Source separated urine as fertiliser

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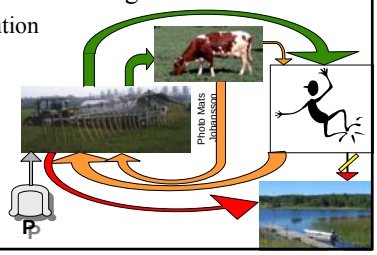
Why reuse?

- Sustainable food production
  - Resource saving; phosphorus, sulphur, energy, other nutrients
- Sustainable environment – get rid of waste
  - Minimize pollution



Urban fertiliser potential in relation to chemical fertilisers 2001 in Sweden

Product	N	P	K
Urine	20%	20%	26%
Blackwater (urine+faeces)	20%	31%	36%
Trade & catering waste	0%	1%	2%
Above + kitchen waste	**1%**	**10%**	**12%**
Blackwater + biowaste	**22%**	**41%**	**47%**

Requirements for reuse

- **HYGIENE – prio 1**
- Chemically safe – not cause pollution
  - Elements
  - Compounds
- Net benefit to sustainability
  - Maximized benefits - using system well
  - Minimized cost – well working system

Chemically safe – elements

- Mass balance
  - Excreta elements = food elements i.e. far safer than fertilizers etc.
- Strict regulations on food
  - ⇒ Element composition of excreta is safe

⇒Minimize pollution by elements to excreta

- ⇒ Urine corrosive – no metals in UD-system
- ⇒ Compost & digestion residues corrosive – minimize metal use and only non-toxic and corrosion resistant metals in solid waste system
- ⇒Careful selection of additives (ash, lime, soil, biowaste, park & garden waste etc.)

Cadmium

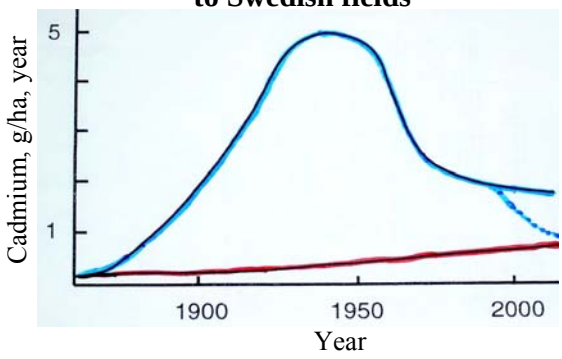
- **Kidney malfunction in general public**
- Affects skeleton strength
- Accumulates in human body
- Easily taken up by wheat and rice

⇒Higher limits in wheat and rice

Cd level in Swedish wheat 2-3x level 1920

- Level in agricultural soil +33% during 1900s
- Accumulation 0.03%-0.1% excl. fertilisers.

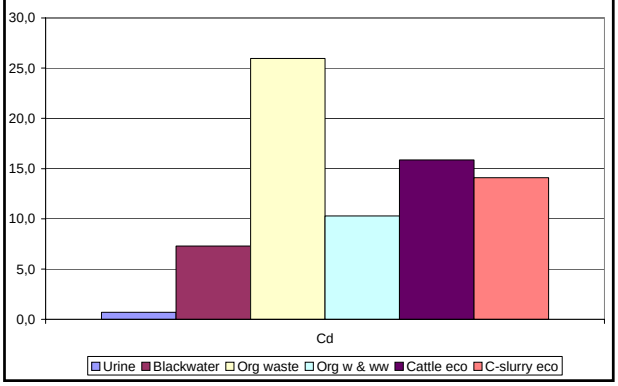
Delivery and removal of cadmium to Swedish fields



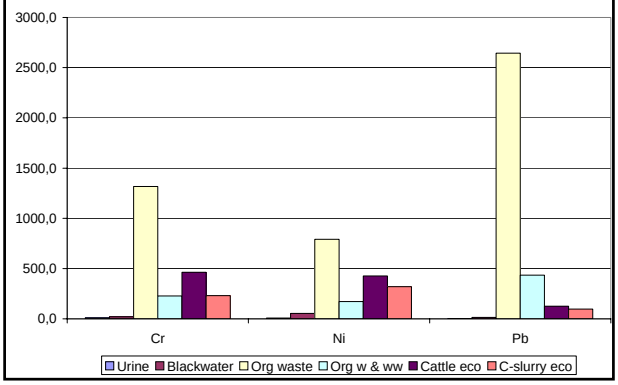
Cadmium in P-mineral

Mineral origin	Cd mg/kg P	Cd g/15 kg P
Removal wheat, Sweden		**0.6**
Human urine	0.6	0.008
Ecological cattle manure	16	0.24
Sewage sludge	30-**40**-500	0.45-7.5
Palfos, South Africa	0.9	0.014
Khourigba, Morocco	113	1.70
Youssofia, Morocco	274	4.11
Texas, USA	278	4.17
Gafsa, Tunisia	380	5.70

