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Elio Dinuccio - Part 1 - CCP and mitigation strategies

UP FARMING Torino, April 2023

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Elio Dinuccio

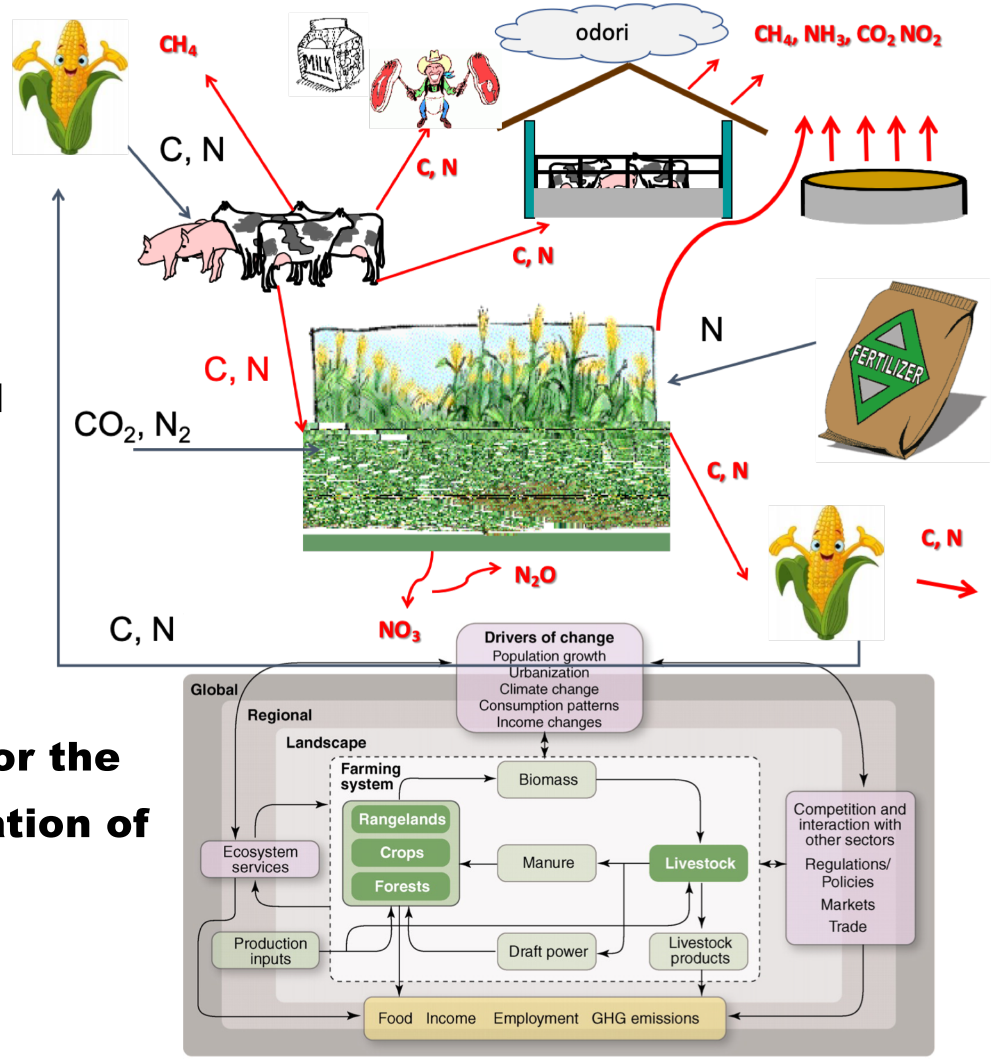
UP FARMING Torino, April 2023

Nutrient flow on livestock farms and interactions

technological innovation

knowledge and competences

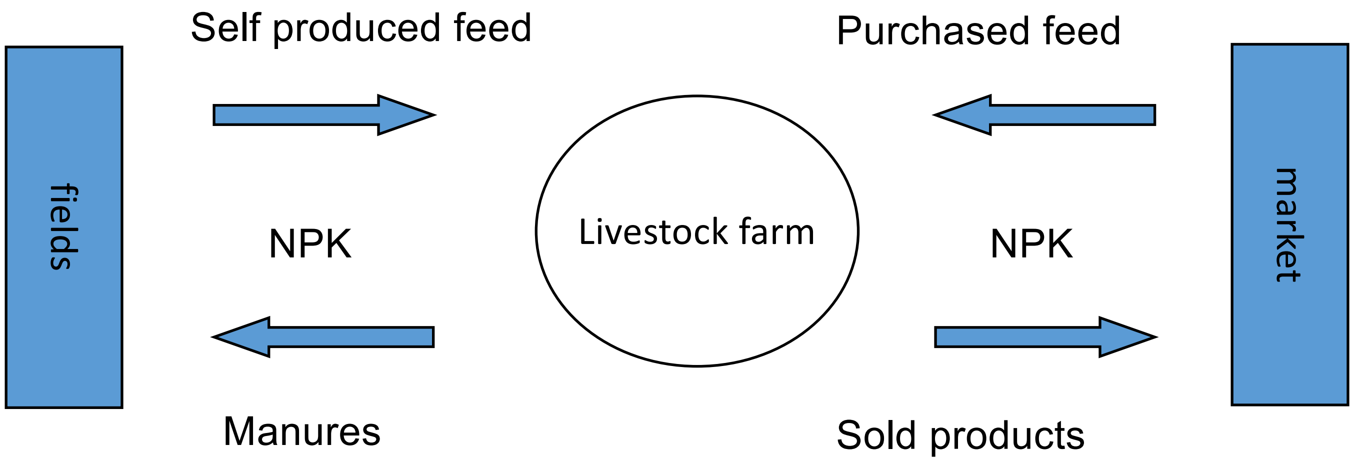
appropriate strategies for the management and valorisation of livestock manure



(Herrero et al. 2010)

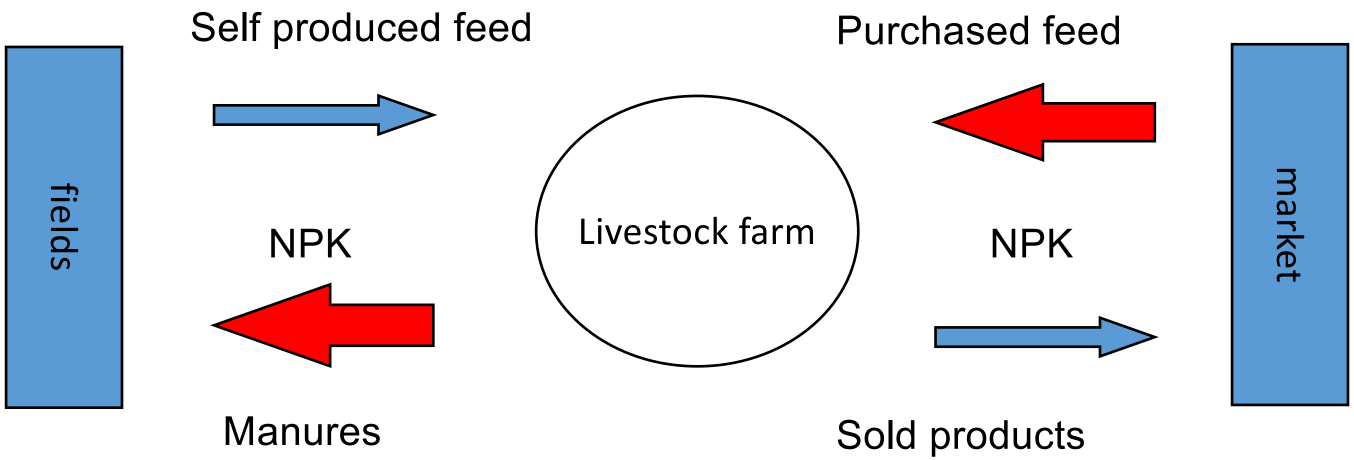
Balanced livestock farm

- The amount of nutrients taken by the crops is the same returned to the soil by livestock manures

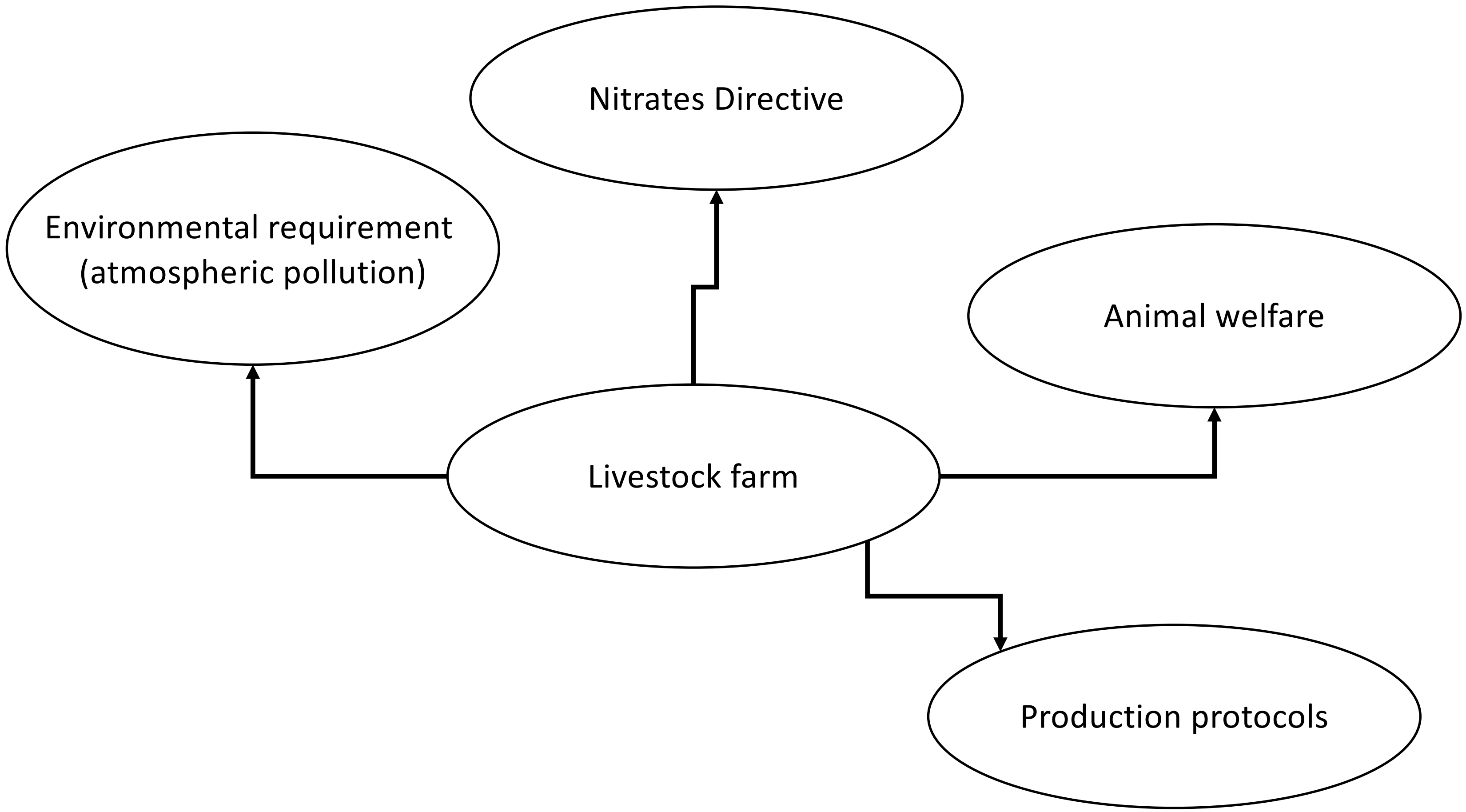


Unbalanced livestock farm

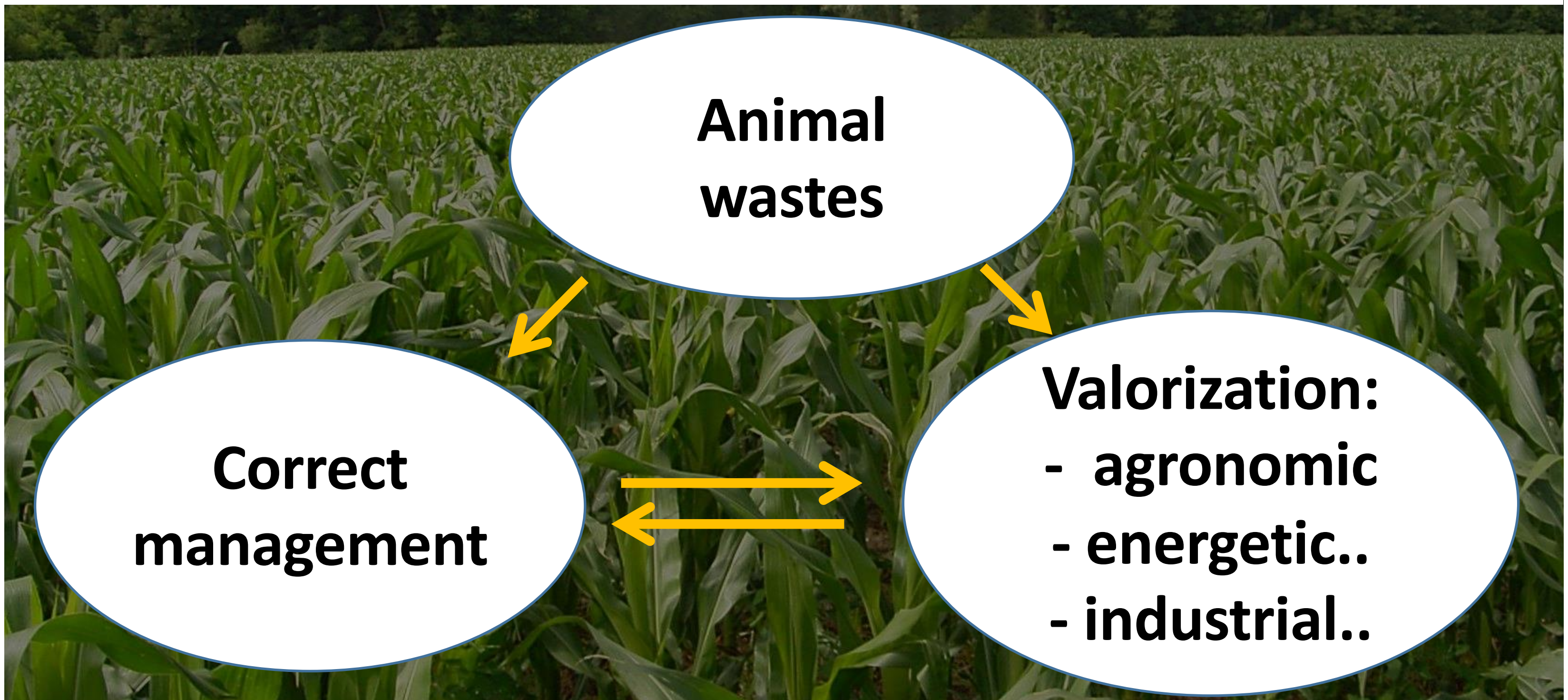
- If most feeds are purchased, manures contains an excess of nutritive elements → soil pollution



Farms have to fullfill several requirements



The correct animal waste management



☞ Animal wastes valorization is a key task but it's important to ensure their correct and sustainable management

