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Electricity from poultry manure:

a resource efficient and clean alternative to direct land application

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Academic Work

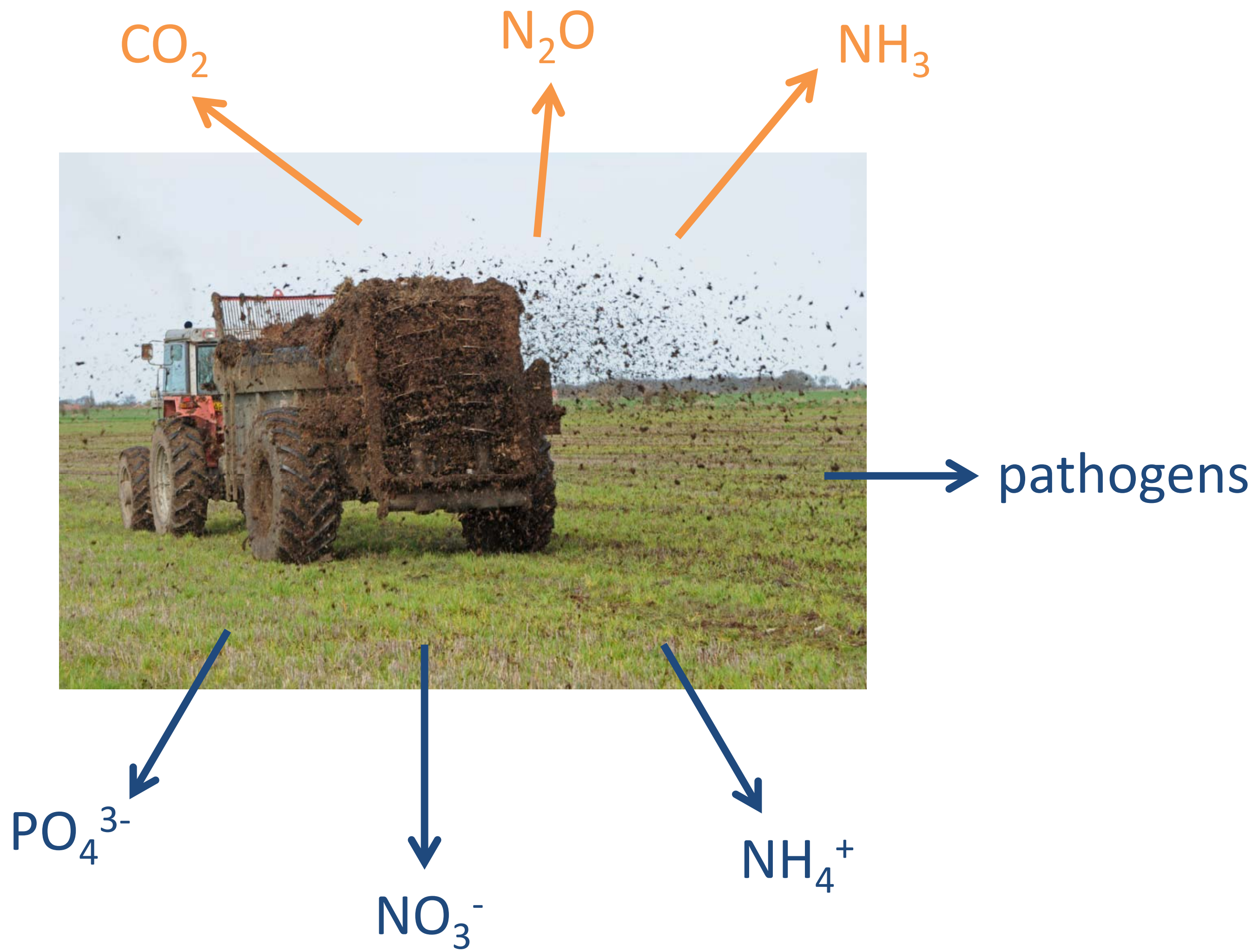
Poultry farming

- NL: 100 M hens per year
- 1.5 Mt/y poultry manure
- Total manure production: 71 Mt/y
- Supply > Demand
  → Excessive fertilization
  → Nitrate directive (91/676/EEC) and national legislation
- Compare
  - 1. land spreading, use it directly as fertiliser
  - 2. combustion to generate electricity

