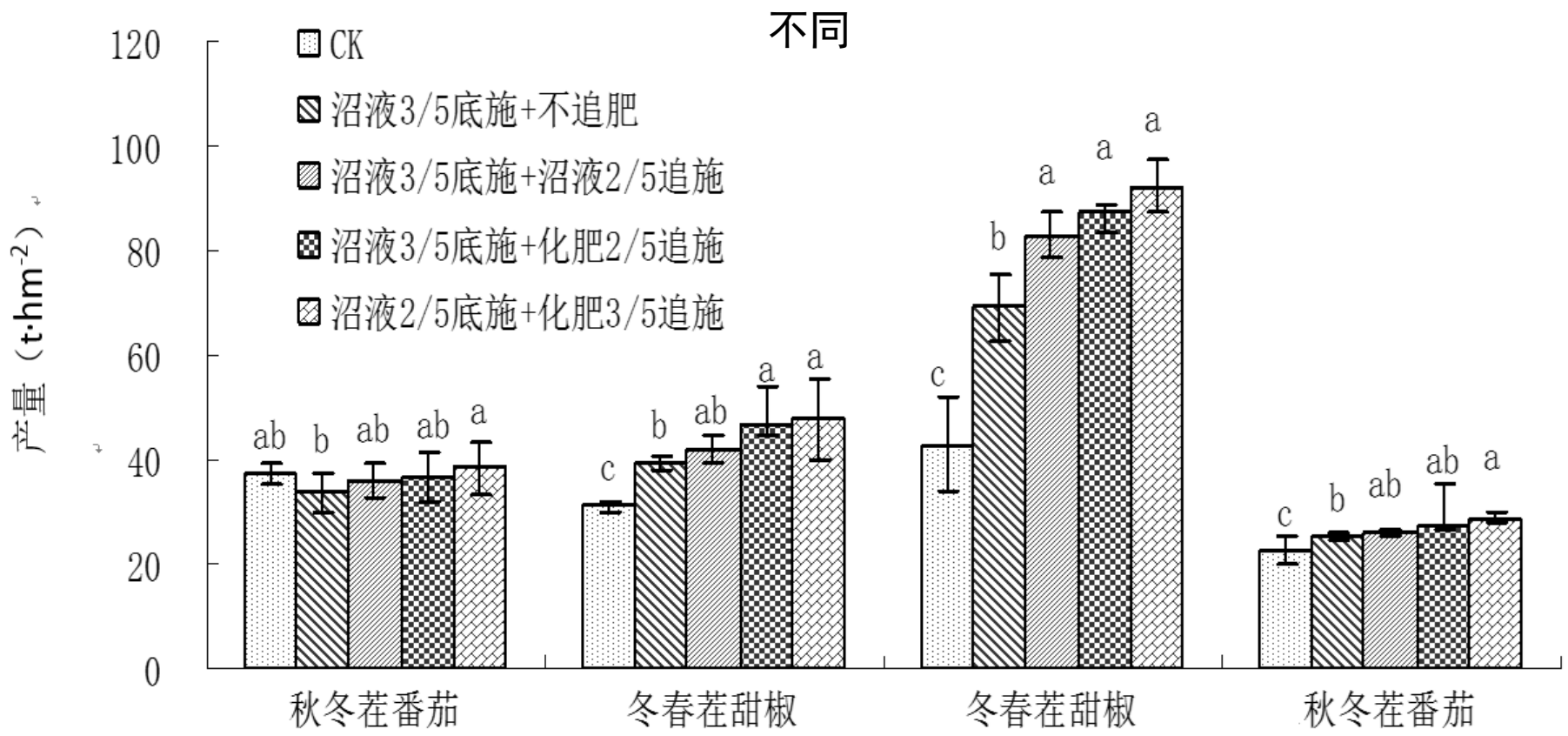


沼渣沼液使用降低硝酸鹽含量

Clements L. J., Salter A. M., Banks C. J., Poppy G. M. The usability of digestate in organic farming[J]. Water Sci Technol, 2012, 66(9): 1864-1870.
Garfi M., Gelman P., Comas J., Carrasco W., Ferrer I. Agricultural reuse of the digestate from low-cost tubular digesters in rural Andean communities[J]. Waste Manag, 2011, 31(12): 2584-2589.

沼液施肥方式對設施蔬菜產量的影響

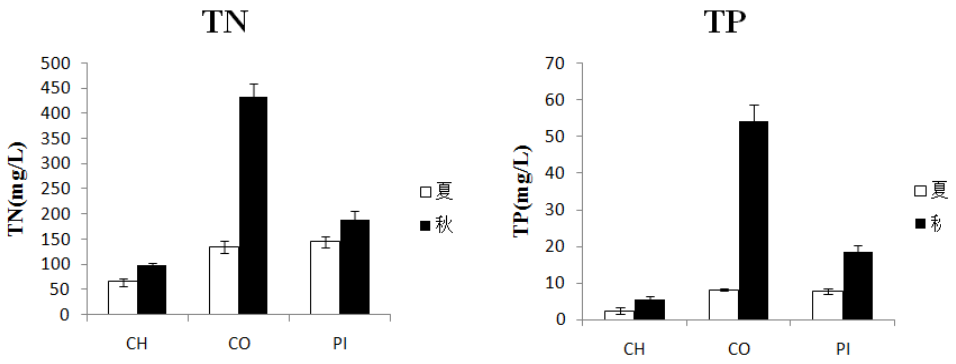
IMPACT ON VEGETABLE PRODUCTIVITY

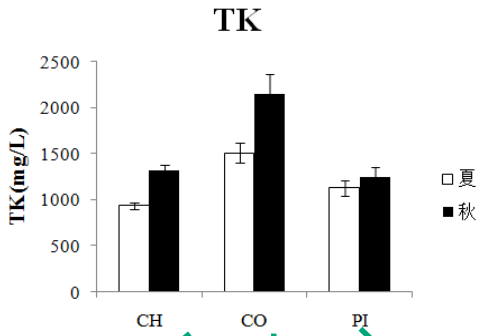


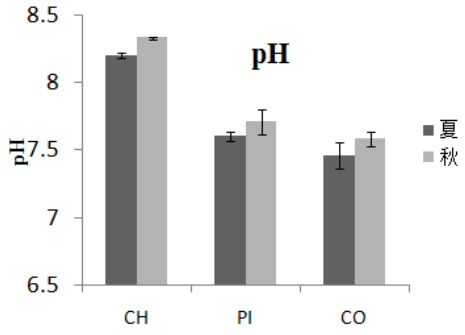
長期試驗證明，在等氮的施肥條件下，沼液的肥效低於化肥，但沼液作為底肥化肥作為後期追肥的施肥方式具有較好的增產作用。

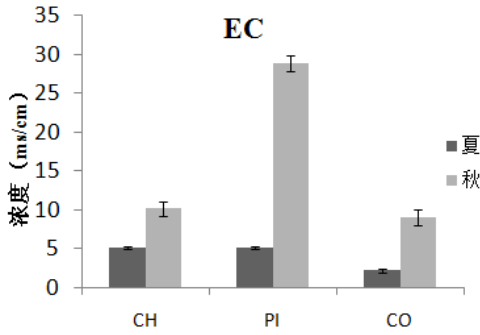
沼液性質（原料與季節）
CHARACTERISTICS OF LIQUID DIGESTATES (FEEDSTOCKS AND SEASONS)