Animal manures composition

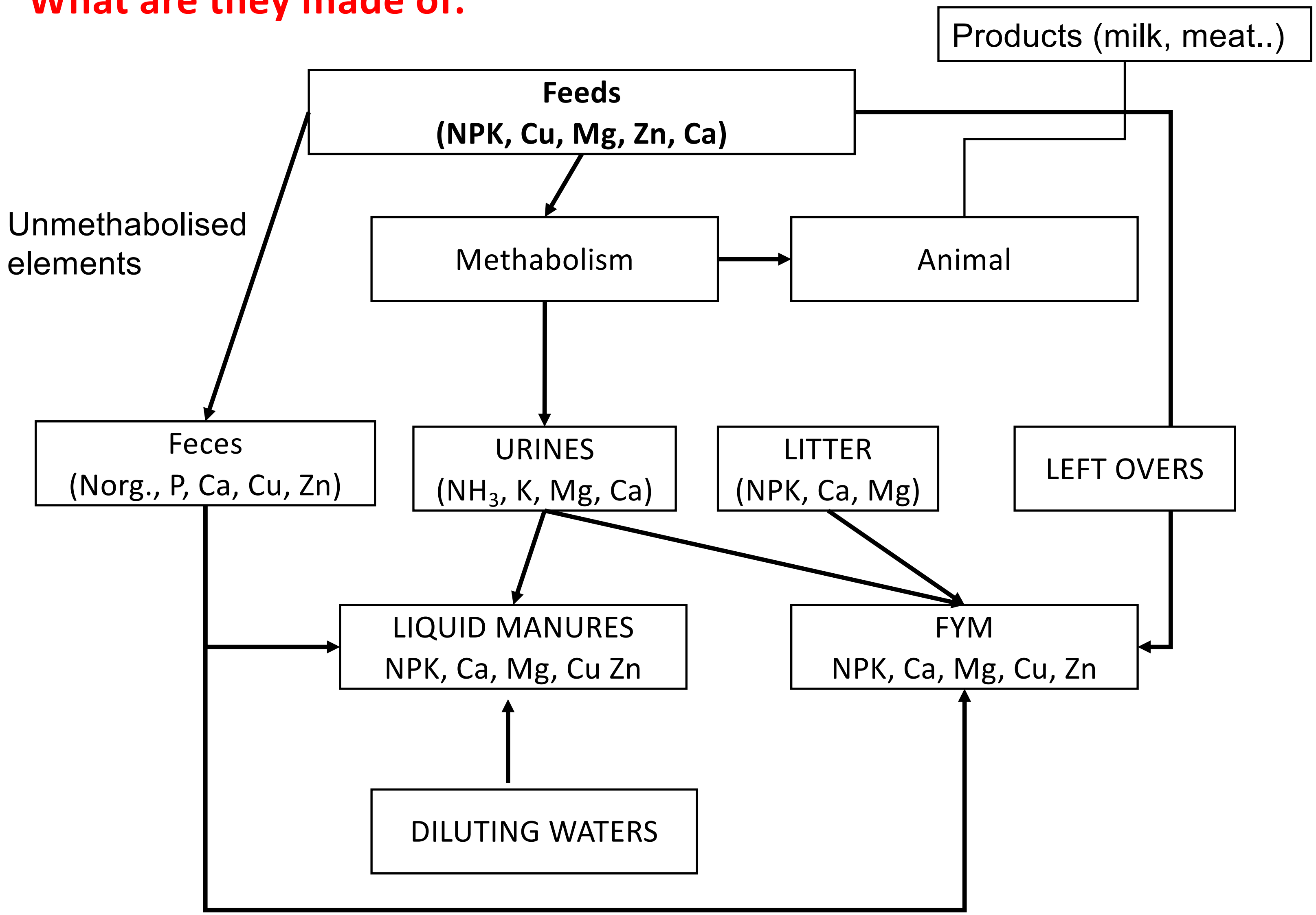
The knowledge of animal manures composition is necessary for:

- their correct agronomic utilisation
- the identification of the most reliable treatment technique
- their utilization for energy production purposes

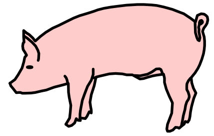
• What are they made of?

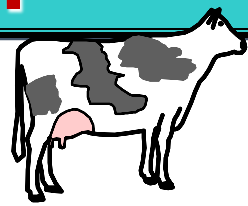
• What parameters can affect their composition?

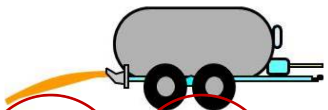
What are they made of:



Animal waste composition







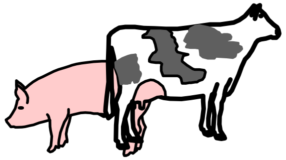
Slurry

	Sostanza Secca (% t.q.)	Solidi Volatili (% SS)	Azoto [a] (kg·t^{-1} t.q.)	Fosforo [b] (kg·t^{-1} t.q.)	Potassio [b] (kg·t^{-1} t.q.)	Rame (mg·kg^{-1} SS)	Zinco (mg·kg^{-1} SS)
Bovini da latte	10-16	75-85	3,9-6,3	1,0-1,6	3,2-5,2	40-70 [c]	150-750 [c]
Bovini da carne	7-10	75-85	3,2-4,5	1,0-1,5	2,4-3,9	40-70 [c]	150-750 [c]
Vitelli carne bianca	0,6-2,9 [d]	60-75	1,3-3,1	0,1-1,8	0,4-1,7	30-60	600-1100
Suini	1,5-6,0	65-80	1,5-5,0	0,5-2,0	1,0-3,1	250-800	600-1000 [e]

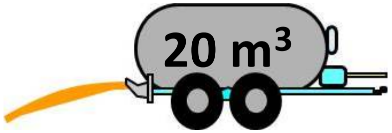
Solid manure

	Sostanza secca (% t.q.)	Solidi volatili (% SS)	Azoto (kg·t^{-1} t.q.)	Fosforo (kg·t^{-1} t.q.)	Potassio (kg·t^{-1} t.q.)
Letame bovino	20-30	75-85	3-7[a]	0,4-1,7[a]	3,3-8,3[a]
Letame suino [b]	25	70	4,7	1,8	4,5

Animal waste composition



Slurry



- **Fertilizer value:**

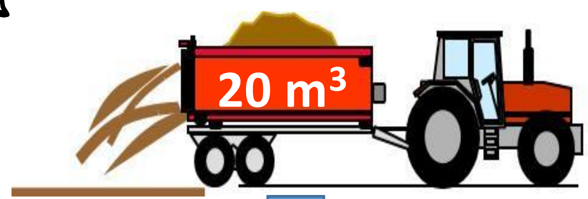
  84 kg N = 184 kg urea

  56 kg P_2O_5 = 122 kg triple superphosphate

  53 kg K_2O = 89 kg potassium chloride

  ≈ 300 kgCO_2eq

Solid Manure (FY)



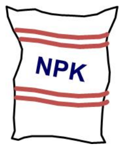
- **Fertilizer value:**

  76 kg N = 165 kg urea

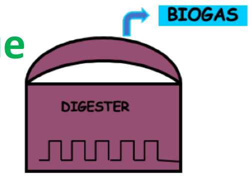
  45 kg P_2O_5 = 97 kg triple superphosphate

  124 kg K_2O = 206 kg potassium chloride

  ≈ 320 kgCO_2eq



- **Energetic value**



Animal wastes composition

Liquid manures

	Total solids (TS) (% WB)	Volatile solids (% TS)	Nitrogen (kg/t WB)	Phosphorous (kg/t WB)	Potassium (kg/t WB)
Dairy cattles	10-16	75-85	3,9-6,3	1,0-1,6	3,2-5,2
Cattles	7-10	75-85	3,2-4,5	1,0-1,5	2,4-3,9
Pigs	1,5-6,0	65-80	1,5-5,0	0,5-2,0	1,0-3,1

FYM (FarmYard Manure)

	Total solids (TS) (% WB)	Volatile solids (% TS)	Nitrogen (kg/t WB)	Phosphorous (kg/t WB)	Potassium (kg/t WB)
Cattle FYM	20-30	75-85	3-7[a]	0,4-1,7[a]	3,3-8,3[a]
Pig FYM	25	70	4,7	1,8	4,5

Total solids (TS):

determined by drying the sample in oven at 105°C (24hrs). It determines animal waste consistency

0-10%TS → liquid → liquid manure (slurry)

10-18% TS → semisolid

>18% TS → solid (palable) → solid manure (FYM)

Organic matter or volatile solids (VS):

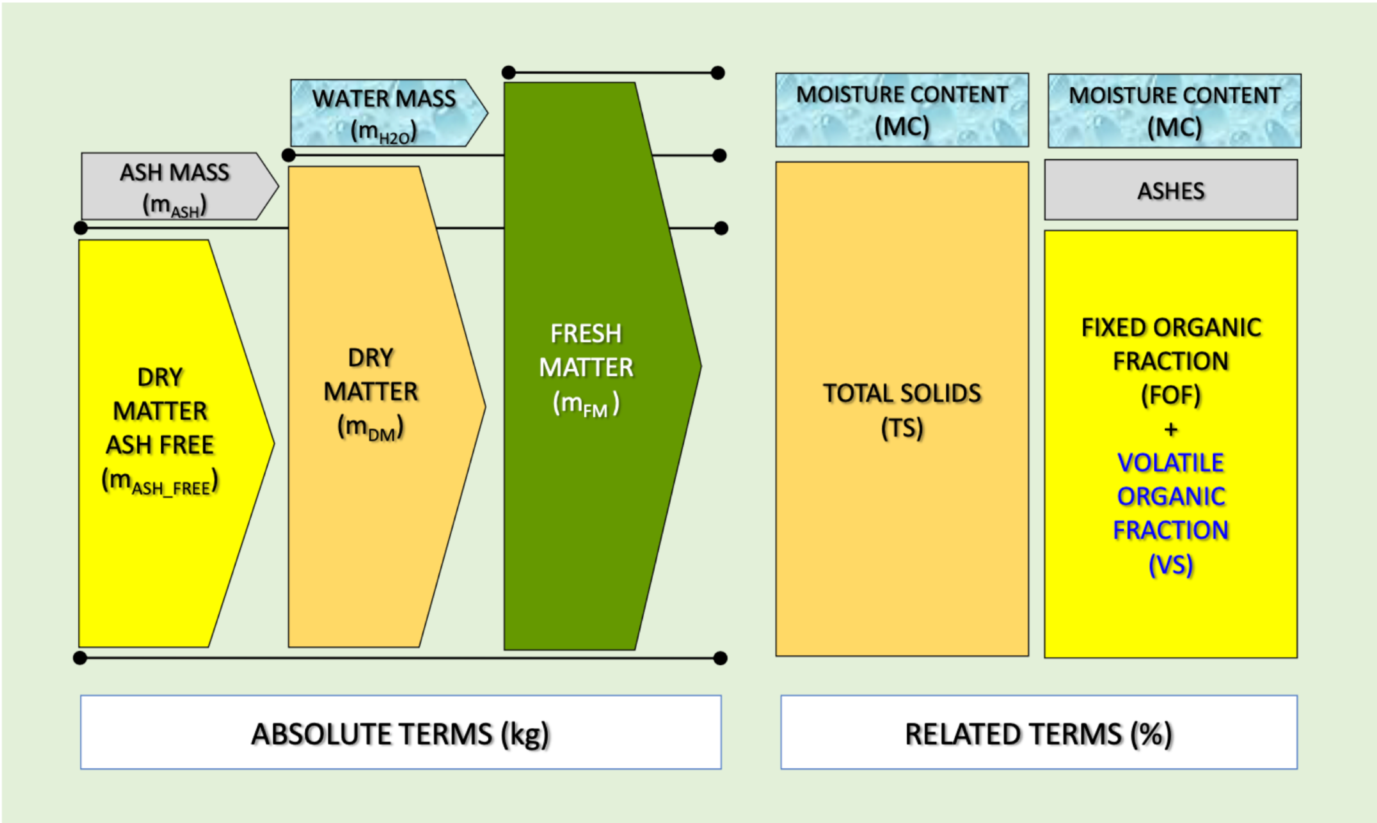
determined by incineration in muffle furnace (75-90% of TS) at 550°C for 4hrs

Ashes

inorganic fraction of animal wastes

Biomass chemical and physical properties

Mass composition



Exercise

- Results of a solid manure (FYM) analysis:
  - Initial weight: 500g
  - Final weight after drying: 115g
  - Weight after incineration (ashes): 24g

Calculate:

1) the amount (g) of total solids (TS)
2) the amount (g) of volatile solids (VS)
3) The amount (g) of water lost
4) The % of TS with respect to raw manure (wet basis);
5) The % of VS with respect to raw manure (wet basis);
6) The % of VS with respect to TS (dry basis)

TS (g) = 115g
VS (g) = total solids – ashes = 115g – 24 g = **91g**
Water (g) = manure (wet basis) – total solids = 500g – 115g = **385g**
TS (%) = final weight drying/initial weight → 115g/500g = 0,23 = **23% (wet basis)**
VS (% wet basis) = weight of VS/weight of raw manure = 91g/500g = 0,182 = **18,2%**
VS (% of TS) = weight of VS/weight of TS = 91g/115g = 0,79 = **79%**

Nitrogen:

present in animal wastes in two forms:

- organic (available for the crops after mineralisation)
- inorganic ($N\text{-}NH_3$) immediately available for the crops (up to 70% of total nitrogen).

⇓

Problem: losses of ammonia nitrogen from:

barns/paddocks
Manures storage
Manures land application

Phosphorous:

present in animal wastes mainly in inorganic form:

- up to 85% of total phosphorous

Microelements (Cu, Zn):

given to animal with rations are expelled with dejections at high ratio: over the 75% (Cu) and 90% (Zn)

⇩

Accumulation in soils

How to determine the chemical characteristics of animal manures (slurry)

1) sampling

Representativity of the collected samples: homogeneity and sampling point

How to determine the chemical characteristics of animal manures (slurry)

- Slurry mixing

- Reliable sampling systems (eg. devices for slurry collection at different depths)

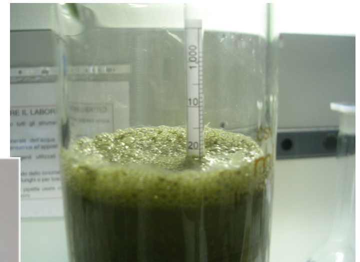
How to determine the chemical characteristics of animal manures (slurry)

2) measurement

Laboratory analysis (expensive, time consuming)

Quick methods

- Densimetric method
- Quantofix
- Conductimeters
-




How to determine the chemical characteristics of animal manures (solid manures)

1) sampling

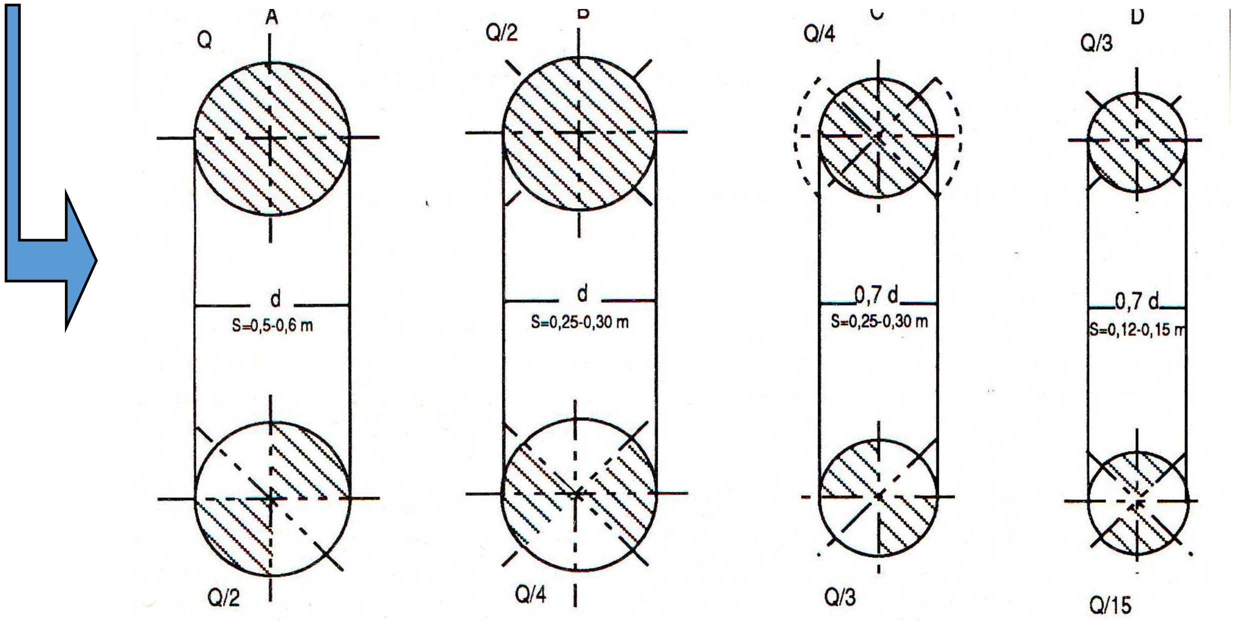
Problem of representitivity of the collected samples (sampling point, homogeneous sample)

How to determine the chemical characteristics of animal manures (solid manures)

1) Sampling

- Collection at different position and depths

- Quarter method (time consuming – difficult to apply)



How to determine the chemical characteristics of animal manures (solid manures)

2) measurement

No quick methods for chemical analysis are available

⇓

Laboratory analysis

Chemical composition of slurry along one week

Campione	ST (%)	SV (%)	SV/ST (%)	N-Kyeldahl (‰)	$N\text{-}NH_3$ (‰)	P_2O_5 (‰)	K_2O (‰)	BOD_5 (mg/1)	COD (mg/l)
1	5,36	3,94	73,5	4,34	2,66	4,40	3,45	n.d.	n.d.
2	6,33	4,74	74,9	4,72	2,96	4,50	2,80	15.300	47.000
3	6,97	5,26	75,5	4,84	3,17	5,00	3,70	18.100	54.400
4	3,80	2,67	70,3	3,69	2,45	3,05	2,90	14.000	39.000
5	3,27	2,30	70,3	3,25	2,33	2,40	3,75	6.300	30.000
6	5,06	3,73	74,9	4,48	3,17	3,50	3,06	14.000	35.600
7	4,60	3,41	74,1	4,48	3,25	3,60	3,69	16.500	41.000
Media	5,05	3,72	73,4	4,26	2,86	3,78	3,34	14.033	41.167

Animal waste composition is very variable and depends on:

- Breed
- Methabolism
- Diet
- System for manure collection/removal
- NH_3 losses
- Manure dilution

Why manures are diluted?