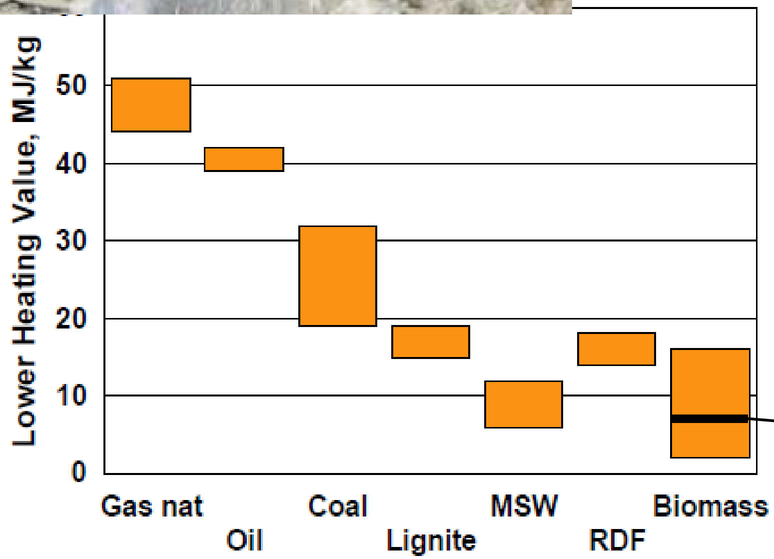
PRO SAAMYA,INC, 2013

Source: CBS, PBL, Wageningen UR (2012)
www.compendiumvoordeleefomgeving.nl

Land spreading



Poultry litter combustion



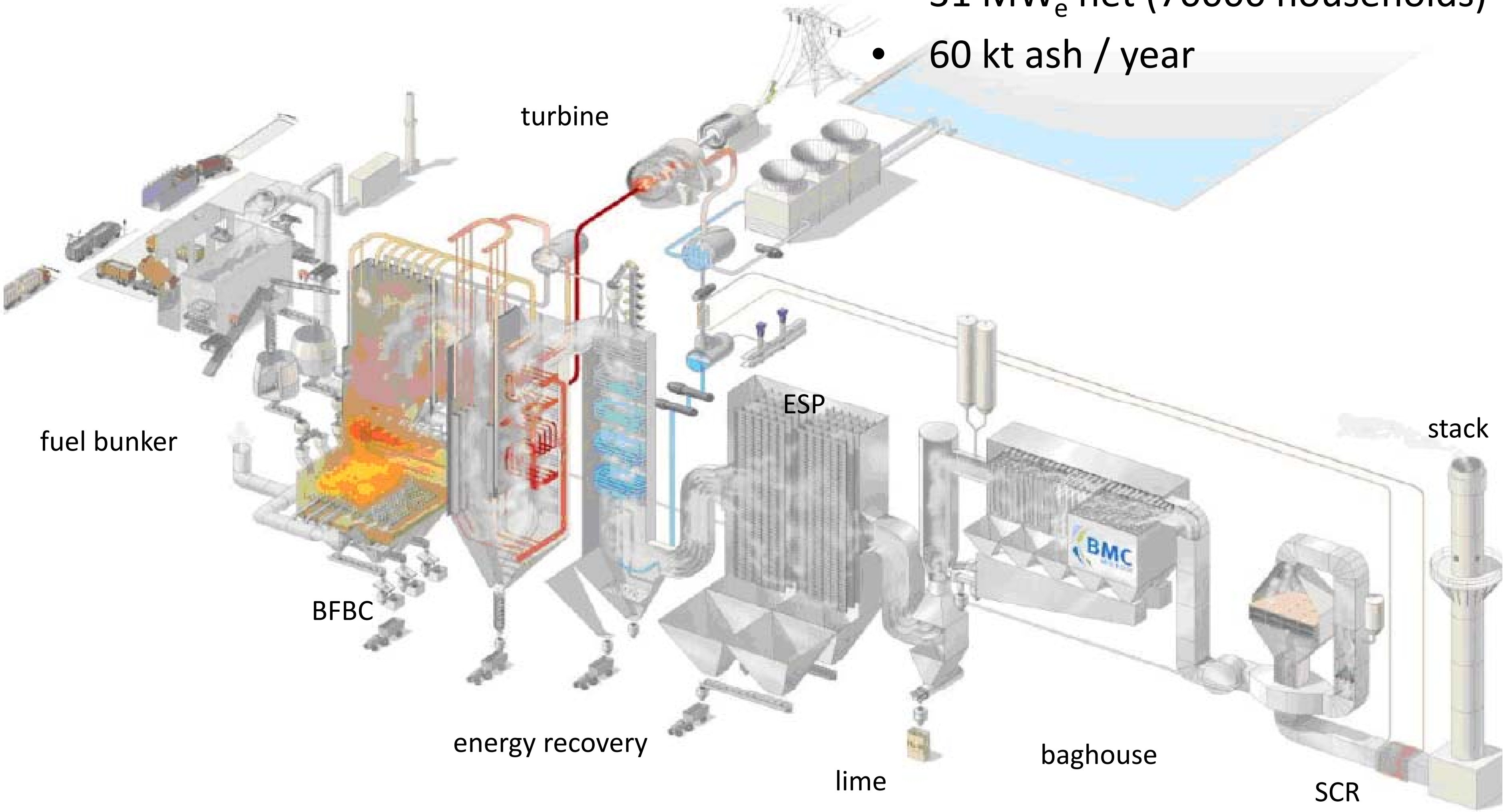
Adapted from: Consonni, S. Energy potential of waste. Athens, 19 june 2012