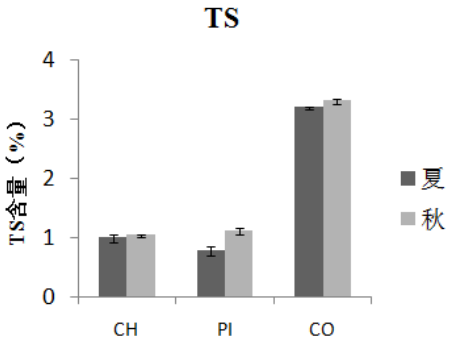
不同原料【豬糞（順義區東華山沼氣工程）、牛糞（密雲縣兩河村沼氣工程）、雞糞（延慶德清源沼氣工程）】

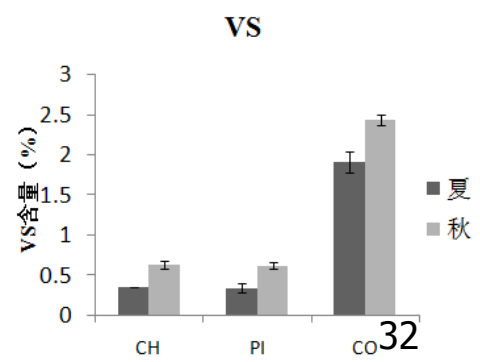












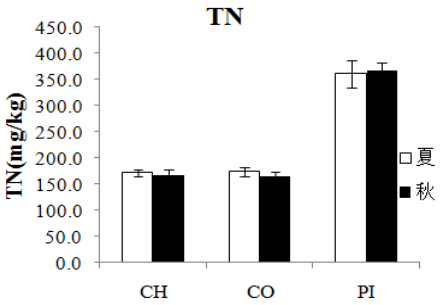
雞糞　牛糞　豬糞

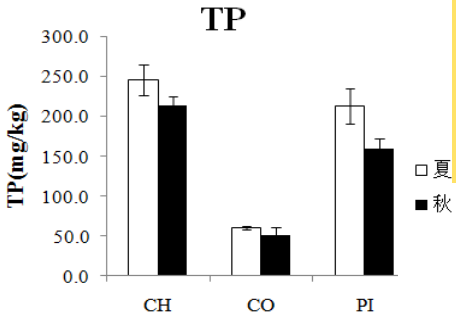
不同季節【春夏秋冬】

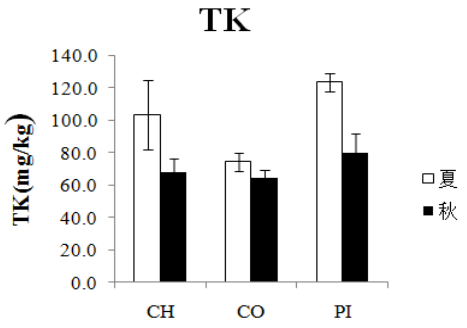
沼渣性質（原料與季節）

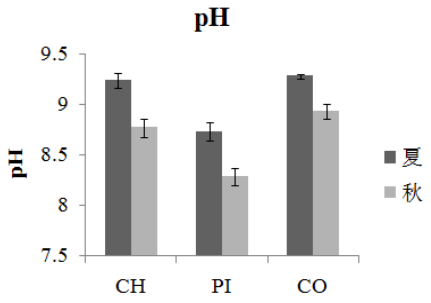
CHARACTERISTICS OF SOLID DIGESTATES (FEEDSTOCKS AND SEASONS)

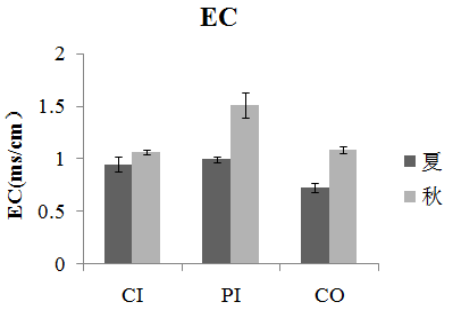
不同原料【豬糞（順義區東華山沼氣工程）、牛糞（密雲縣兩河村沼氣工程）、雞糞（延慶德清源沼氣工程）】