- Rainfall (uncovered storage tanks)
- Cleaning waters
- Drinking waters

- It's necessary to reduce water content of slurry

- High pressure cleaning systems
- Intervention on animal diet, drinking system able to reduce the waste of water (pig often plays with water)

Advantages in reducing slurry volumes

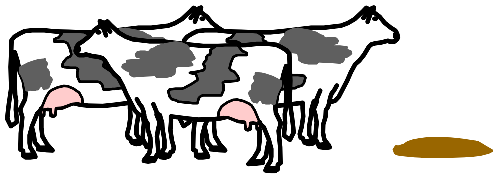
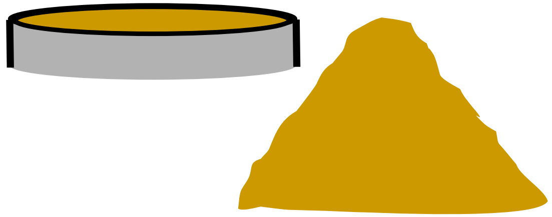
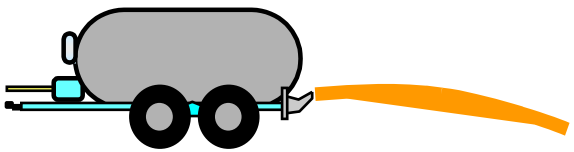
- Smaller storage tanks
- Cheaper treatment systems
- Lower expenses for land application and transport
- Higher fertilising value

Main environmental problems related to manure management

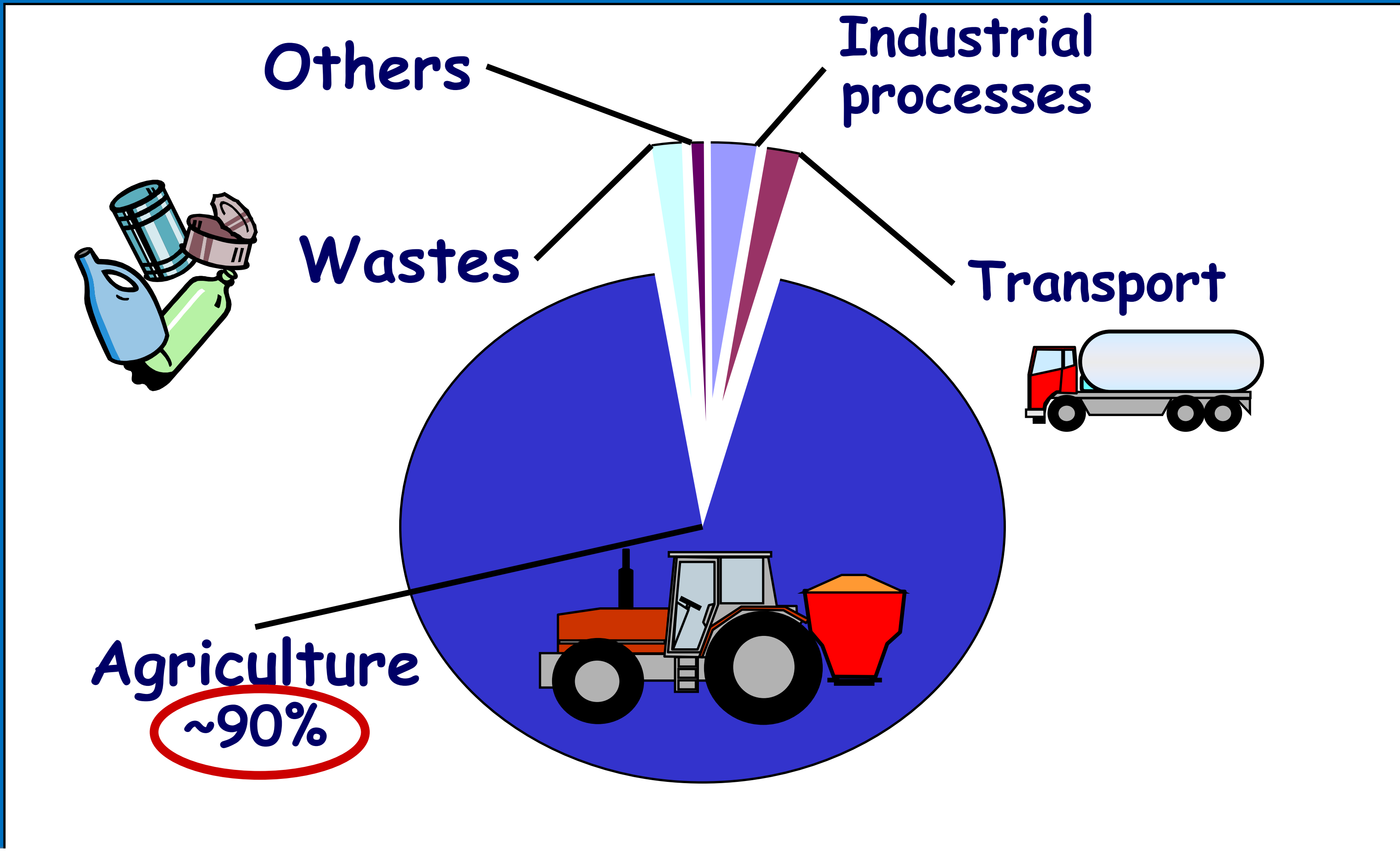
Soil and water pollution
(N, P, heavy metals)

Air pollution
(NH_3, CO_2, CH_4, N_2O, odours)