		Average	Std. Dev.
Moisture	wt%	44.8	3.0
Ash	wt% DM	21.5	3.1
C	wt% DM	39.1	1.8
H	wt% DM	5.7	1.7
N	wt% DM	4.2	0.7
S	wt% DM	0.7	0.1
Cl	wt% DM	0.5	0.1
Ca	wt% ash	21.0	4.9
Mg	wt% ash	3.7	0.9
K	wt% ash	14.0	3.2
Na	wt% ash	2.2	0.3
P	wt% ash	6.7	1.2

Poultry litter: LHV = 7.2 MJ/kg

BMC Moerdijk (FBC for poultry manure)

- 440 kt / year
- ca. 600 farmers contracted
- 31 MW_e net (70000 households)
- 60 kt ash / year



Is combustion cleaner- sustainable production?

- UNEP:
  RECP (Resource Efficient and Cleaner Production)
- Advance

Production efficiency
optimize use of natural resources (materials, energy, water)

Environmental management
minimize adverse impacts on nature and the environment

Human development
minimize risks to people and communties, support their development

Sustainable energy production and GHG emissions

Electricity production

- Net 31 MW_e, η_{net}=28%

  1 ton of poultry litter replaces about 200 kg coal, avoids 425 kg of emitted CO_2-eq.