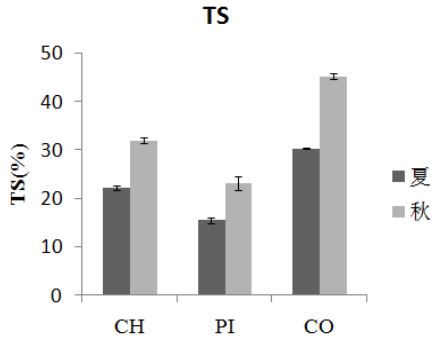


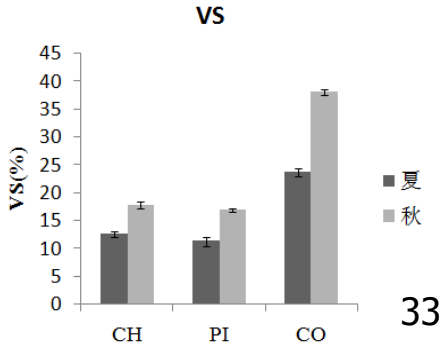








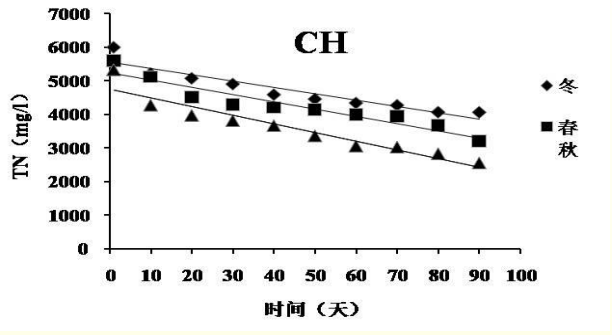


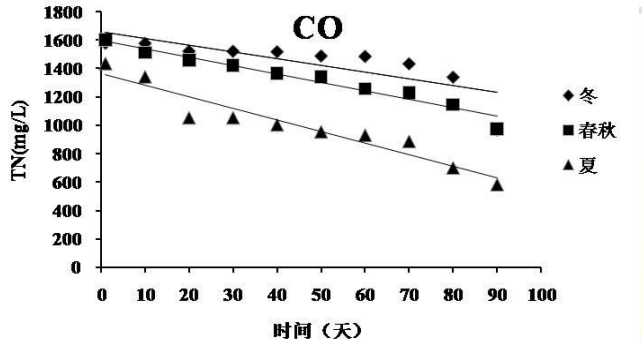


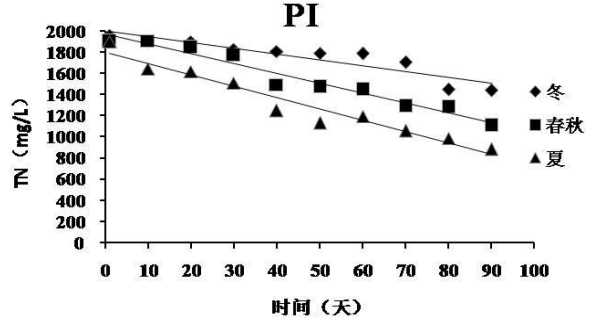
不同季節【春夏秋冬】

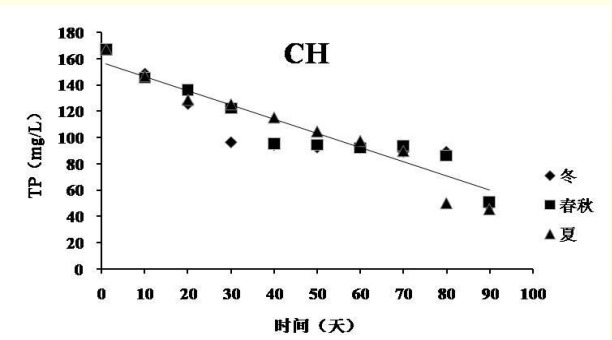
沼液性質隨貯存時間的變化

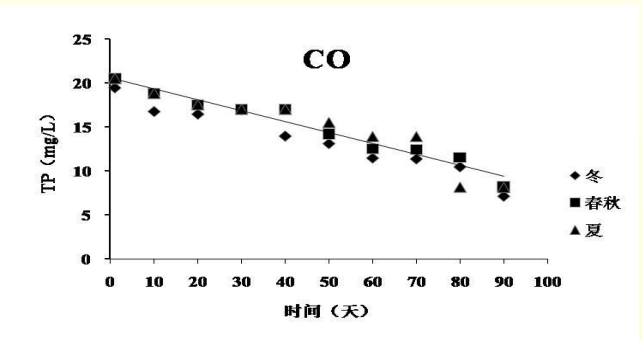
CHARACTERISTICS OF LIQUID DIGESTATES VS STORAGE PERIOD

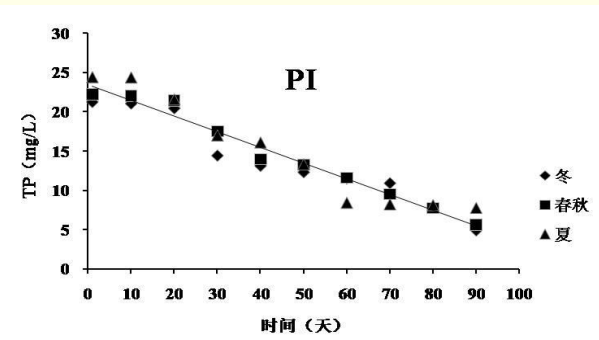


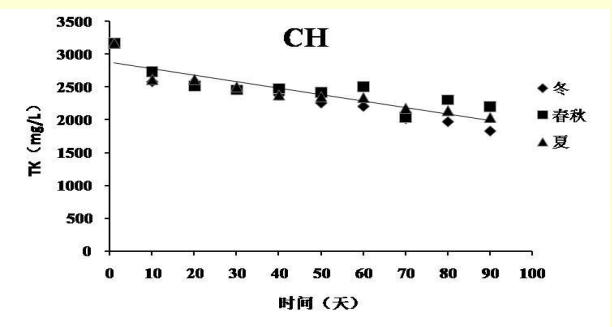


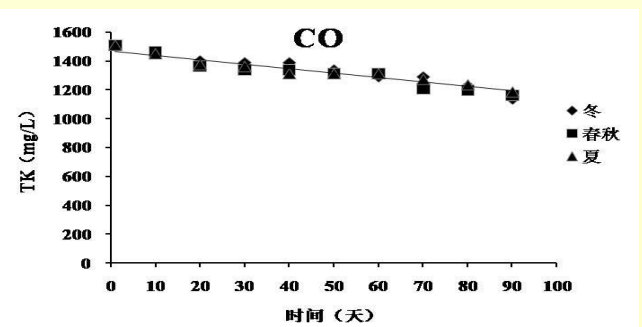


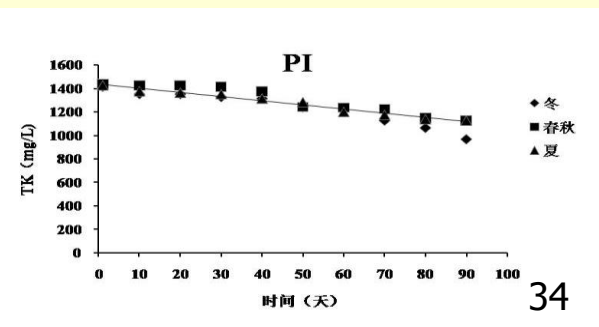