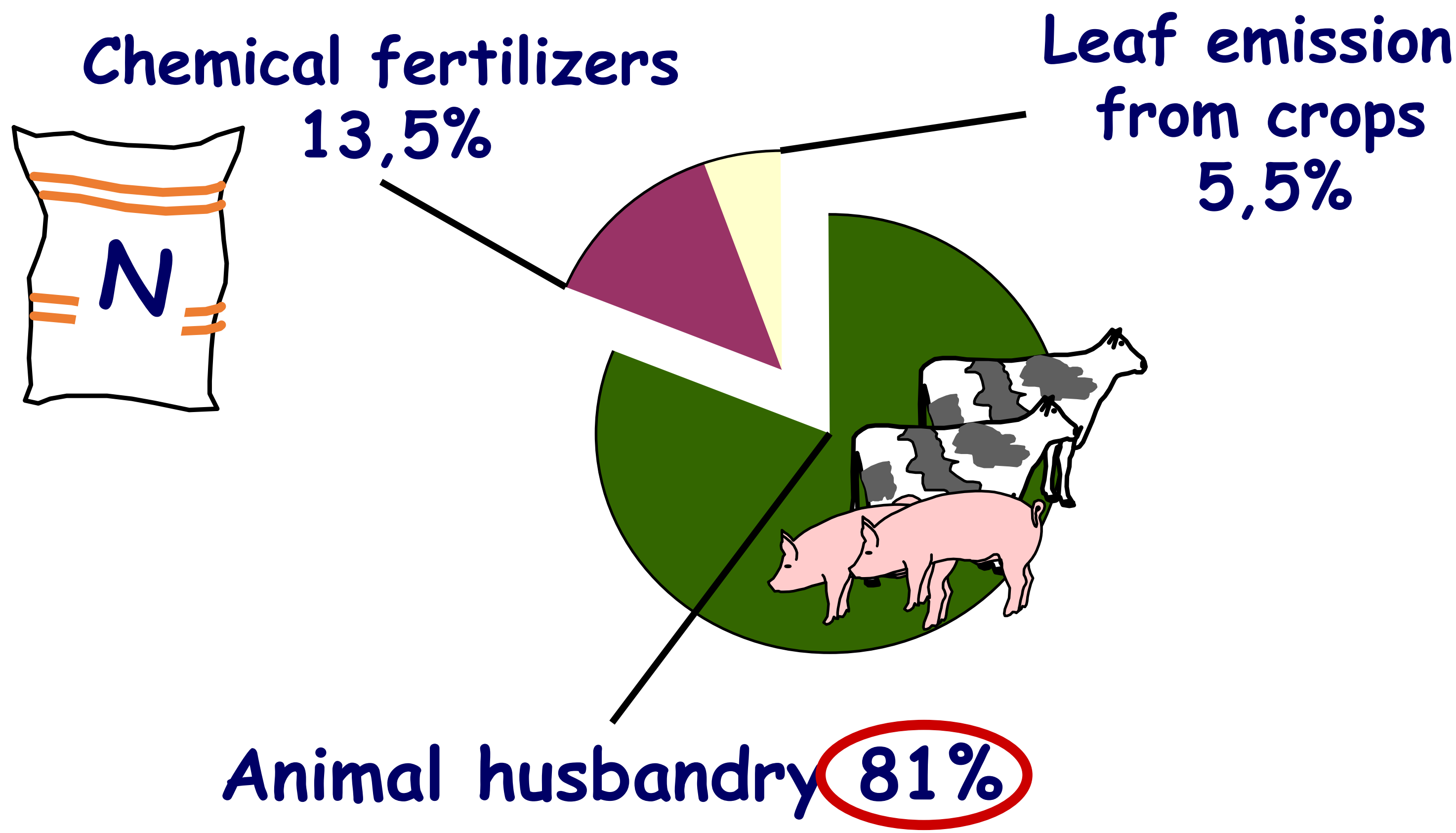
Gaseous emissions from livestock farms

	NH_3	CH_4	N_2O
	+	+++	+
	++	+	-/+
	+++	-	+++

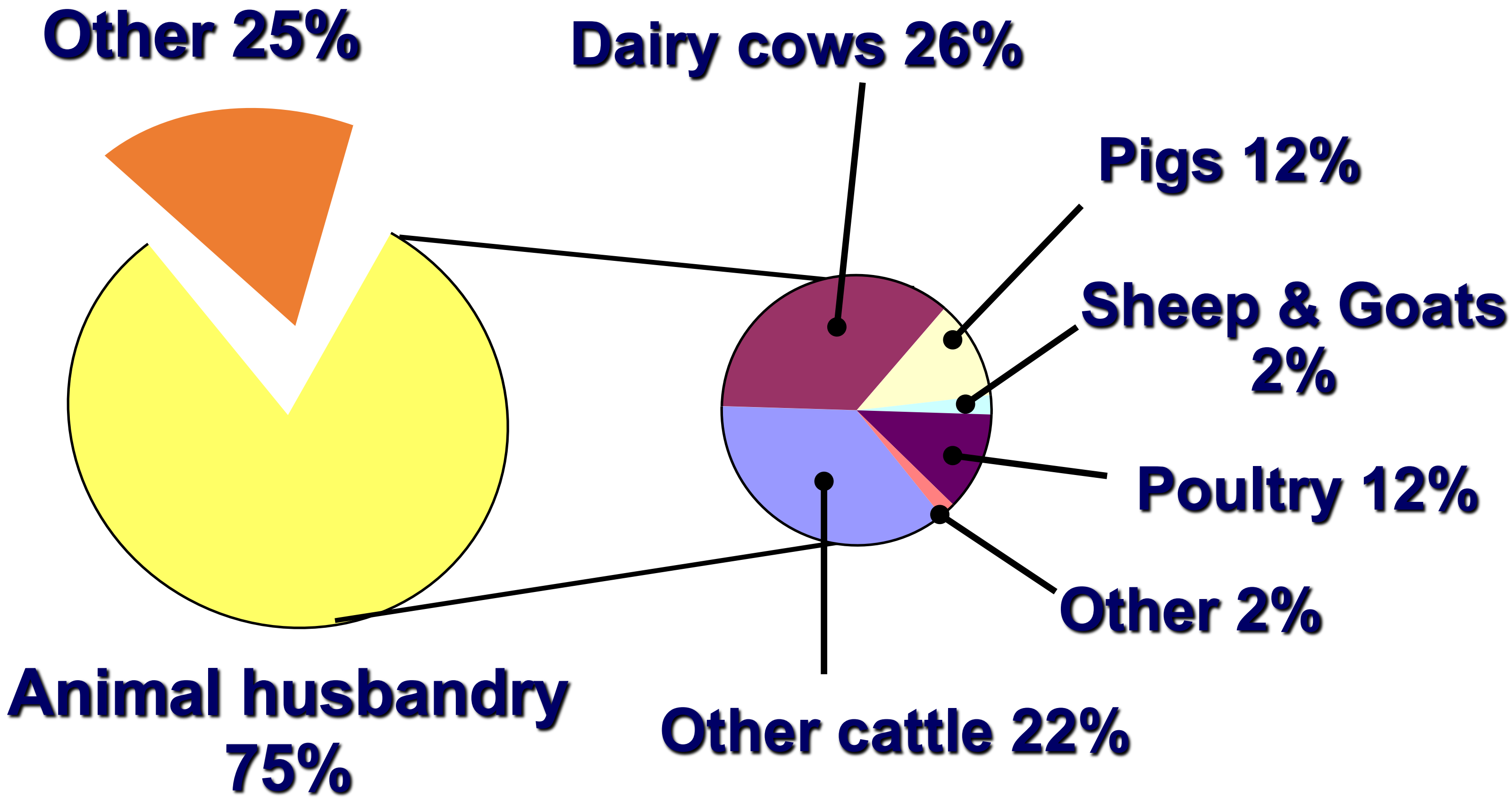
European NH_3 emissions by sector



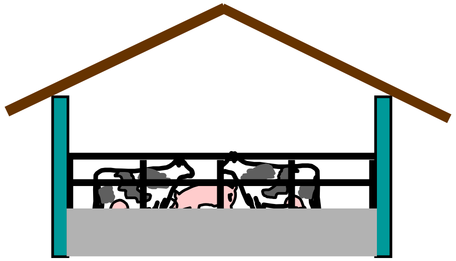
Agricultural NH_3 emissions in Europe



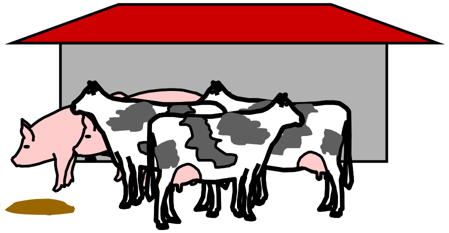
Agricultural NH_3 emissions in Italy

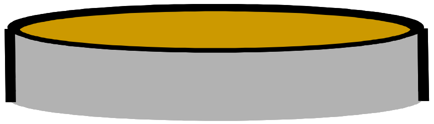


NH_3 emissions from manure management

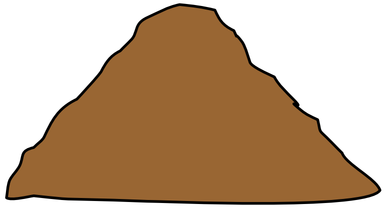


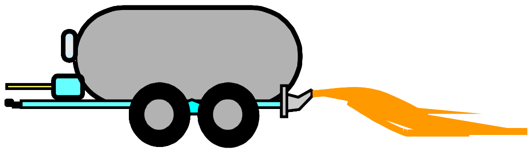
Buildings: 5-25%



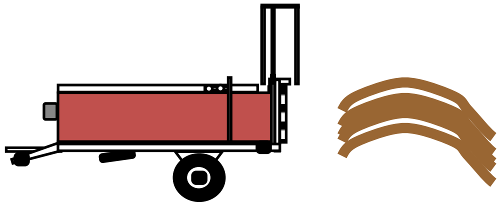


Storage: 15-25%



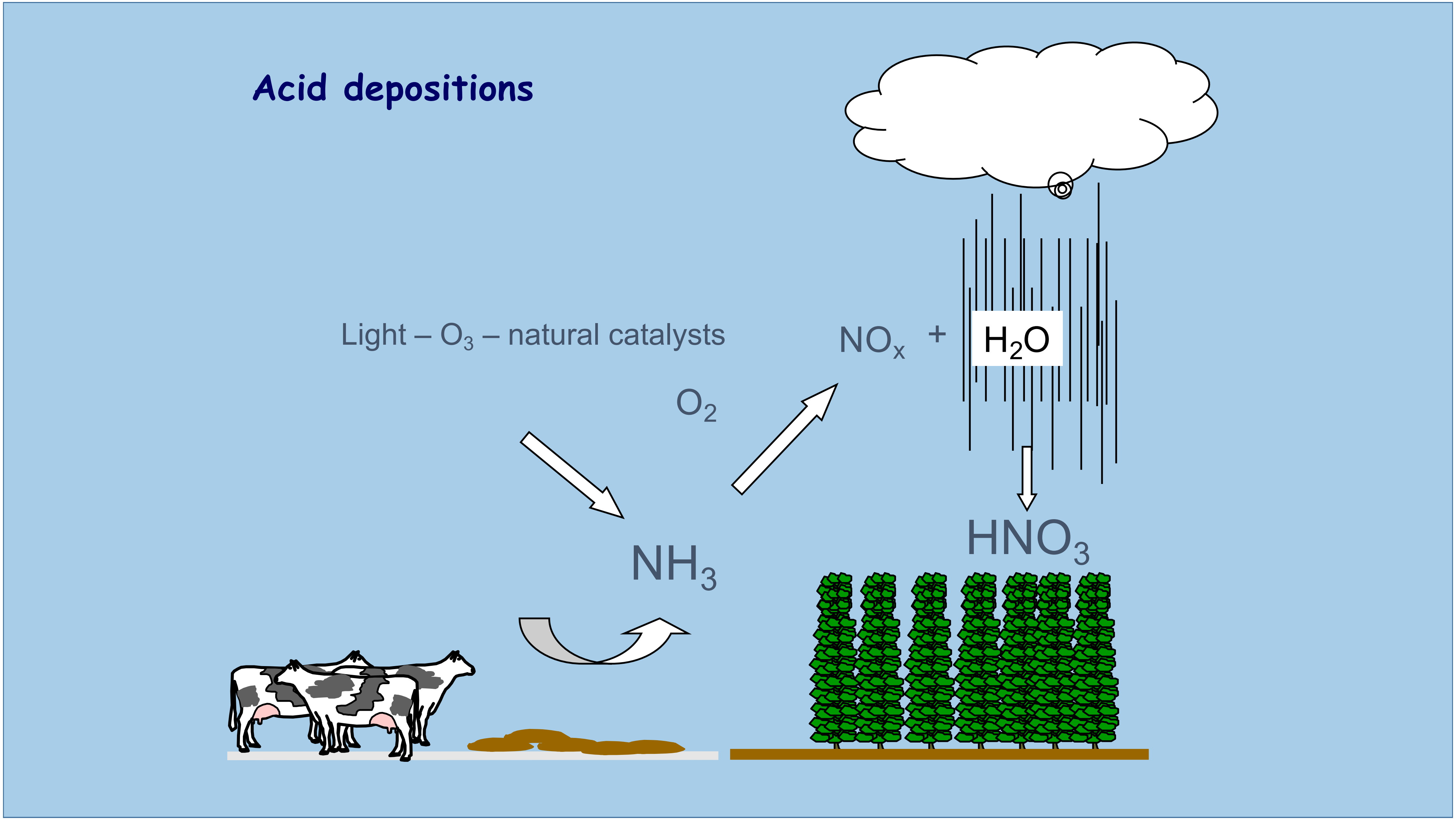


Land application:
45-80%



Gaseous emissions from animal manure management: NH_3

- Environmental pollution
  - Degradation of aquatic and terrestrial ecosystems
- Health hazards for humans and animals
- Contribute to the atmospheric particulate matters ($PM_{2.5}$)
- Economic loss for farmer
- Contribution to the N_2O formation by increasing the N-cycling in natural ecosystems
  - Indirect effect on global warming → GWP= 2.65
- Acid rains



Acid depositions
Light – O_3 – natural catalysts
NO_x + H_2O
O_2
NH_3
HNO_3

NH_3 SOME CHARACHTERISTICS

Pungent smell

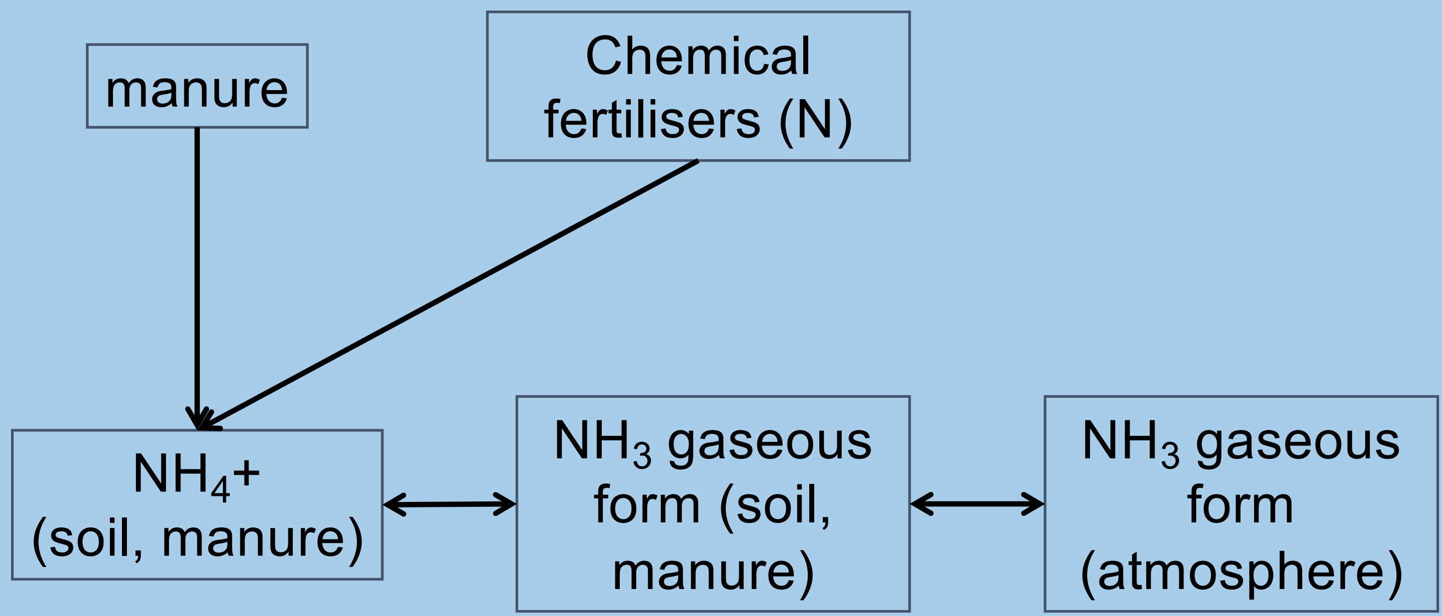
Corrosive on metals

Highly soluble in water

Toxic: 15mg/m^3 air

Can be explosive when in contact with some metals (e.g Hg)

NH_3 how it is emitted to air



The reaction is strongly influenced by pH

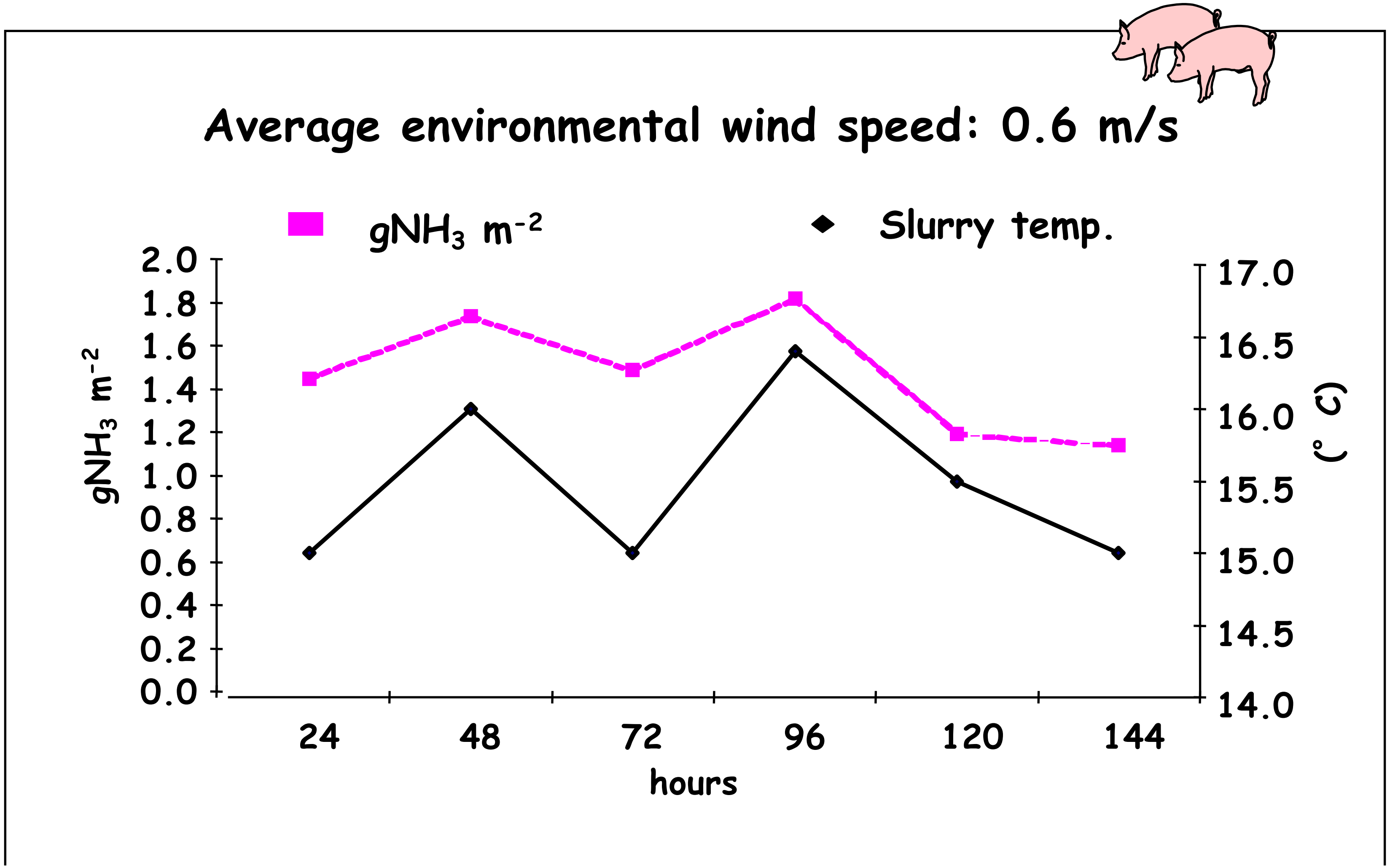
AMMONIA EMISSION FROM STORAGE

Factors affecting NH_3 emissions from stored manure

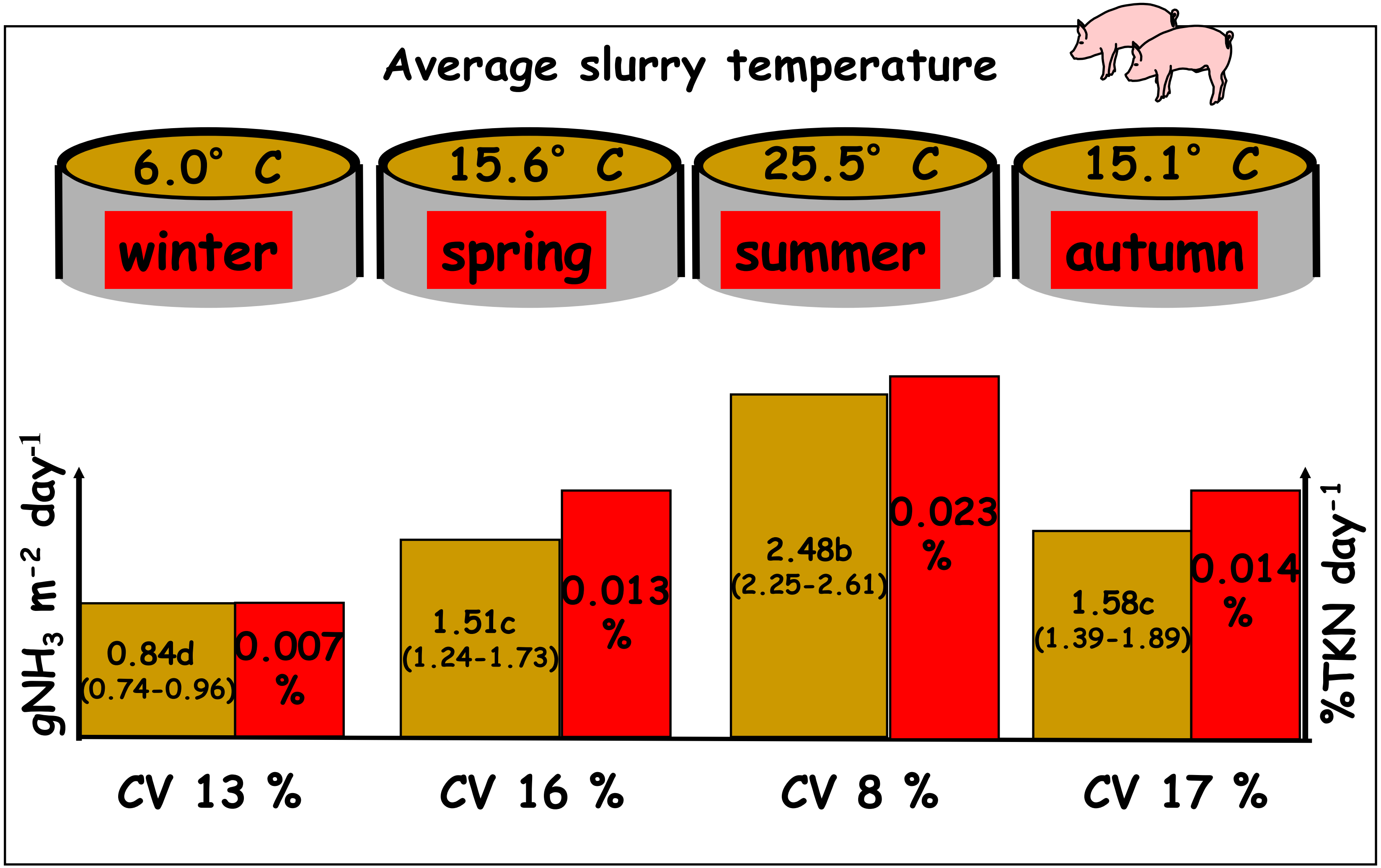
☞ **Losses affected by:**

- **Manure characteristics:**
  - TS content, pH, TKN, NH_4-N,
- **Weather conditions**
  - temperature, wind speed
- **Manure management type**
  - solid-liquid separation, anaerobic digestion, ….