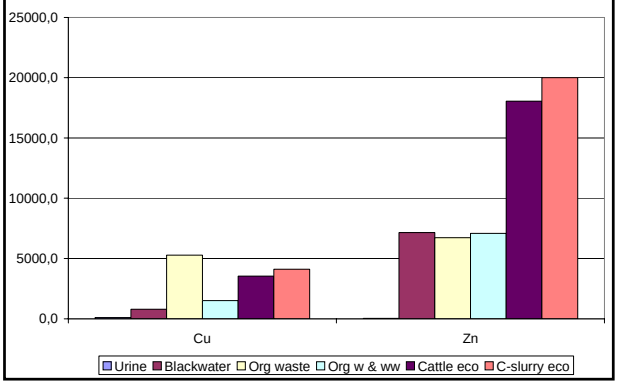
Cd, mg per kg P



Cr, Ni, Pb, mg per kg P



Cu, Zn, mg per kg P



Chemically safe - compounds

- Strict regulations on food
  - ⇒ Very low level of hazardous compounds in food & in excreta
- Natural hormones
  - ⇒ Terrestrial system can handle these
- Medicines and pharmaceutical residues
  - Few (~ 1000) compared to frequently used chemical compounds (~30.000)
  - Long retention time in active soil (~months – years)
    - ⇒ Good degradation
  - Efficient barrier soil – plant
    - ⇒Low risk of compound in crop

Hygiene – urine

- Normally sterile in bladder
- Excretion of pathogens only in few diseases
  - ⇒Reuse safe in small (household) systems without storage
    - ⇒Barrier 1 – min 1 month application – harvest
    - ⇒Barrier 2 – incorporate or water down into soil
    - ⇒Barrier 3 – illness is known and resistance maybe increased
  - ⇒Reuse safe in larger systems after storage
    - ⇒Adds another 3rd barrier to the two above
    - ⇒Processed foods - 1 month if temperature ≥20°C or 6 months if temperature ≥4°C
    - ⇒Fresh vegetables – 6 months at temperature ≥20°C
- Check with new WHO guideline

Who guideline (final draft)

Table: Recommended guideline storage times for urine mixture[a] based on estimated pathogen content[b] and recommended crop for larger systems[c]. (Adapted from Jönsson *et al.*, 2000 and Höglund, 2001)

Storage temperature	Storage time	Possible pathogens in the urine mixture after storage	Recommended crops
4°C	≥1 month	Viruses, protozoa	Food and fodder crops that are to be processed
4°C	≥6 months	Viruses	Food crops that are to be processed, fodder crops[d]
20°C	≥1 month	Viruses	Food crops that are to be processed, fodder crops[d]
20°C	≥6 months	Probably none	All crops[e]

[a] Urine or urine and water. When diluted it is assumed that the urine mixture has at least pH 8.8 and a nitrogen concentration of at least 1 g/l.

[b] Gram-positive bacteria and spore-forming bacteria are not included in the underlying risk assessments, but are not normally recognized for causing any of the infections of concern.

[c] A larger system in this case is a system where the urine mixture is used to fertilize crops that will be consumed by individuals other than members of the household from which the urine was collected.

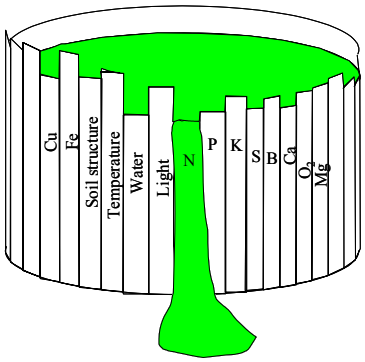
[d] Not grasslands for production of fodder.