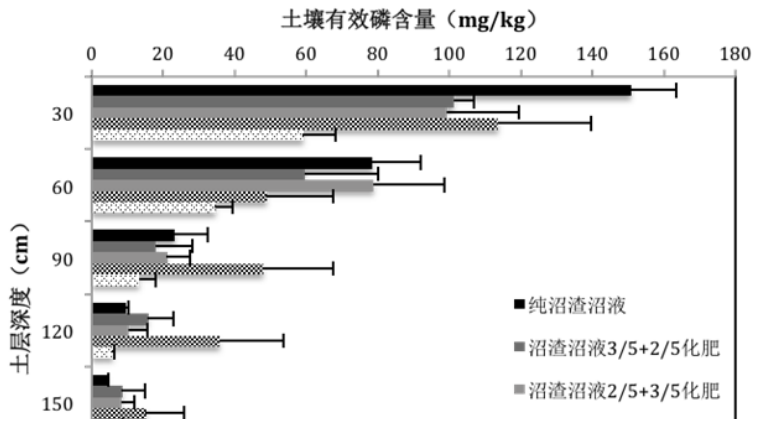


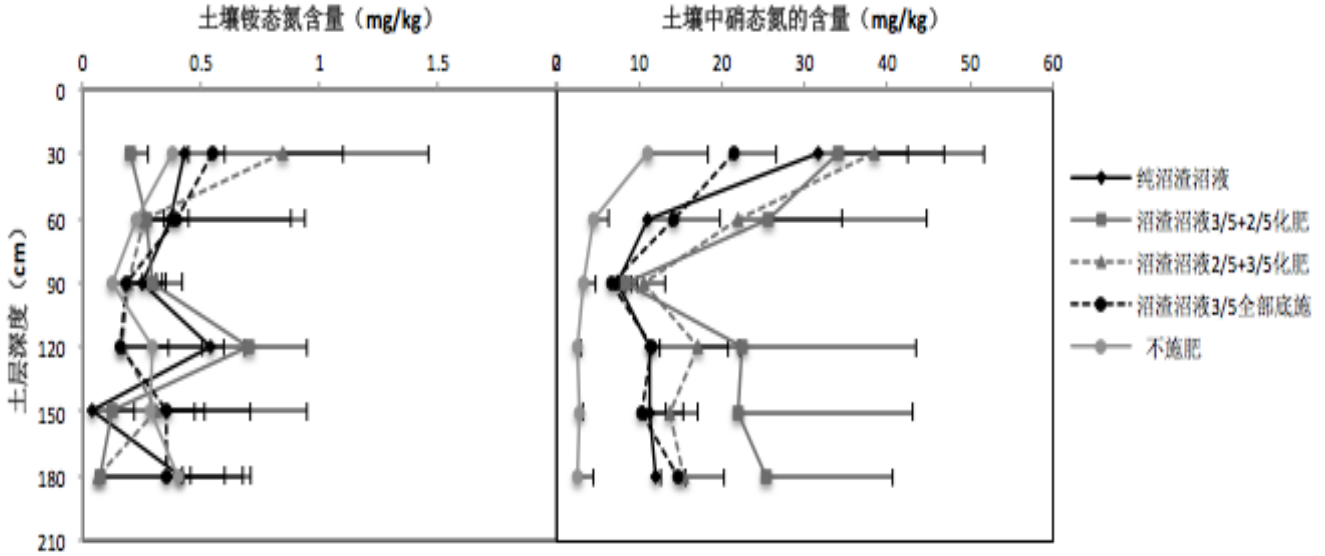
沼液沼渣農田施用後的土層養分殘留

N AND P IN THE SOIL AFTER DIGESTATES APPLICATION PLUS CHEMICAL FERTILIZERS

土層銨態氮含量差異小，硝態氮含量升高，具有淋洗的風險。

表層土壤出現磷素累積現象，純沼渣沼液處理速效磷含量明顯高於其他處理。

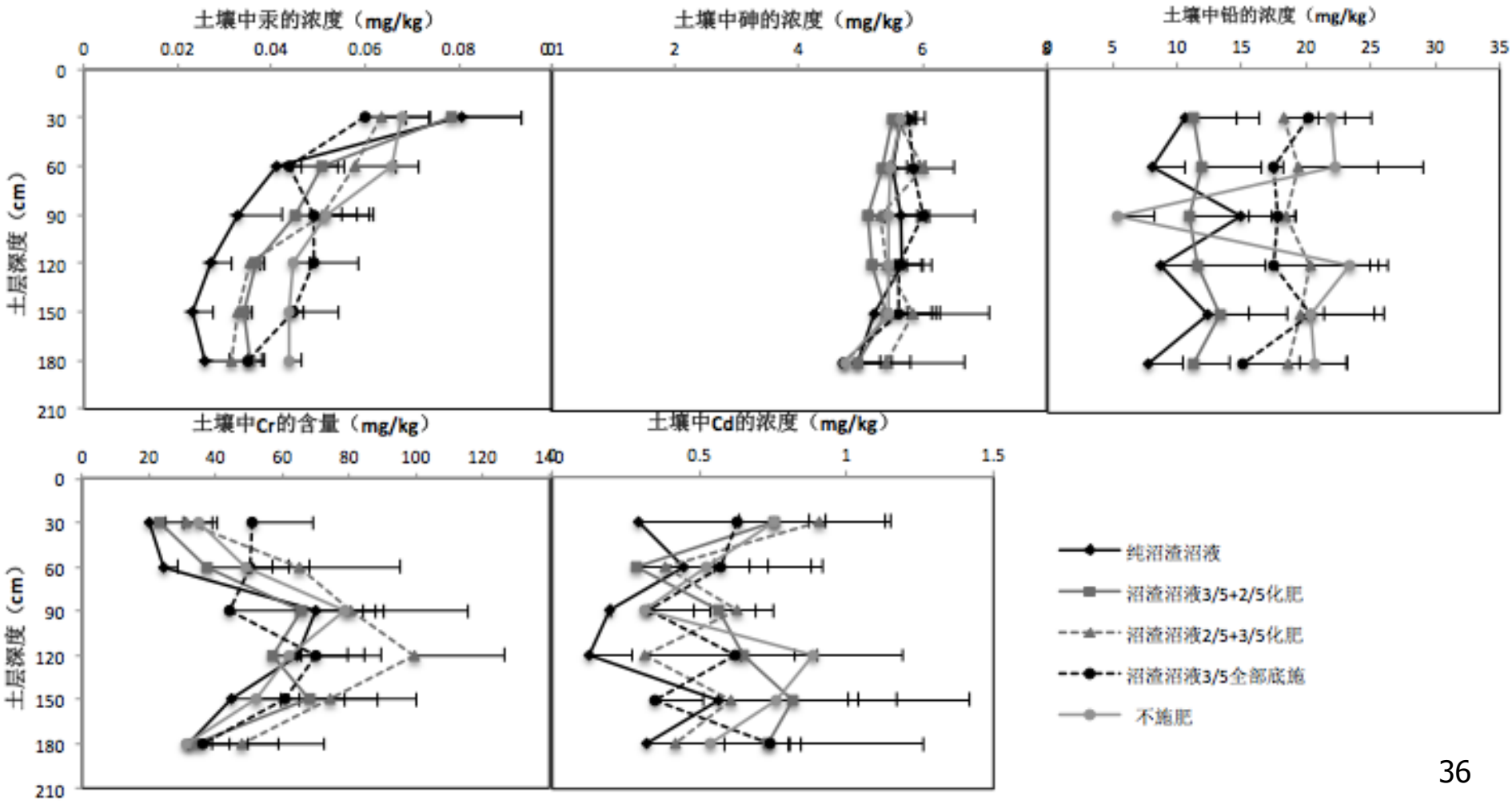




北京市延慶縣康莊鎮小豐營村現代設施農業示範基地

沼液沼渣農田施用後的土層重金屬累計

HEAVY METALS IN THE SOIL AFTER DIGESTATES APPLICATION



沼液沼渣農田施用田間試驗
DIGESTATES APPLICATION FIELD EXPERIMENTS

- 70 mm/h
- 30 min
- 5 min

UC:空白對照；FC:化肥對照； M:糞肥處理；E:沼液處理

沼液沼渣農田施用後氮遷移轉化

N TRANSPORTATION IN SOIL AFTER DIGESTATES APPLICATION