Ammonia emissions from pig slurry storage: effect of temperature

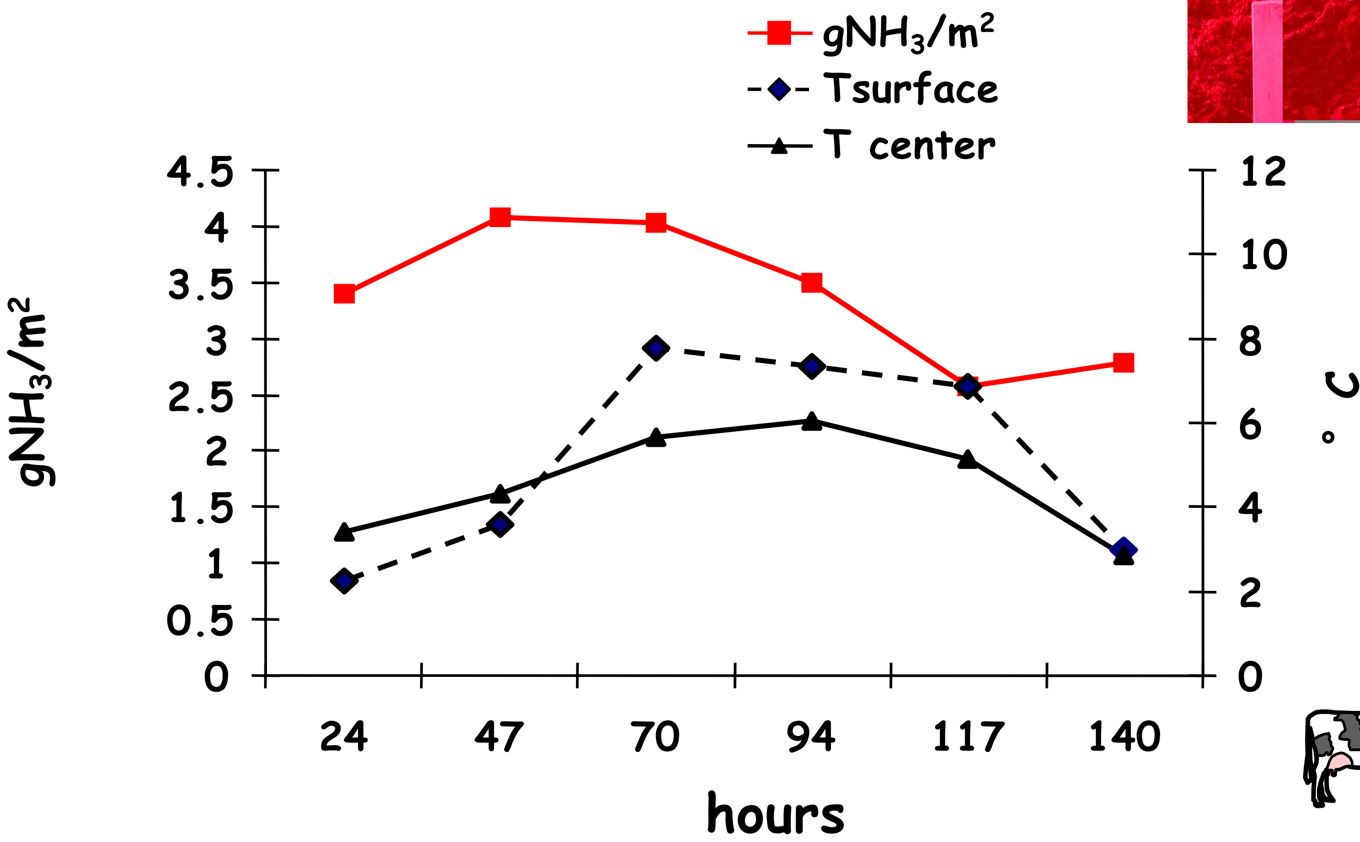


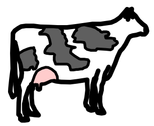
Ammonia emissions from pig slurry storage: effect of temperature



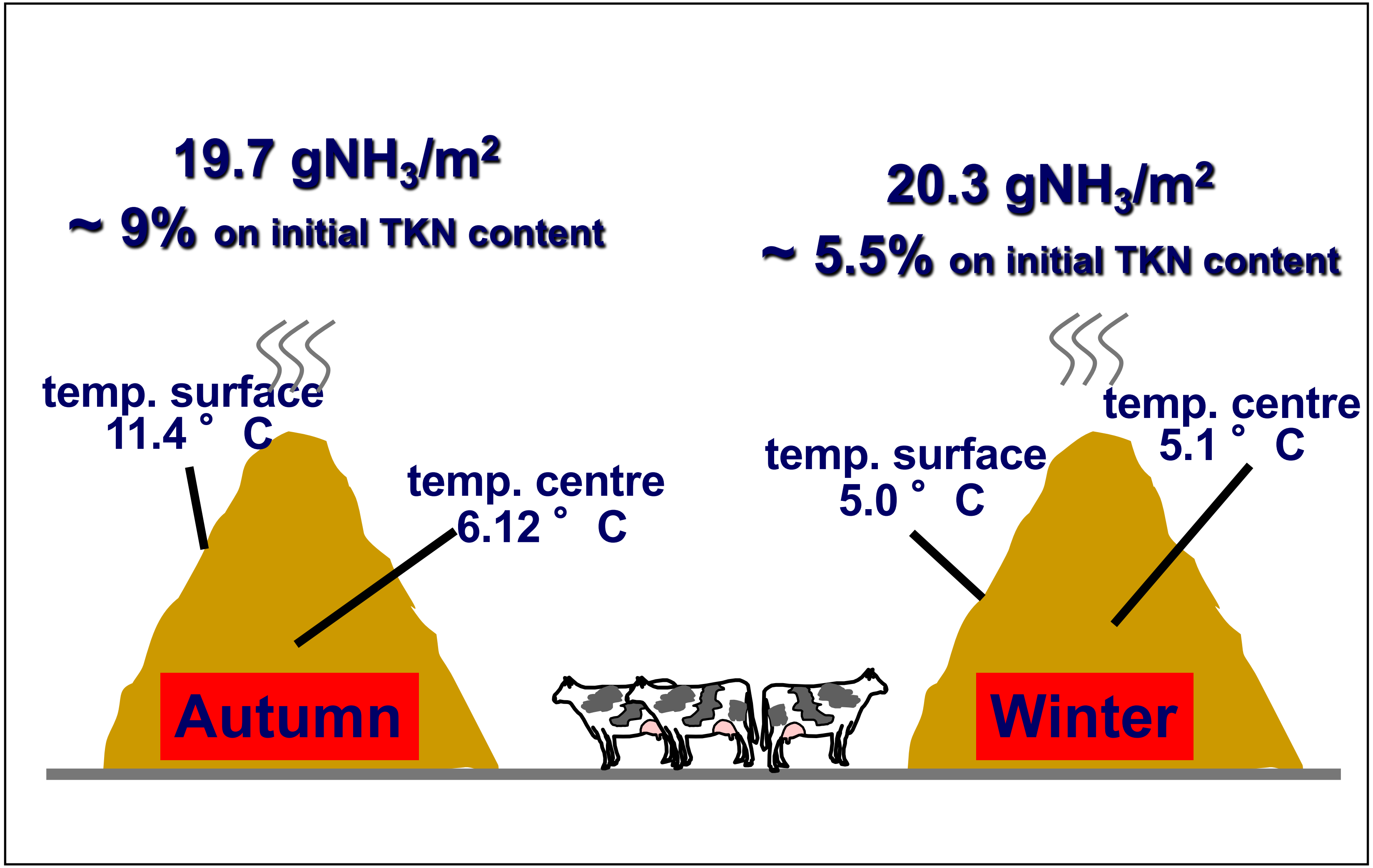
Ammonia emissions from FYM heaps

Effect of heap temperature

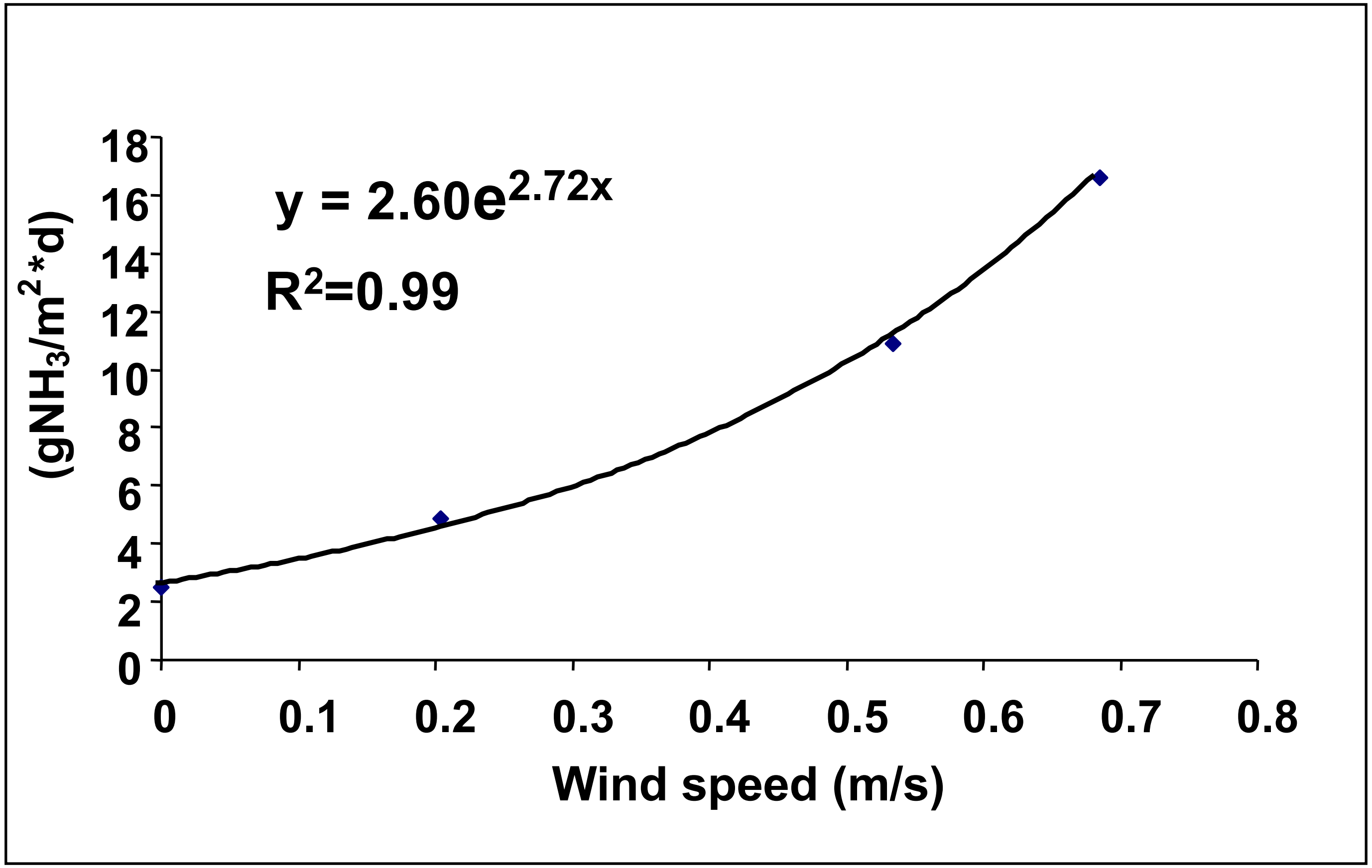




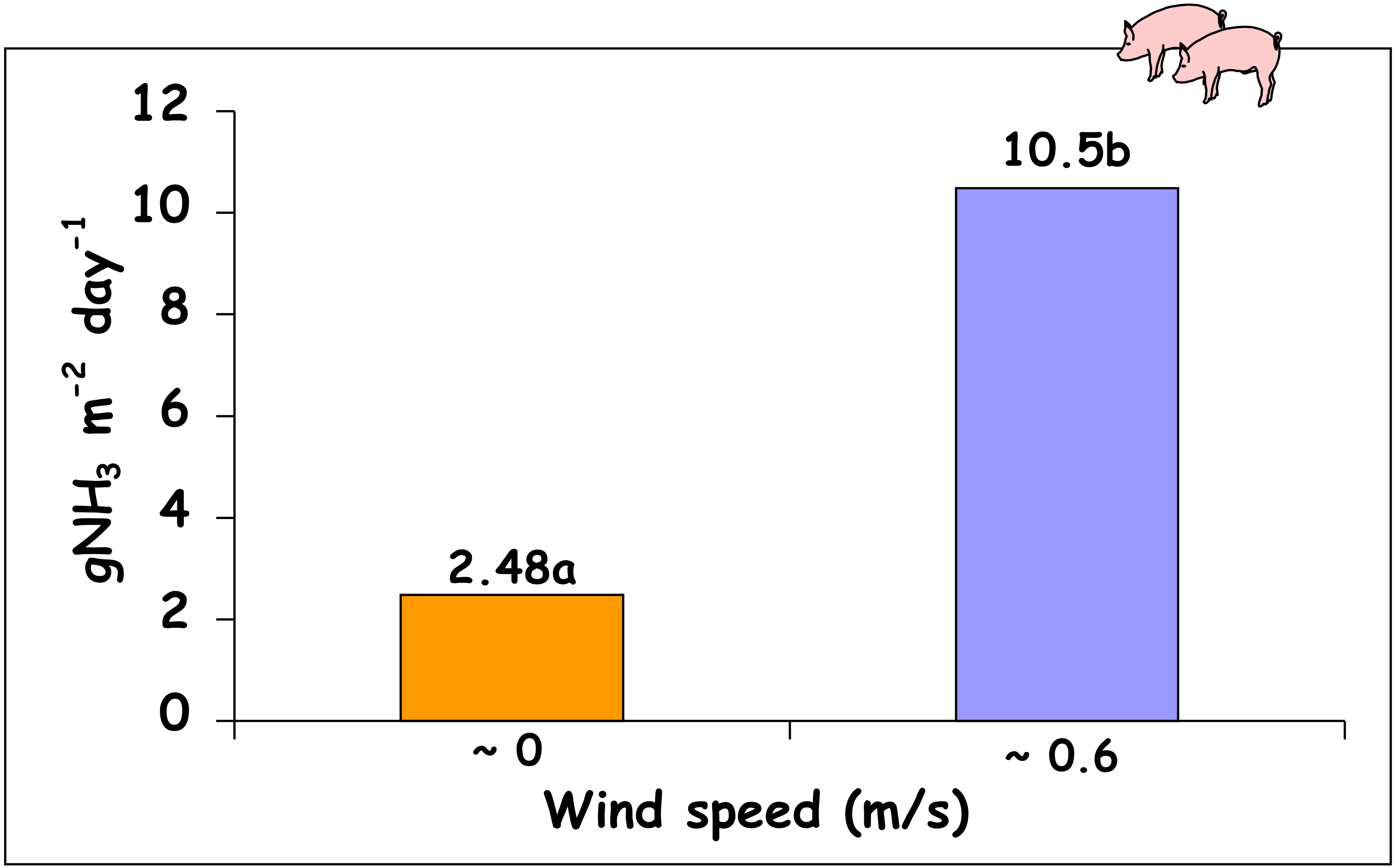
Ammonia emissions from FYM heaps



Ammonia emission from pig slurry storage: effect of wind speed



Ammonia emission from pig slurry storage: effect of wind speed



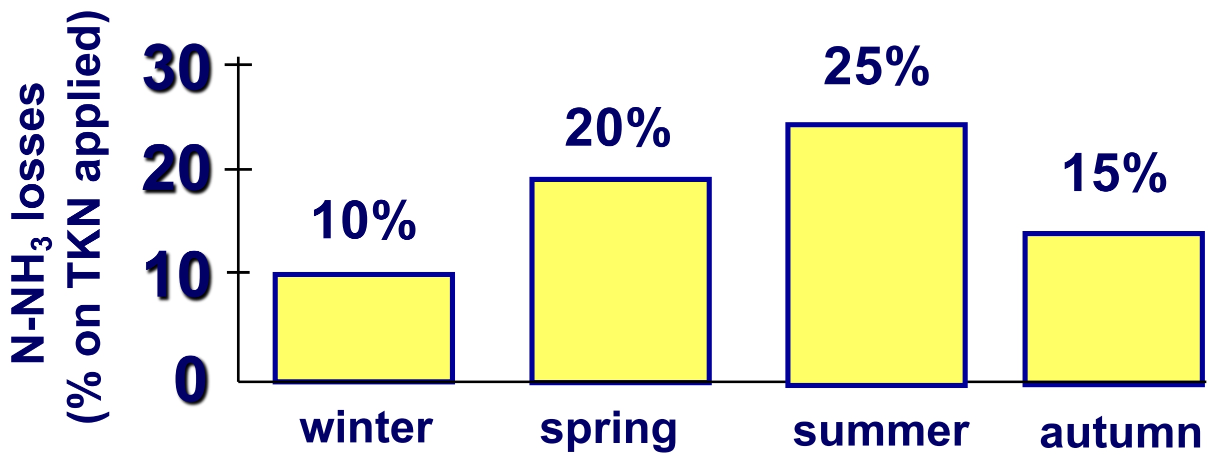
AMMONIA EMISSION FROM LAND APPLICATION OF MANURE