- GHGs
  - CO_2
  - CO: negligible
  - N_2O: 25-50 kg CO_2-eq. per t

Indirect:
Transport
Flue gas heating (SCR)
Lime and NH_3 production

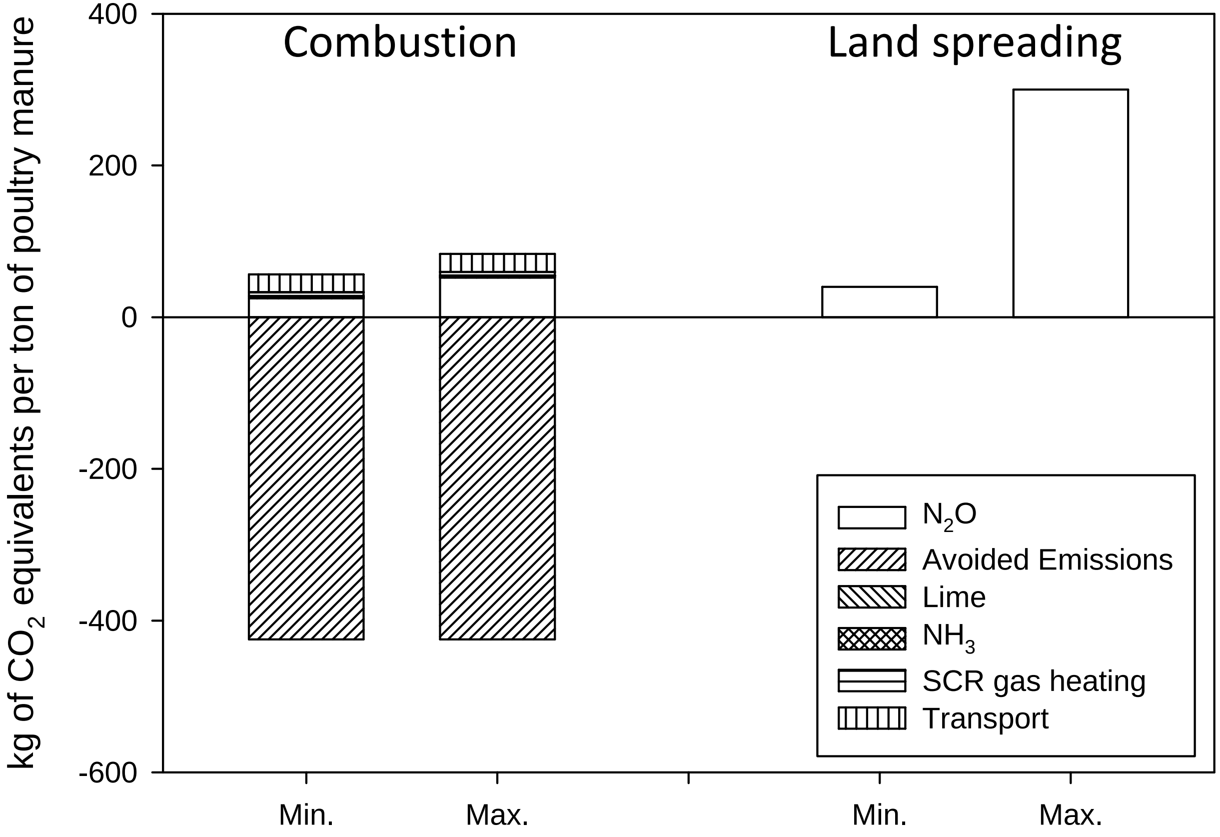
Land application

- Energy content is lost
- No electricity produced
- GHGs
  - CO_2
  - CO: negligible
  - N_2O: 40-300 kg CO_2-eq. per t

Indirect:
Transport (unknown)

Biogenic

Sustainable energy production and GHG emissions



Optimise use of materials

- Dry flue gas cleaning (no water needed)

- Ash (bottom ash, boiler ash, fly ash and APC residue) used as fertilizer/soil amendment
  - No pathogens
  - No NH_3 emissions
  - Odorless and dry, ensuring easy handling and transportation

Use of materials

- Ash composition
  (combined bottom ash, boiler ash, fly ash and APC residue)

	Specification	Composition
	wt% DM	
CaO		21
K_2O	>11	12
Na_2O		1.1
MgO	> 4	5.1
P_2O_5	>10	12
SO_3		5.0
Cl		2.0

	wt% DM
P_2O_5 sol. in water	0.06
P_2O_5 sol. in neutral ammonium citrate	5.1
P_2O_5 sol. in 2% citric acid	8.5

	wt% DM
K_2O sol. in water	11
K_2O sol. in neutral ammonium citrate	12
K_2O sol. in 2% citric acid	12

- De facto PK fertilizer, but low P solubility
  → upgrade opportunities
- Balance the nutrient supply and demand of regions

Use of materials

Minimization of impacts on the environment

- Electricity production from fossil fuels is replaced

	BMC emissions (kg/ton wet poultry manure combusted)	**Emissions** for **fossil fuel**+
$CO_{2,\ fossil}$	0	397
CO	0.05	0.09
NO_x	0.22	0.50
NH_3	0.017	0.007
SO_2	0.02	0.24
HCl	0.004	0.003
PCDD/Fs	$< 44 \cdot 10^{-12}$	$22 \cdot 10^{-12}$

+to produce same amount of electricity as produced from 1 ton of wet poultry manure (NL)