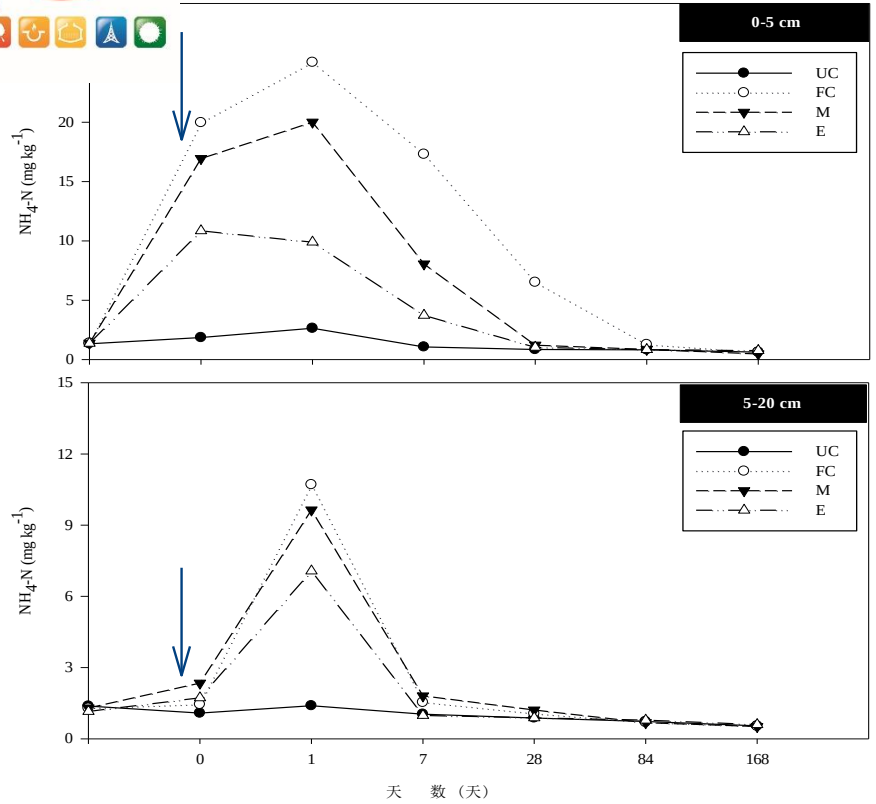


圖3-5 不同施肥處理下土壤剖面中NH_4-N隨時間的變化

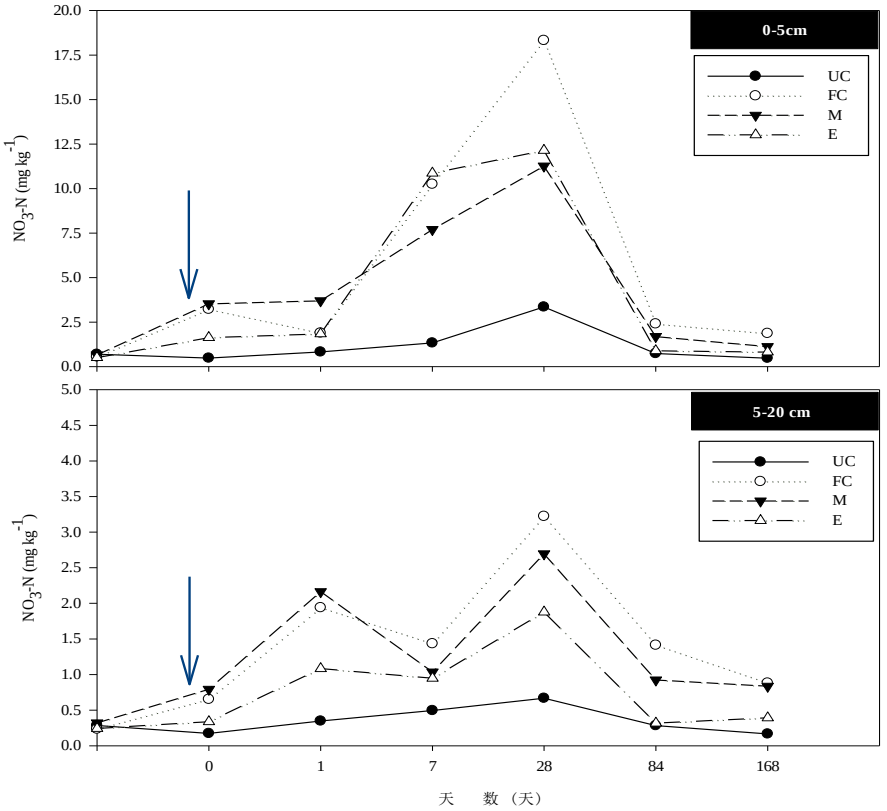


圖3-6 不同施肥處理下土壤剖面中NO_3-N隨時間的變化

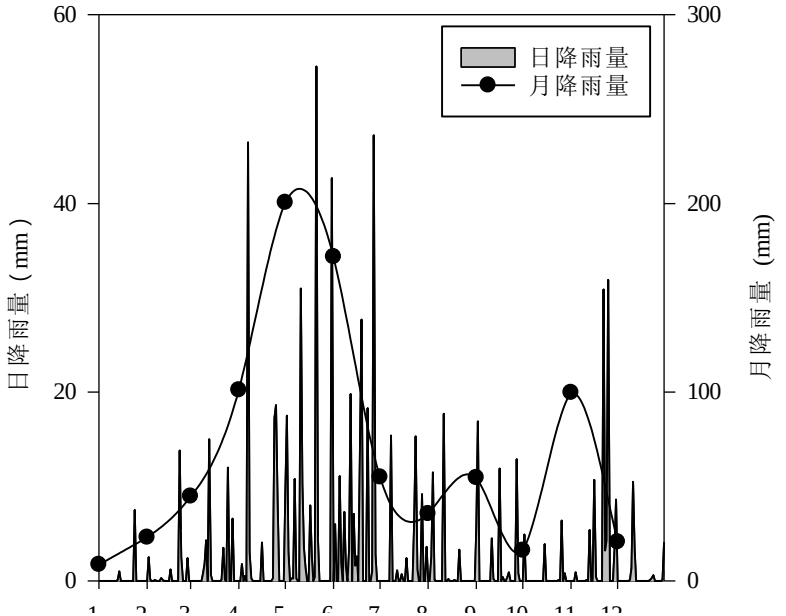
在硝化反應的作用下，肥料施用導入土壤中的大量NH_4-N隨時間的持續濃度逐漸降低，而土壤NO_3-N濃度不斷升高，並在第28 d達到峰值

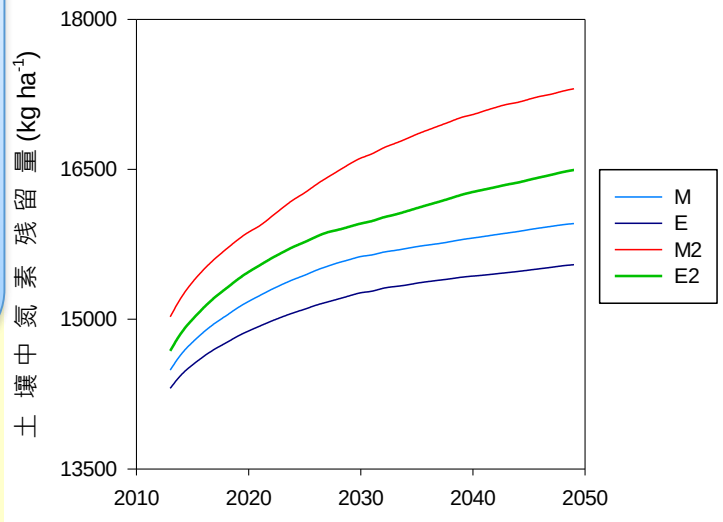
沼液沼渣農田施用後氮遷移轉化長期預測

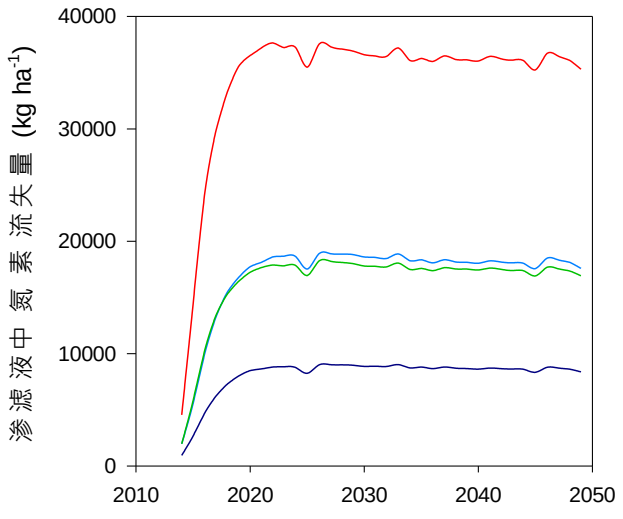
LONG-TERM PREDICTION OF N TRANSPORTATION IN SOIL AFTER DIGESTATES APPLICATION

利用2010年周年的降雨資料，預測了從2011年至2050年使用不同沼液的農田土壤中氮殘留量和滲濾流失量。發現農田施用沼液與化肥等氮的條件下，農田1 m深地下水中硝酸鹽的流失量逐年增加，在施用10年時間後會穿透1 m土層。