Factors affecting NH_3 emissions from land application

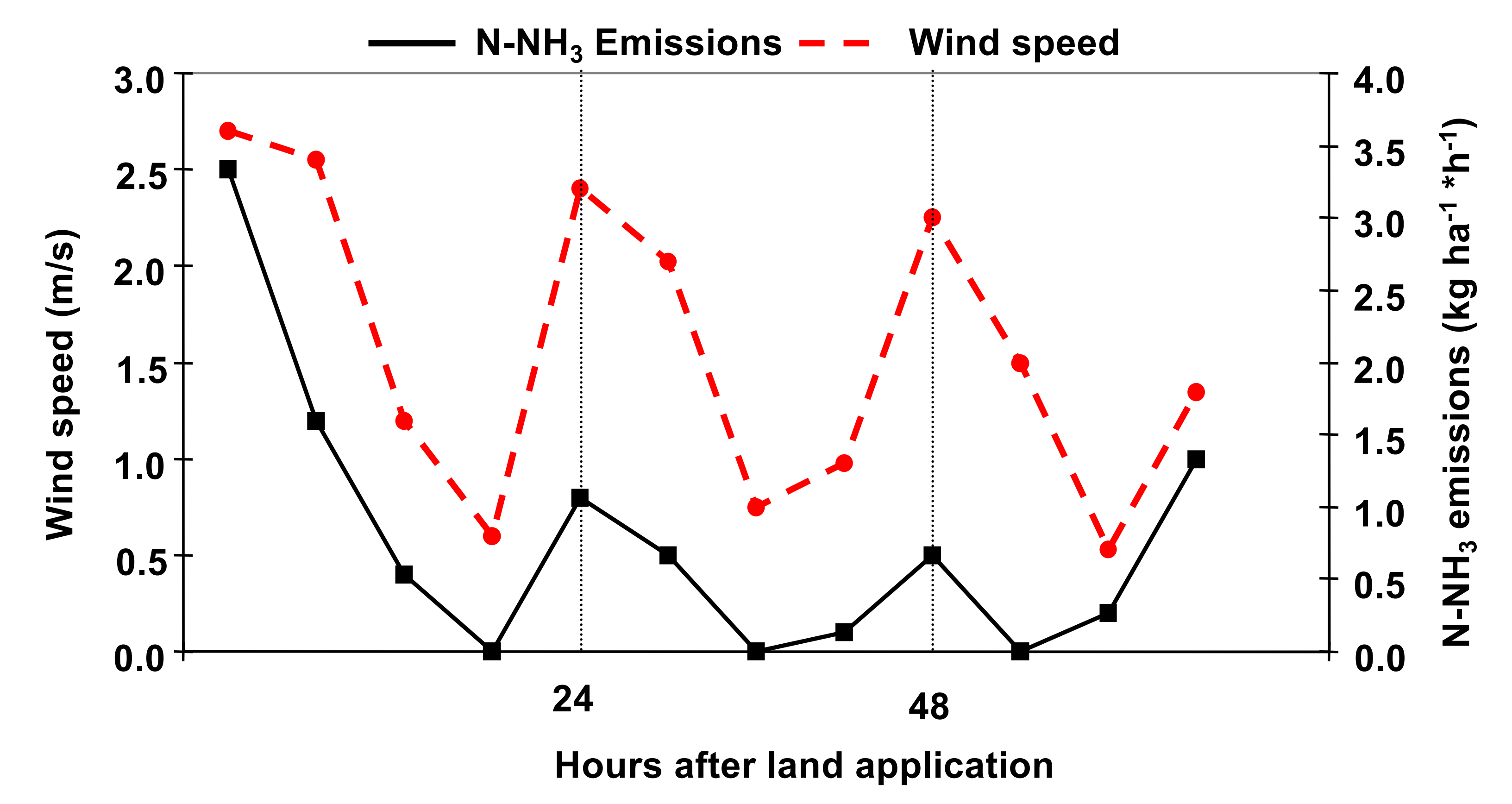
☞ **Losses affected by:**

- Manure characteristics:
  - TKN, NH_4-N, TS content
- Application rate
- Weather conditions
  - temperature, wind speed, air humidity, rainfall
- Soil factors
  - chemical properties: OM, CEC, pH
  - physical properties: infiltration, texture, moisture
  - presence of coltural residues
- Land application technique

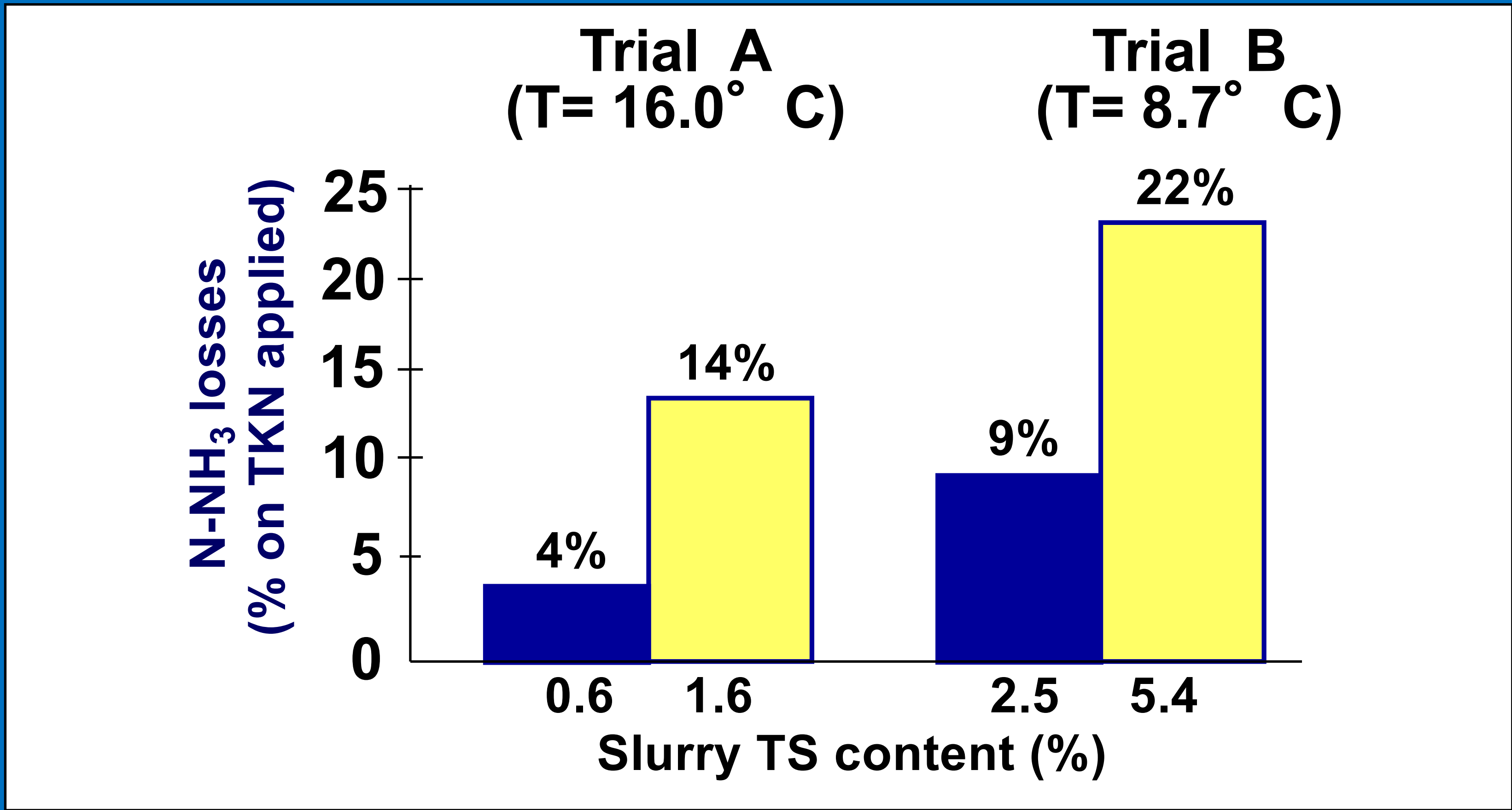
NH_3 losses from land application: effect of Temperature



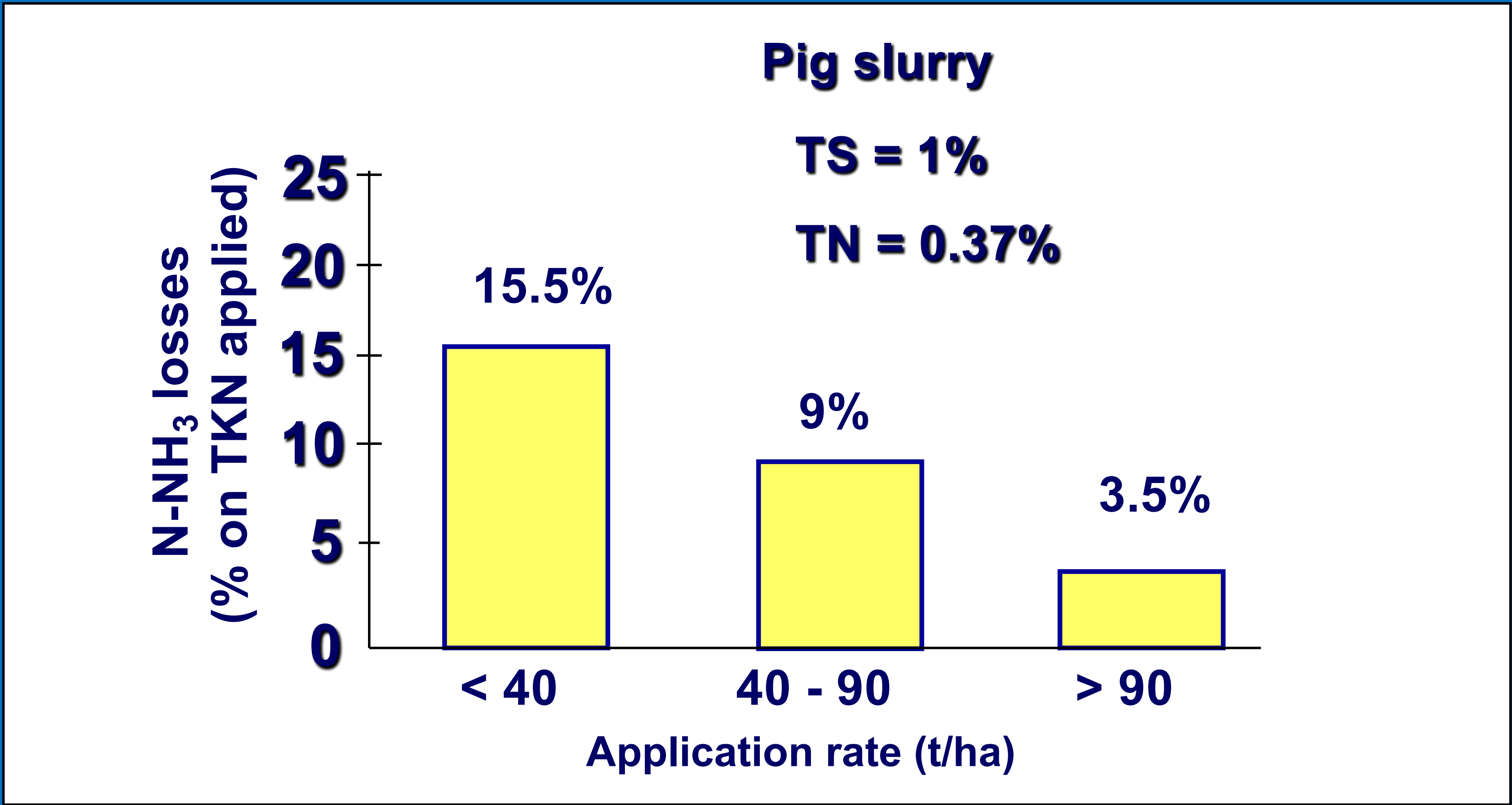
NH_3 losses from land application: effect of wind speed



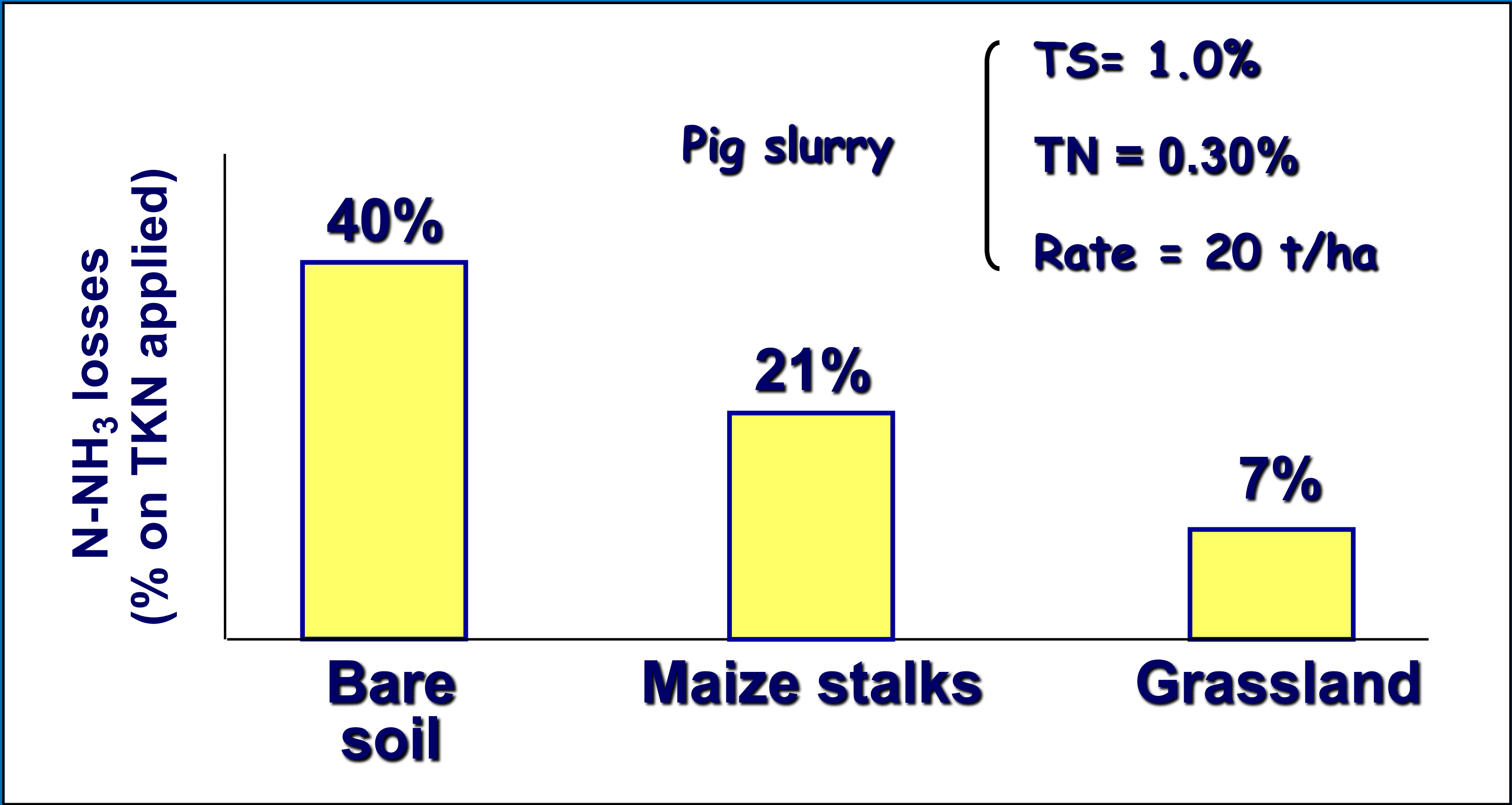
NH_3 losses from land application: effect of slurry TS content