→less emissions to the environment, except NH_3

Minimization of risks to people

- All heavy metals in ash below limit for land application (combined bottom ash, boiler ash, fly ash and APC residue)

	Limit	**Composition**
	mg/kg DM	
Al	7000	4044
As	5	<3.0
Cd	3	0.8
Co	20	5.3
Cr	100	13
Cu	600	353
Hg	1	<0.05
Mn	10000	1822
Ni	50	17
Pb	45	10.2
Zn	2400	1567

Minimization of risks to people

- Based on the K_2O/P_2O_5 application rate,
  the amount of HM spread on land is identical for ash and for manure

- Pathogens destructed

- Limited formation of PCDD/Fs, due to
  - low Cl of poultry manure
  - low HM concentration in ash (catalyst)

Community development

- Sustainable demand for manure is offered to contracted farmers
- Contribution to regional employment
  - Direct: ca. 30 jobs mainly for technically skilled persons
  - Indirect: transport, ash upgrading …

Conclusion: RECP

Valorization of energy content

Use of ash

No water use

Production efficiency
protective use of natural resources
(materials, energy, water)

Biogenic CO_2

Employment

Environmental management
minimize adverse impacts on nature and the environment

Human development
minimize risks to people and communties, support their development

Lower NH_3 emissions than land spreading

Emissions < or comparable to other energy plants

HM spreading identical

Destruction of pathogens

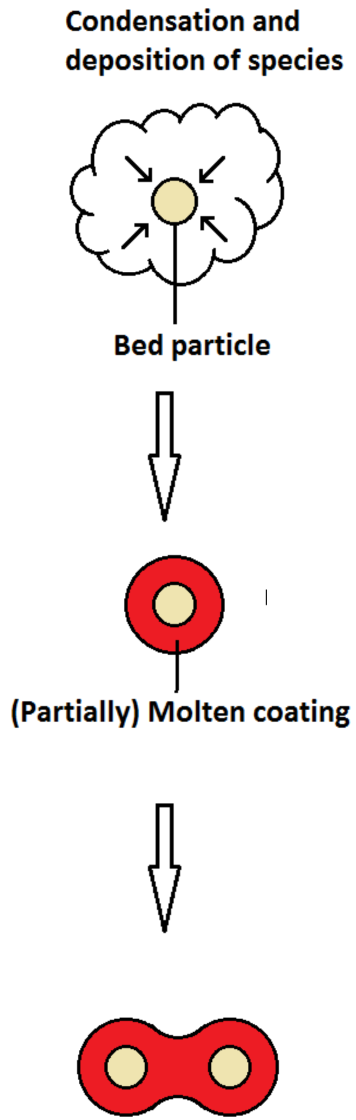
Technological issue

- Agglomeration in bed due to low melting salts in the ash
- E.g. $K_2Si_4O_9$ (770°C), KPO_3 (810°C), …
- Eutectics: lower T_m

- Consequence: Defluidization (few times a year)→ downtime, cleaning of installation
  Availability < 90%