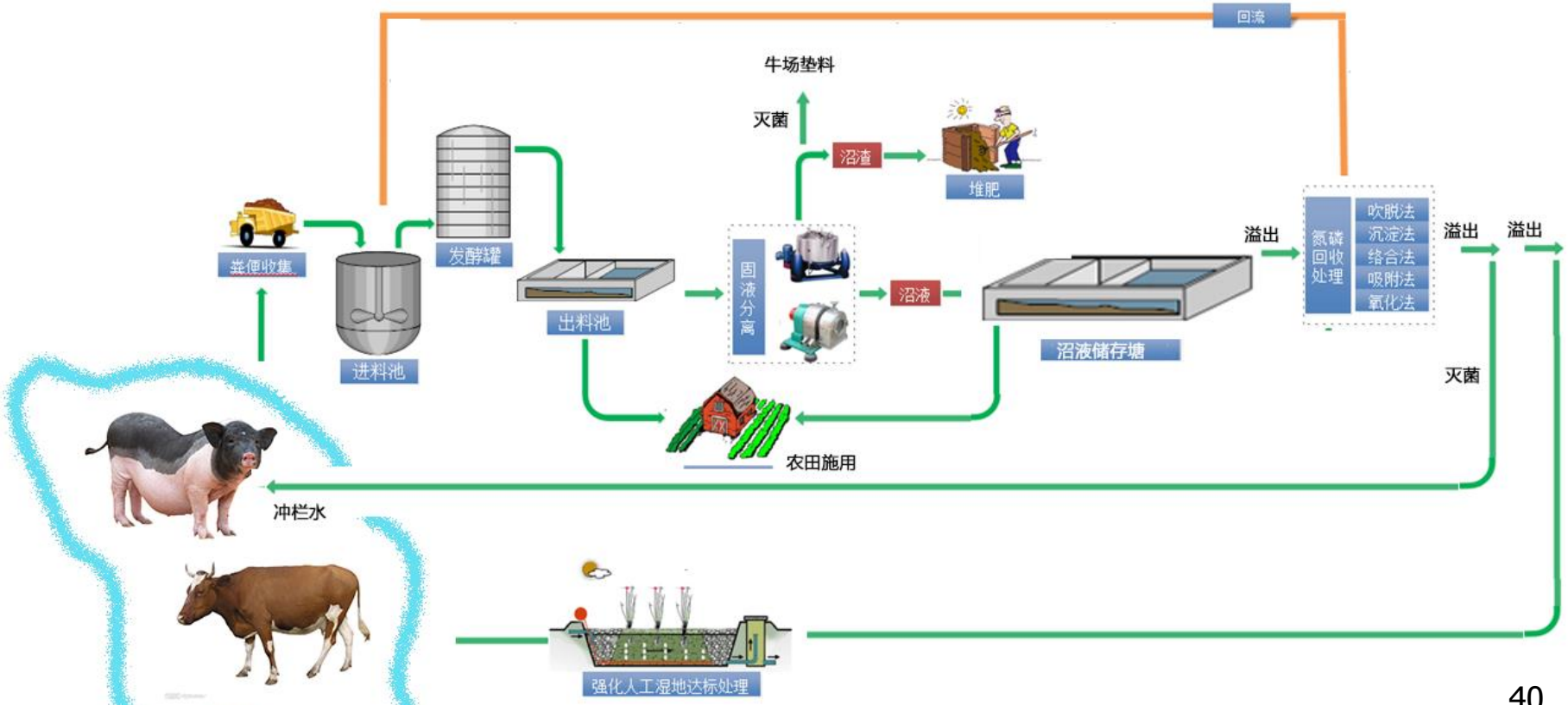
此模型還不成熟，未充分考慮長期沼液農田施用後土壤結構重構及土壤微生物功能相應，需要進一步開發及驗證。