NH_3 losses from land application: effect of slurry application rate

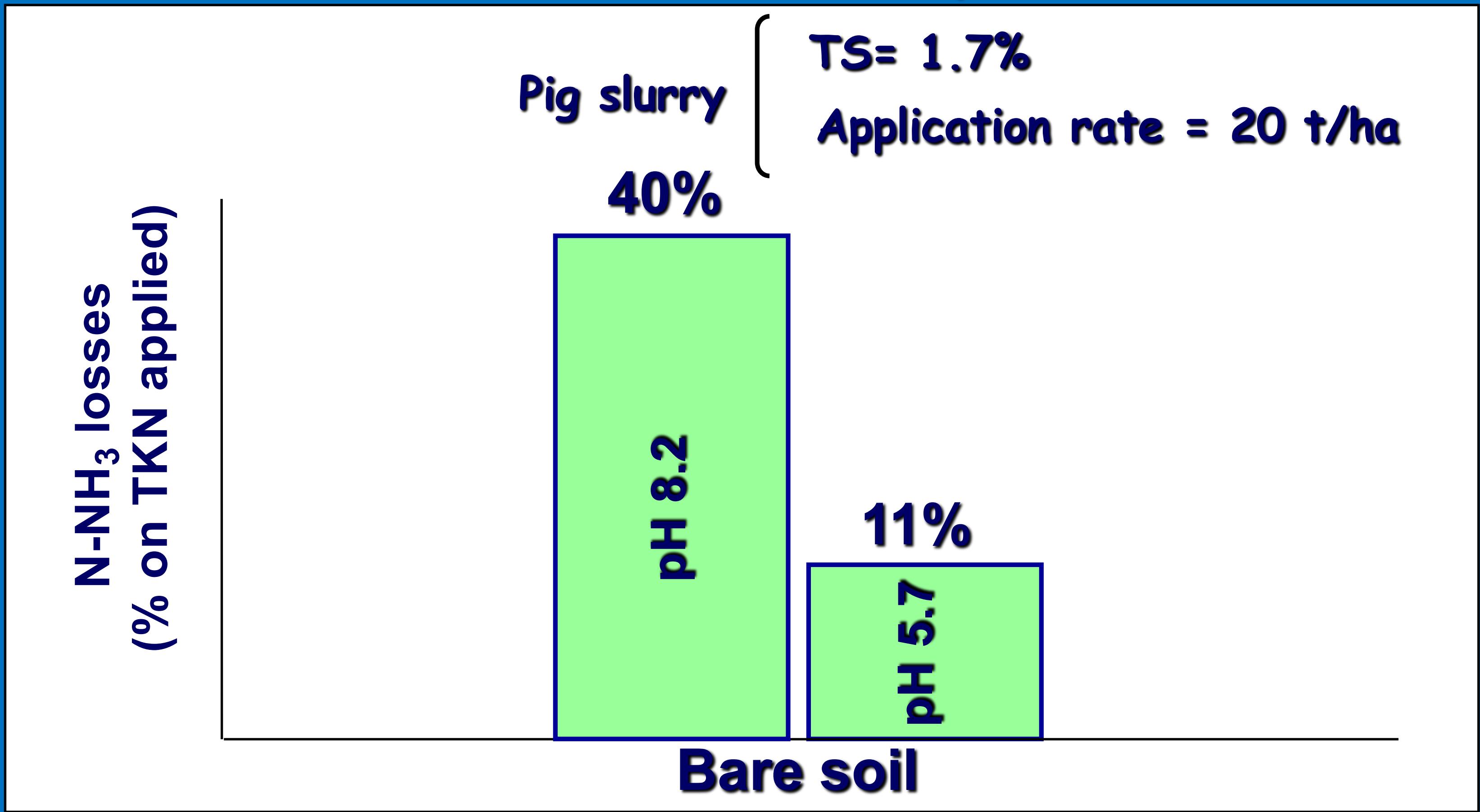


NH_3 losses from land application: effect of soil residues/vegetation



(Balsari et al., 1994)

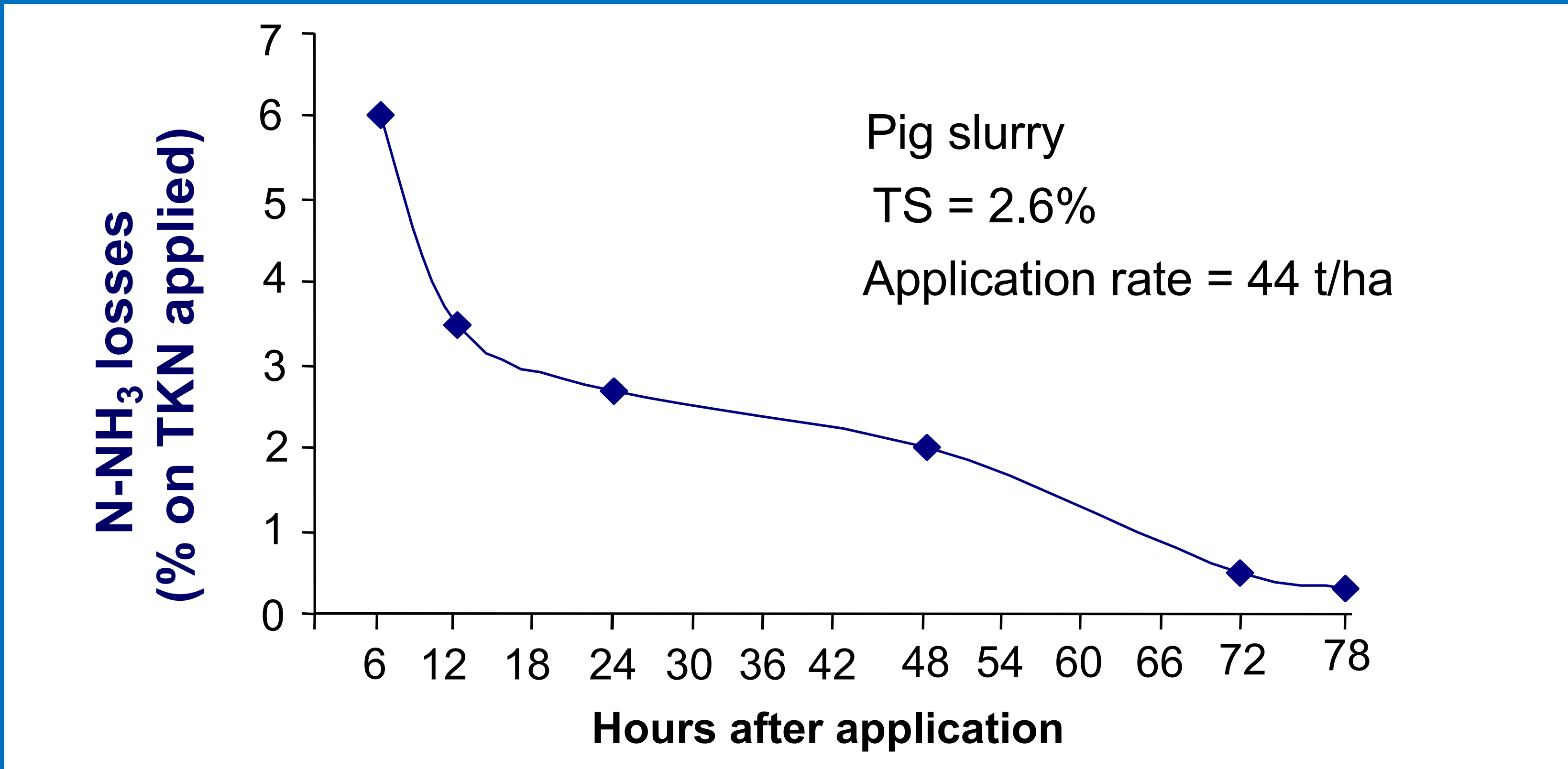
NH_3 losses from land application: effect of soil pH



NH_3 losses <u>during</u> land application

~ 2% of N-NH_3 in slurry

NH_3 losses after land application: emission pattern



NH_3 losses after land application: effect of spreading technique

Gun sprayer

> 30%
of NH_3-N applied

NH_3 losses after land application: effect of spreading technique

Splash plate

up to **25-30%**
of NH_3-N applied

NH_3 losses after land application: effect of spreading technique

trailing hoses

up to 15-20%
of NH_3-N applied

NH_3 losses after land application: effect of spreading technique

Slurry injection

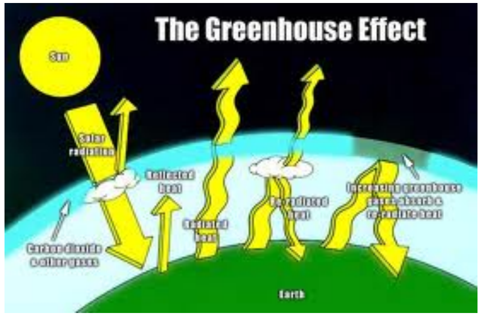
2 - 3%

of NH_3-N applied

GREENHOUSE GASES (GHG)

Gaseous emissions from animal manure management: CO_2, CH_4, N_2O

Greenhouse gases



Contributing to global warming and related climate change

Greenhouse effect

Composition of Earth's atmosphere

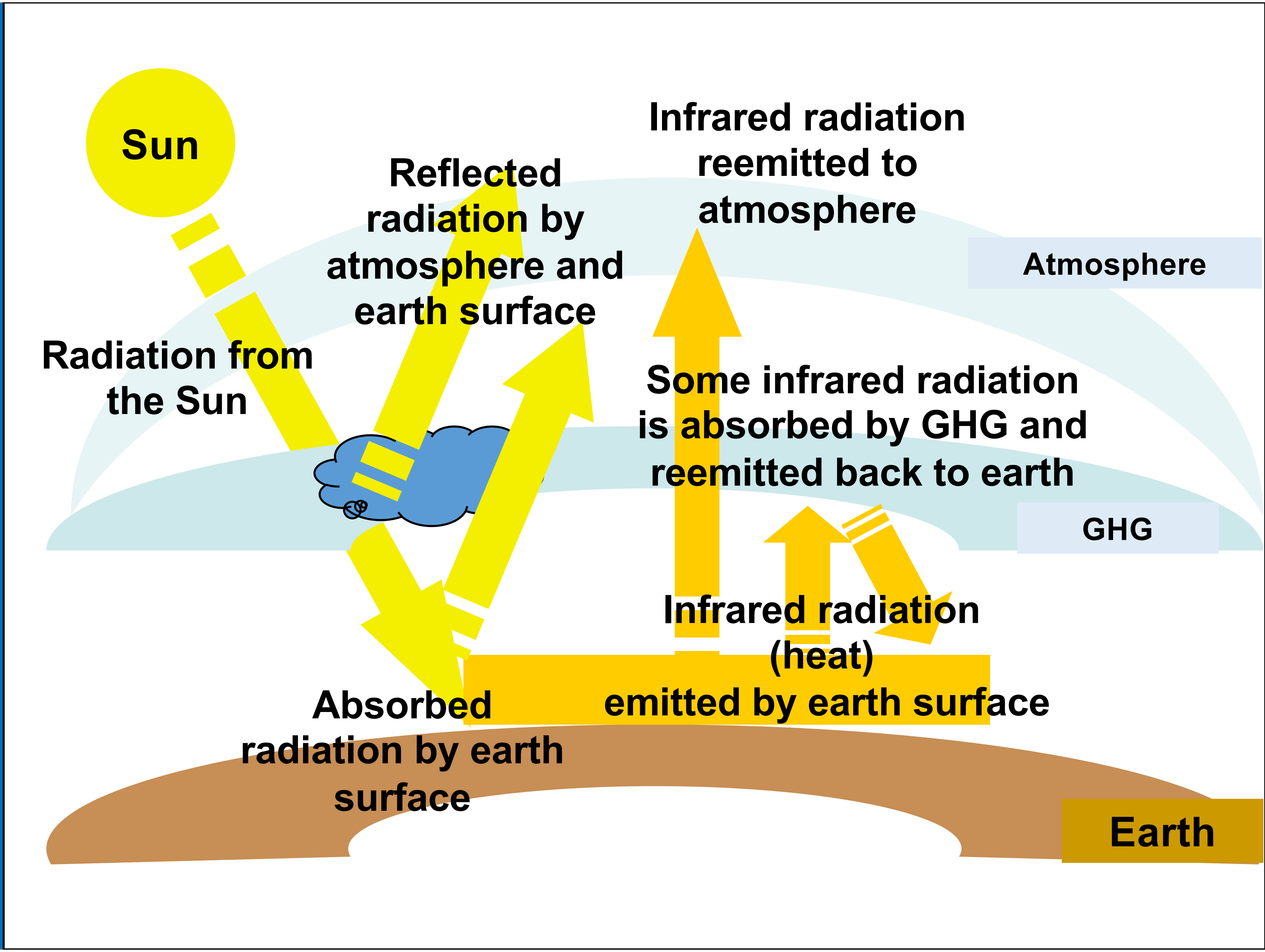
Nitrogen: ~78%

Oxigen: ~21%

H_2, He, Xe, Ar, CH_4, CO_2, N_2O, O_3: ~1%

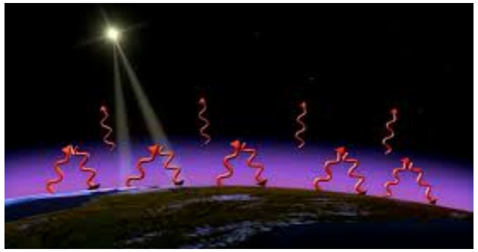
Troposphere (about 15km from terrestrial surface)

CH_4 (0.00017%)
CO_2 (0.037%)
N_2O (0.00003%)


Sun
Radiation from the Sun
Reflected radiation by atmosphere and earth surface
Infrared radiation reemitted to atmosphere
Atmosphere
Some infrared radiation is absorbed by GHG and reemitted back to earth
GHG
Infrared radiation (heat) emitted by earth surface
Absorbed radiation by earth surface
Earth