Research

Mechanism 1



Ash formation

↓

Reactions in bed ash

Thermodynamics

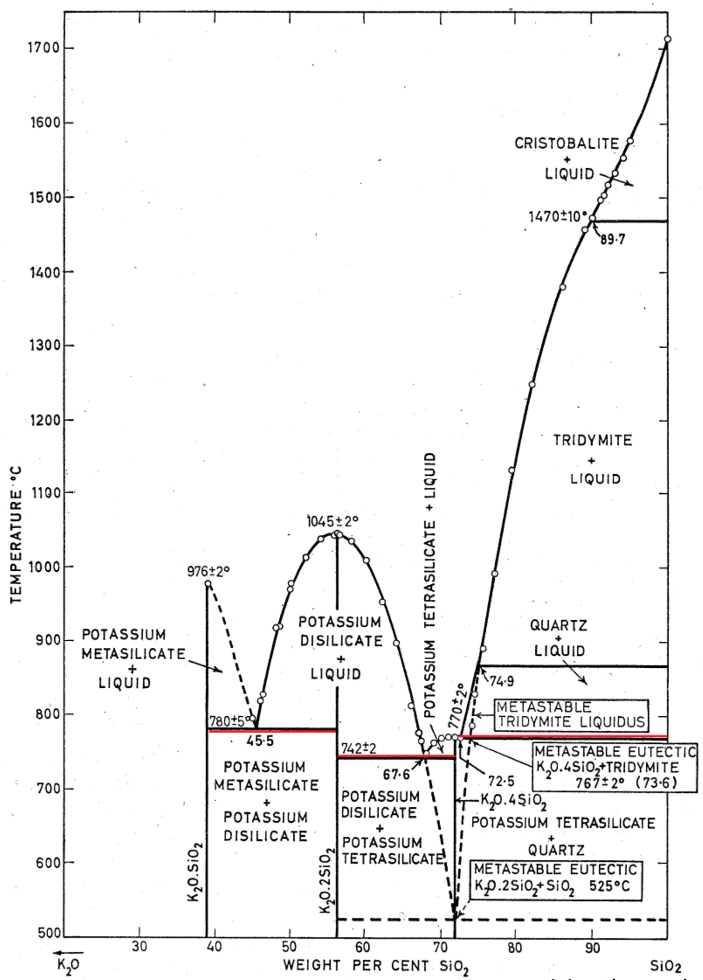
↓

Melting

Phase diagrams

↓

Agglomeration

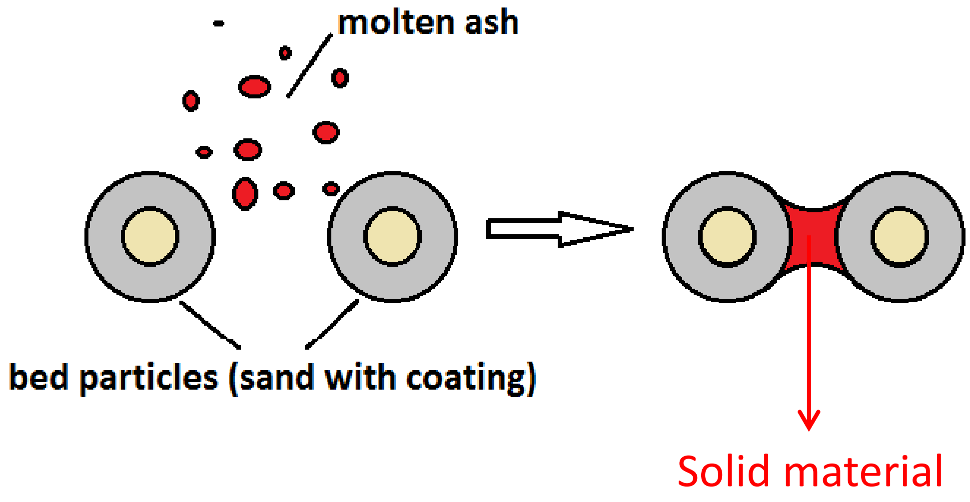


Roedder (1959)

Research

Mechanism 2

Ash formation → Melting of ash → Agglomeration → Reaction with bed ash → Solidify



$$KH_2PO_{4\,(s)} \rightarrow KH_2PO_{4\,(l)} \rightarrow H_2O_{(g)} + KPO_{3\,(l)} \xrightarrow{+\,CaO} Ca_3(PO_4)_{2\,(s)} + K_2O$$

Research

- Variations of the fuel

	Layer hens	Broiler hens
Ash [wt% DM]	19.3	25.3
Al [mg/kg DM]	730	900
K [mg/kg DM]	31900	35100
Na [mg/kg DM]	5700	7000
Ca [mg/kg DM]	50200	31800
Si [mg/kg DM]	3400	4100
Mg [mg/kg DM]	8700	7700
Fe [mg/kg DM]	1100	n.r.[1]
P [mg/kg DM]	21000	17400

Source: ECN Phyllis 2 Database

- Countermeasure: addition of $CaCO_3$

References

Van Caneghem, J., Brems, A., Lievens, P., Block, C., Billen, P., Vermeulen, I., Dewil, R., Baeyens, J., Vandecasteele, C.: Fluidized bed waste incinerators: Design, operational and environmental issues. Prog. Energy Combust. Sci. 38(4), 551-582 (2012)