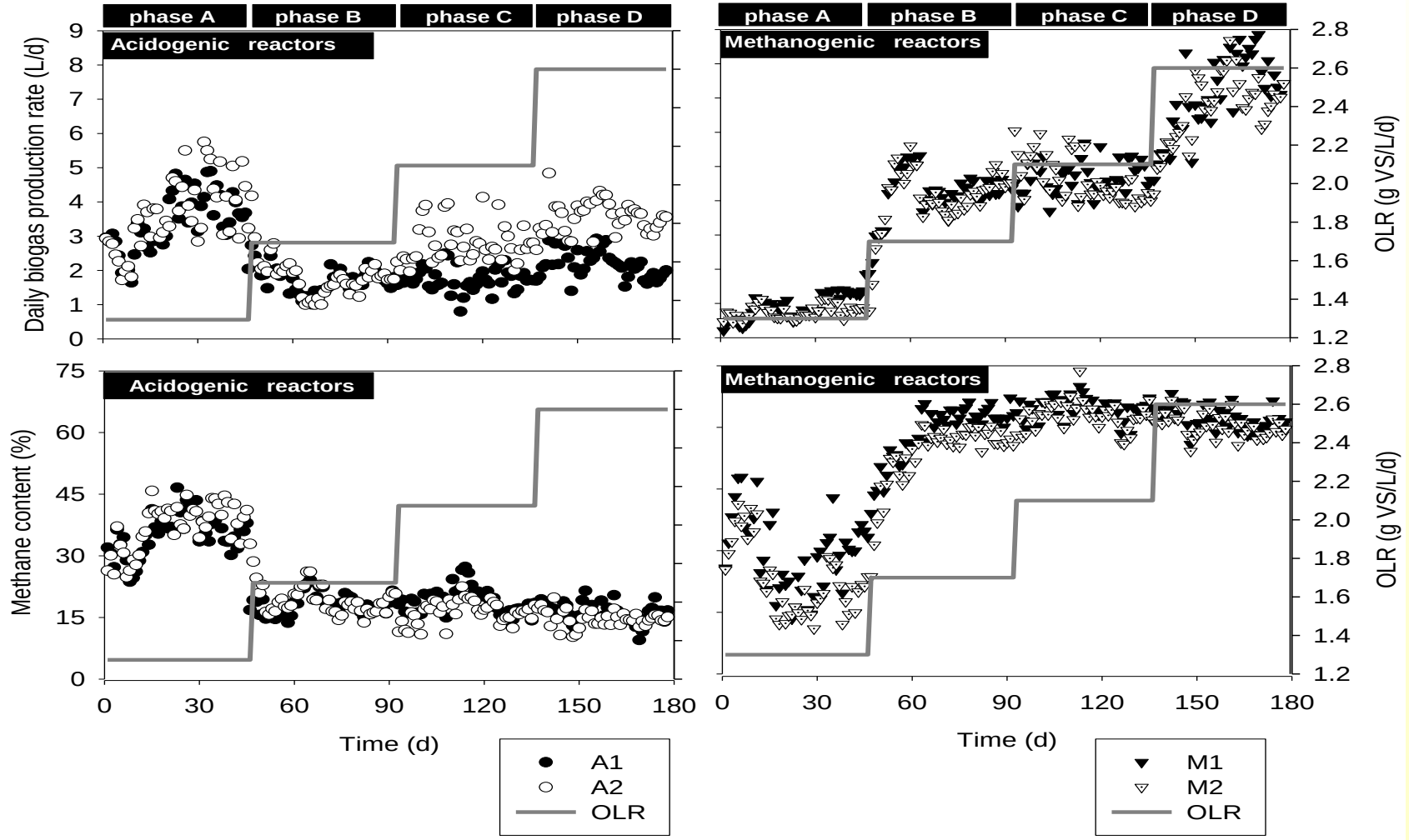


畜禽場沼液沼渣BEST解决方案
BEST Solutions for Livestock Farm BP



回流提高易降解原料產氣量，改善運行穩定性

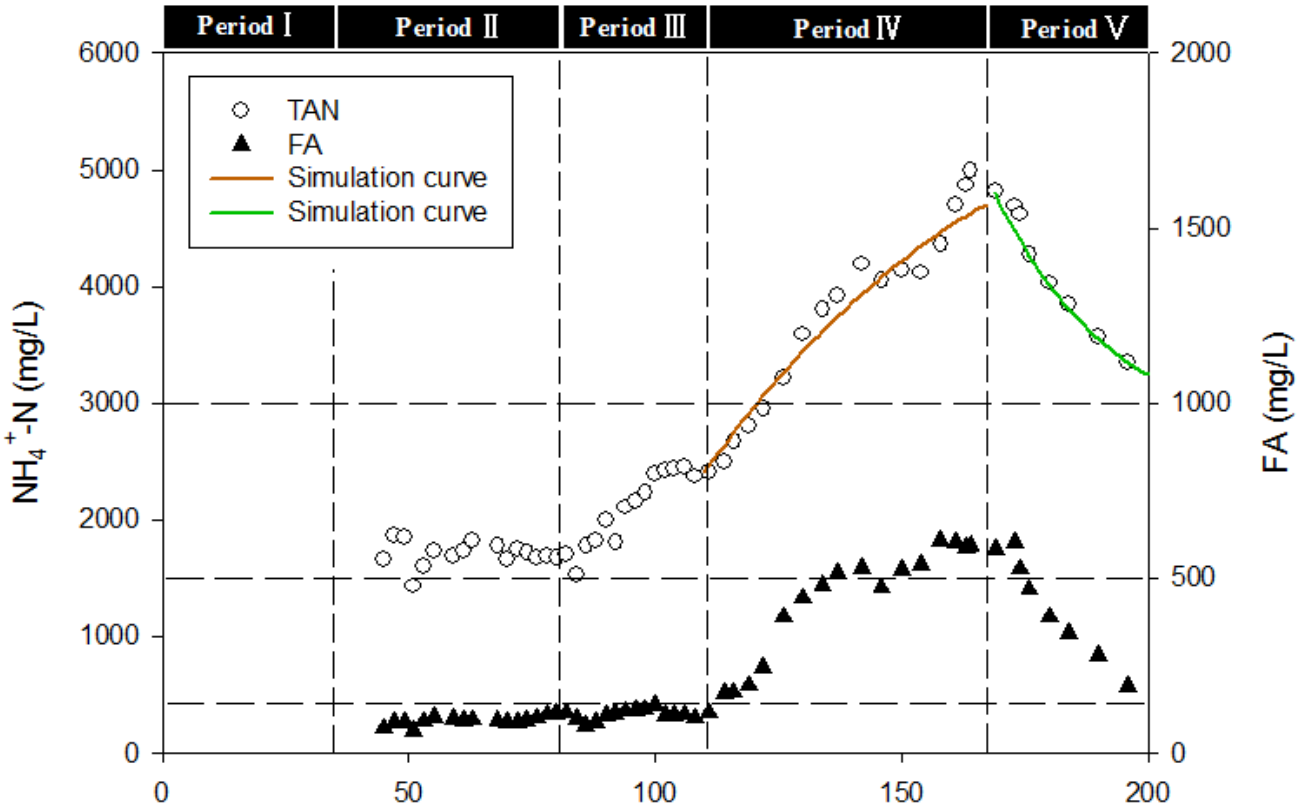
RECIRCULATION IMPROVES BIOGAS PRODUCTIVITY AND STABILITY



沼液回流的氨氮累積

DIGESTATES RECIRCULATION ON AMMONIA ACCUMULATION

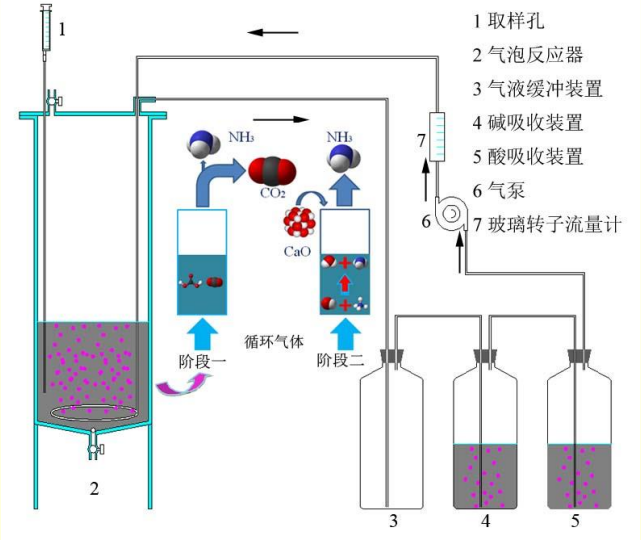
$$\frac{NH_3}{TAN} = [1 + \frac{10^{-pH}}{10^{-\left(0.09018 + \frac{2729.92}{T(K)}\right)}}]$$

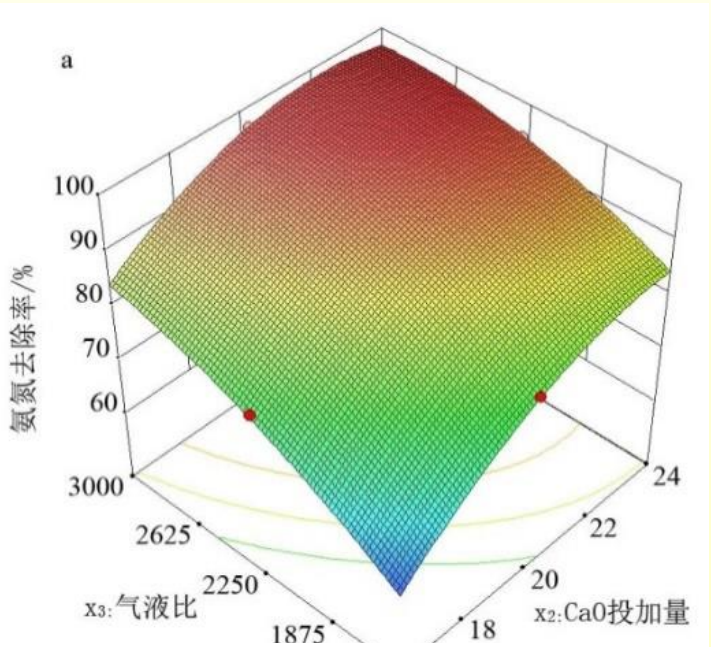


Kroeker et al (1979) reported the inhibitory TAN concentration that caused a 50% reduction in methane productionranging from 1.7 to 14 g/L;Hashimoto (1986) reported that both thermophilic and mesophilic processes are inhibited at a TAN of 2500 mg/L; Angelidaki and Ahring (1993) reported the concentrations of ammonia tolerated in livestock digestion at 3000-4000 mg/L; Gallert and Winter (1997) studied the anaerobic digestion of organic wastes and reported that methane production was inhibited 50% by 0.22 g/L FA at 37℃