Characteristics of Greenhouse gases

- They trap heat in the Earth's atmosphere

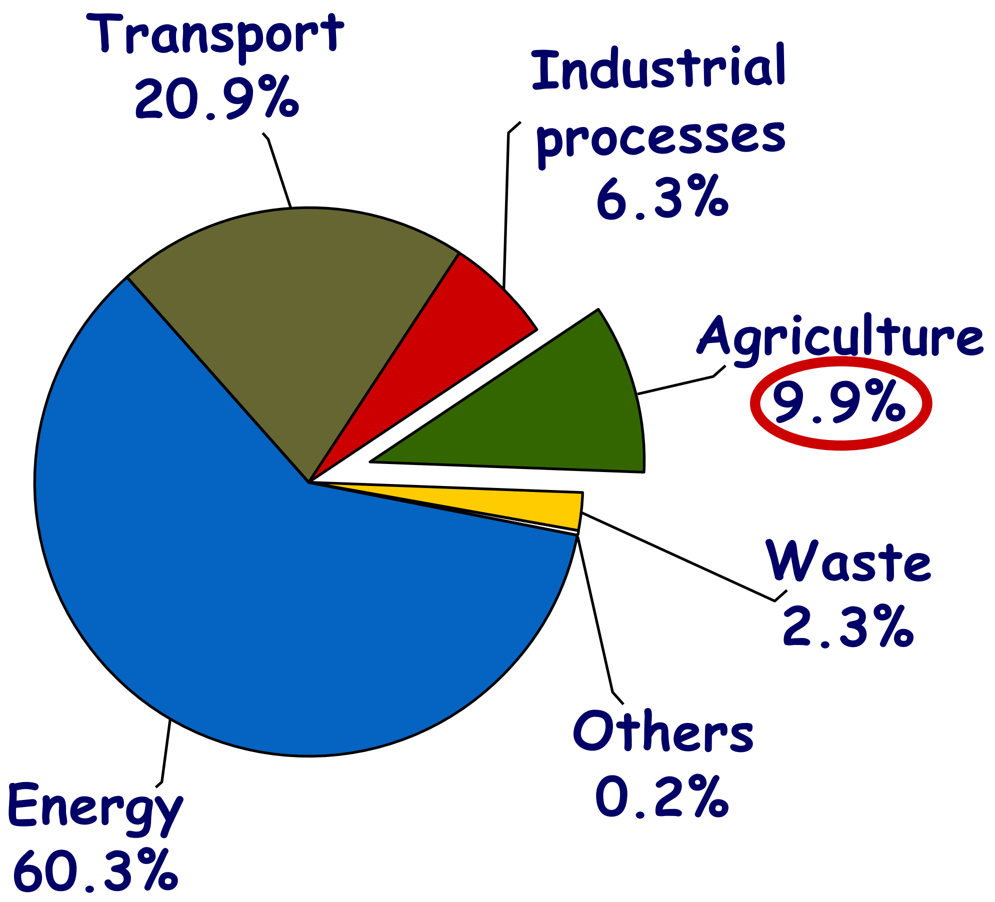


- Global Warming Potential (GWP)
  - The global warming potential of a gas refers to the total contribution to global warming resulting from the emission of one unit of that gas relative to one unit of the reference gas, **CO_2**, which is assigned a value of 1.

		GWP
Carbon dioxide	(CO_2)	1
Methane	(CH_4)	28
Nitrous oxide	(N_2O)	265

(IPCC, 2013)

European GHGs emissions by sector



Agricultural GHGs emissions in Europe

CH_4 N_2O

50% of the total anthropogenic emissions

Enteric fermentation (75%)

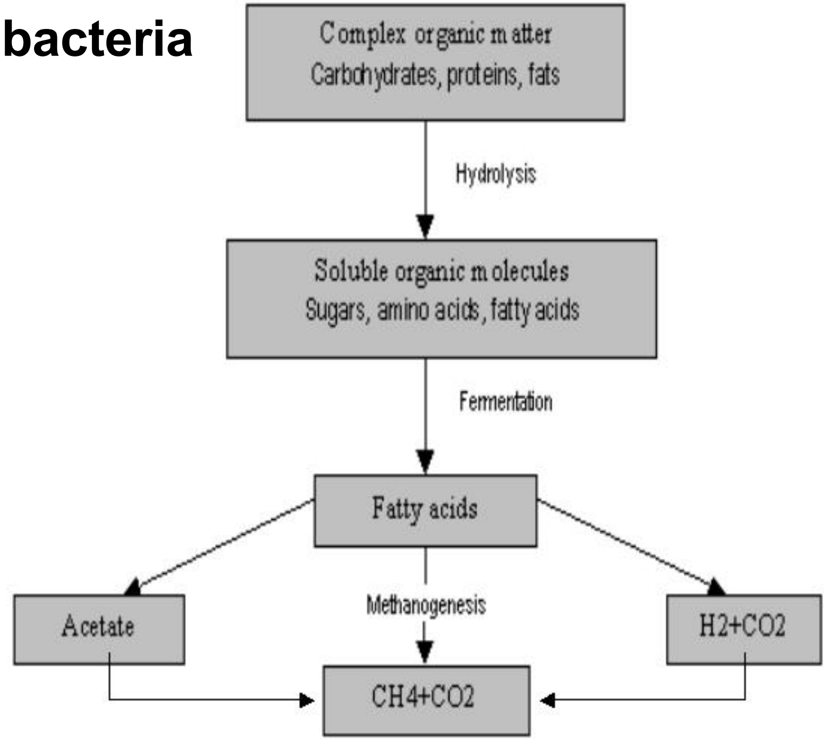
Manure management (25%)

Manure management (15%)

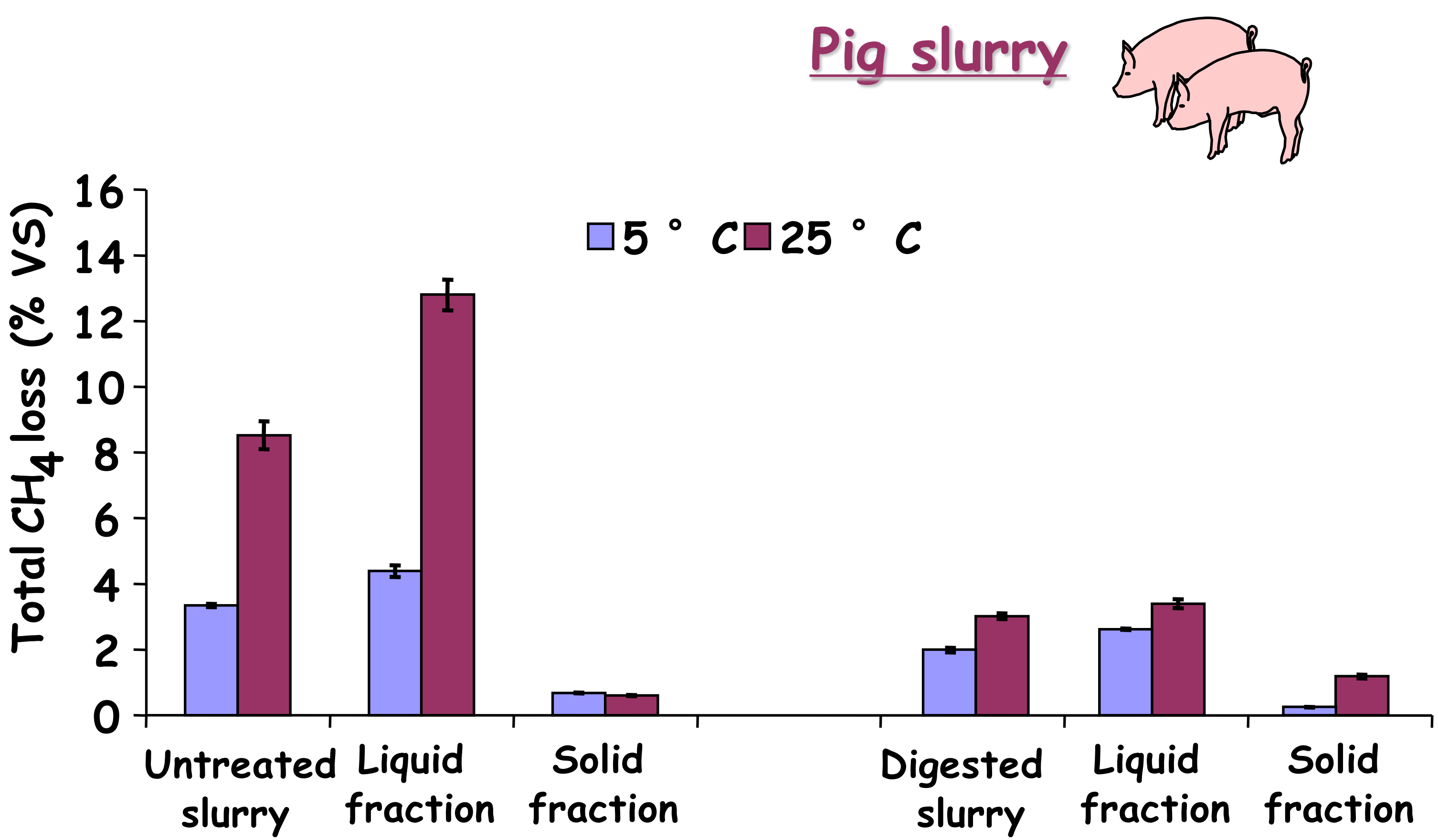
Agricultural soils (85%)

Factors affecting emissions of CH_4

- **Presence of methanogenic bacteria**
- **Anaerobic conditions**
- **Manure characteristics:**
  TS, VS, pH
- **Temperature**
- **Manure management type**

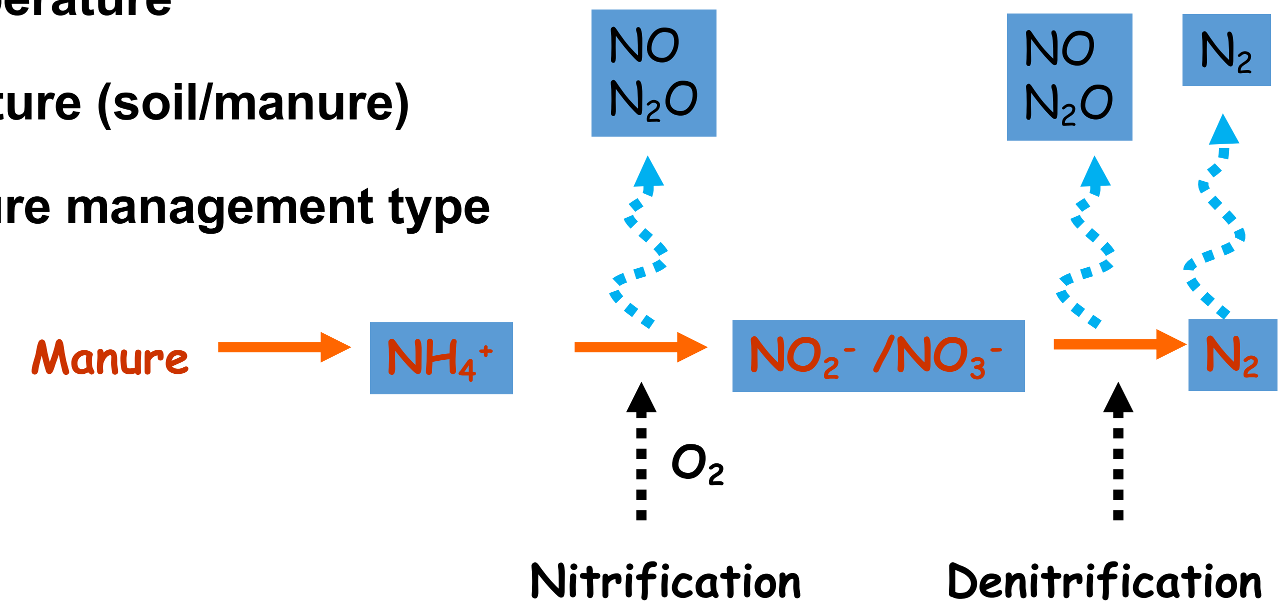


CH_4 losses from stored manure

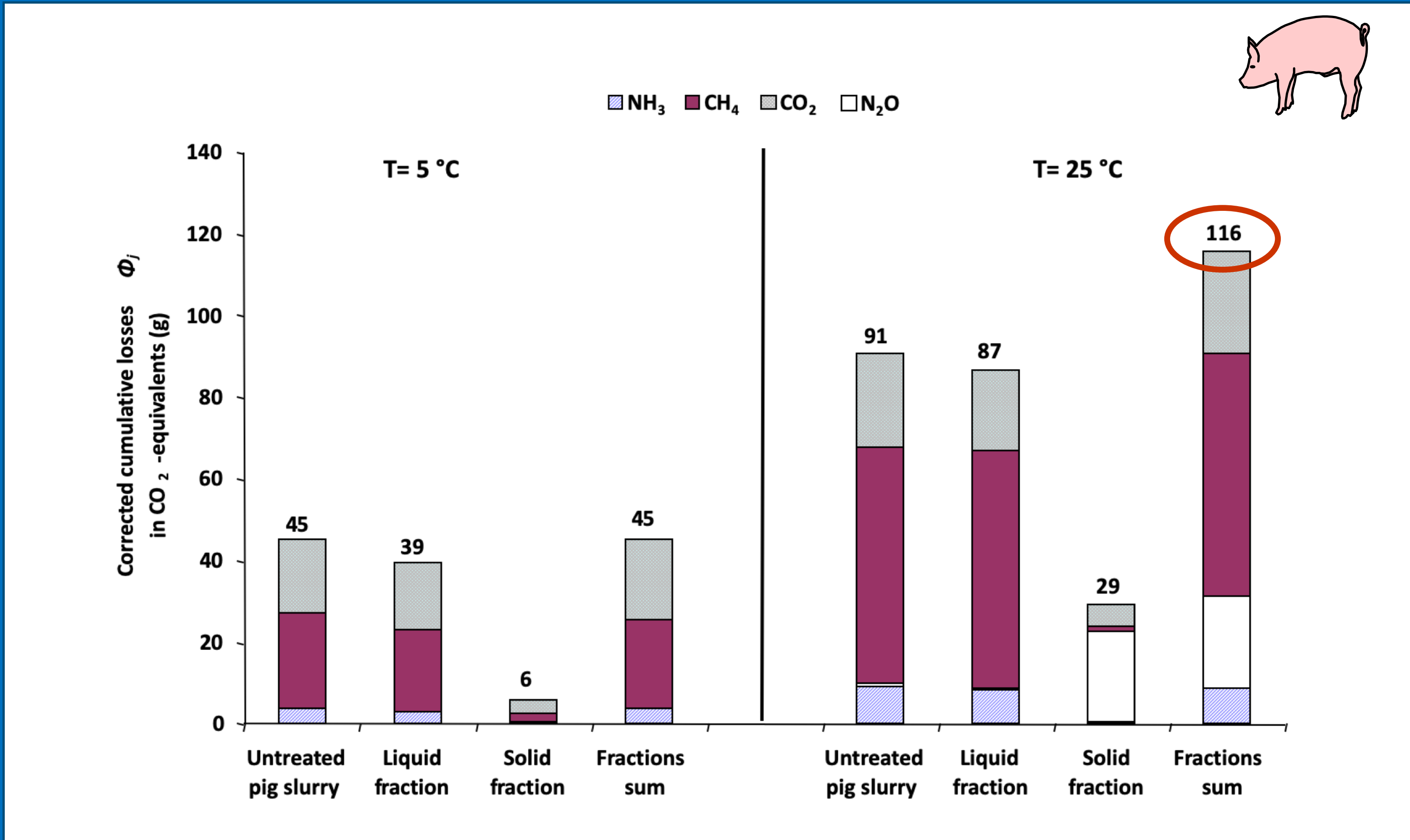


Factors affecting emissions of N_2O

- Mixed anaerobic/ aerobic conditions
- Manure characteristics:
  NH_4-N, pH
- Temperature
- Moisture (soil/manure)
- Manure management type



Effect mechanical separation on gaseous emissions: pig manures



N_2O losses from stored manure