沼液回流的氨氮累積
DIGESTATES RECIRCULATION ON AMMONIA ACCUMULATI

沼液密閉式迴圈吹脫系統，CO2的前期吹脫可有效降低沼液酸堿緩衝能力，減少後期投堿量30%。在氣液比300時沼液氨氮的脫除率為96. 8%。

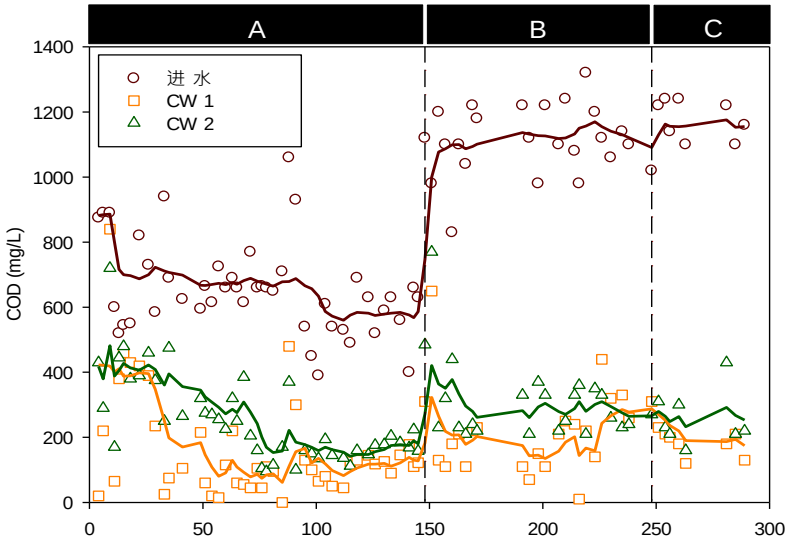


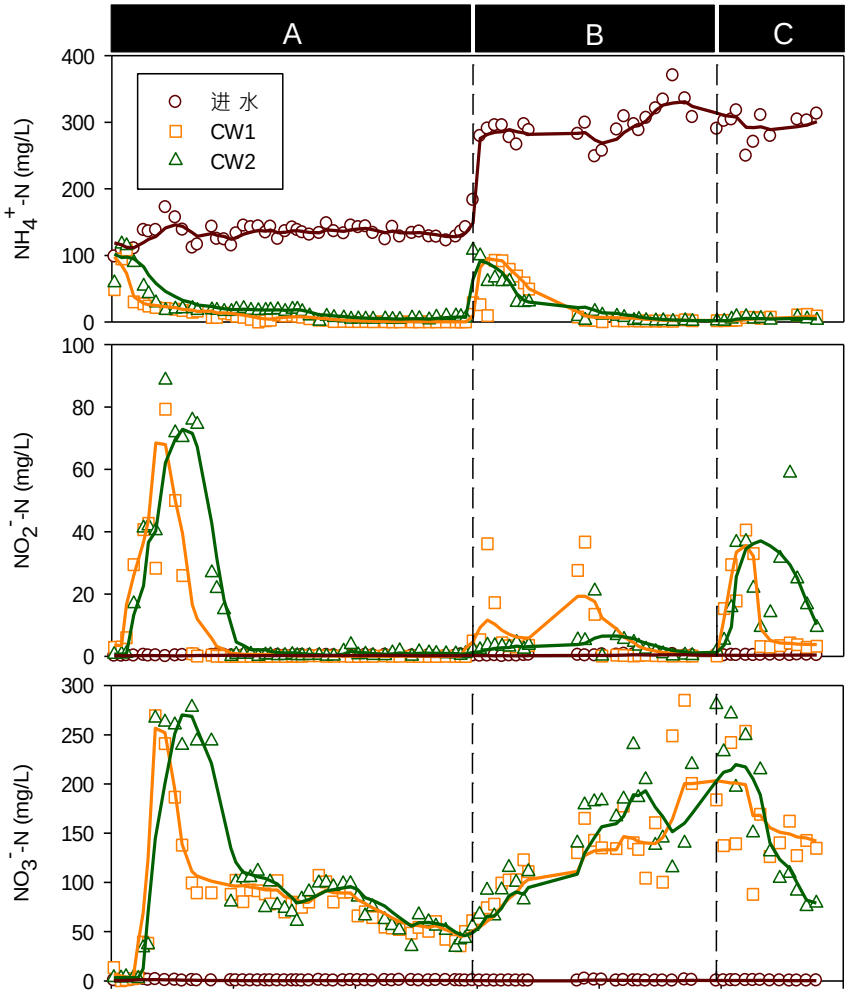


Liang Liu, Changle Pang, Shubiao Wu, Renjie Dong. Optimization and evaluation of an air-recirculated stripping for ammonia removal from the anaerobic digestate of pig manure [J]. Process safety and environmental protection, 2015, (94): 350-357.

強化人工濕地技術，處理不得不外排的微量沼液

ENHANCED CW FOR MINOR DISCHARGE OF DIGESTATE





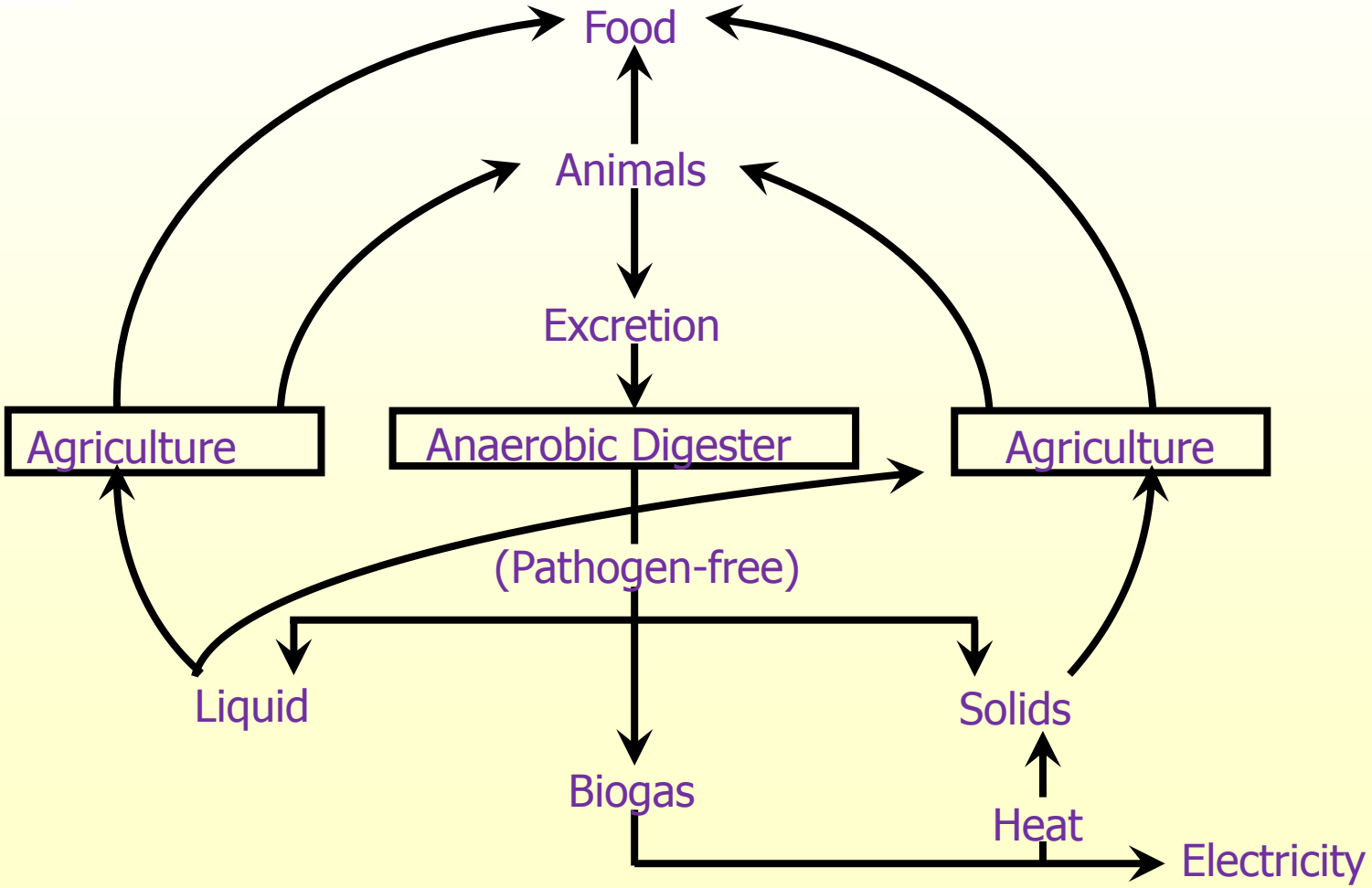
Shubiao Wu, Ming Lei, Qimin Lu, Luchen Guo, Renjie Dong. Intensified Treatment of Liquid Digestate from Anaerobic Digestion of Pig Manure in Horizontal Flow Constructed Wetlands: Effect of Aeration and Recirculation [J]. Environmental Pollution, 2015, Under Review.

沼氣工程沼液沼渣利用規範：有，不系統
REGULATIONS FOR RECYCLING/UTILIZATION OF DIGESTATES: YES BUT...

42：農作物沼肥施用技術，糧油作物沼肥施用技術，果樹、蔬菜施用技術，農作物沼液浸種技術，沼液噴施防治病蟲害技術，沼液無土栽培技術。沒有提及沼液儲存時間以及考慮環境風險而限制的最大施用量。

43：沼液利用必須經過消毒處理（臭氧100-200 mg/L，30 min），不包含沼液儲存及農田利用詳細要求。沼液的後處理技術為沼液-沉澱-曝氣池-穩定塘-膜生物反應器-消毒-排放。處理後向水體排放標準要滿足GB8978（幾級？）。其他後處理技術包括：氧化溝、A2O、生物濾池、SBR、仿生態塘、藻網濾床、人工濕地。

東方智慧，和則雙贏
COOPERATION: WIN-WIN



THANKS FOR YOUR ATTENTION

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謝謝

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