[e] For food crops that are consumed raw it is recommended that the urine be applied at least one month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

Kvarnström et al. 2006. Urine diversion – one step towards sustainable development. www.ecosanres.org

Maximize benefits – crop growth

- Plants need many things!
- Everything in optimal amounts and ratios!
- Most limiting factor determines yield
- Some compounds are toxic



Factors often limiting yield

- Water
- Temperature
- pH
- Soil volume/structure
- Macronutrients
  - N – most frequently limiting nutrient
  - P – second most frequently limiting nutrient
  - K, S, micro-nutrients sometimes limiting
- **Only most limiting factors limit!**
  - **No use to fertilise if nutrients do not limit!!**

Nutrient uptake

- Taken up as ions, not organics
  - N as $\mathbf{NO_3^-}$ or NH_4^+ **not** in organic form
  - NH_4^+ converted to $\mathbf{NO_3^-}$ within few days in normal soil.
  - P as ions of PO_4^{3-}, mainly HPO_4^{2-} and $H_2PO_4^-$
  - K as K^+
  - S as SO_4^{2-} and HSO_4^{2-}

Nutrient forms – stored urine

- **N** mainly as **NH_4^+** + some easily degraded organic forms ⇒ all rapidly available
- **P** as ions of **PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$** and precipitation **$MgNH_4PO_4$ & $Ca_X(OH)_y(PO_4)_Z$**
- **K** as **K^+**
- **S** as **SO_4^{2-}**
- **All readily plant available – same forms as chemical fertilisers**

Nitrogen form and availability

compared to mineral fertiliser

- **Urine** - NH_4^+ or urea - 90-100% of tot N
- **Digestion residue** - NH_4^+ or org N ~ 40-70% of tot N
- **Compost** - org N ~ 10-20% first year, 20-30% in total
- **Ash –** No N

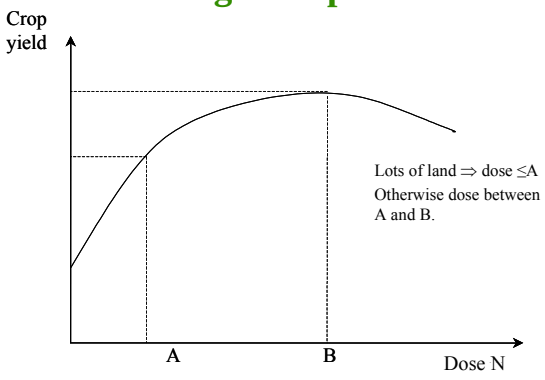
⇒**Urine** is N fertilizer – use for N demanding crops – risk of ammonia loss ⇒ Incorporate or growing crop

⇒**Digestion residue** – all around fertilizer – risk of pathogens & ammonia loss ⇒ Incorporate

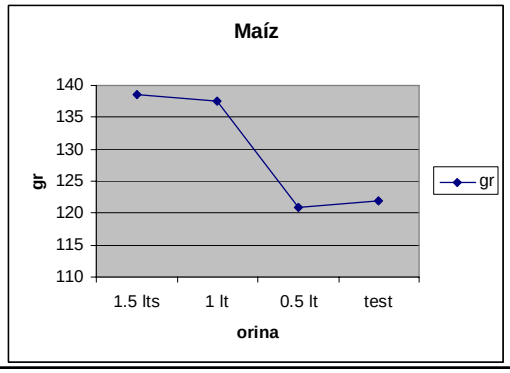
⇒**Compost** - soil amendment – Incorporate to minimize pathogen risk & maximize P use

⇒**Ash –** K, P & Ca fertilizer – No N

Nitrogen response



Maize Tepozeco



Phosphorus availability

compared to mineral fertiliser

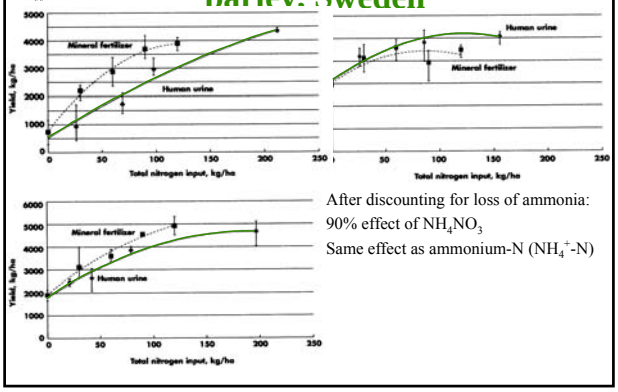
- Harder to measure than N
- **Urine** - ~ 100% of tot P
- **Digestion residue** - ~ 100% of tot P, but slower than urine
- **Compost** - ~ 100% of tot P, but slower than digestion residue
- **Ash –** probably lower and slower than the others – depends on temperature and time

Potassium & sulphur availability

compared to mineral fertiliser

- Harder to measure than N
- **Urine** - ~ 100% of tot K & S
- **Digestion residue** - ~ 100% of tot K & S
- **N-treated product** - 100% of tot K & S
- **Compost** - ~ 100% of tot K & S
- **Ash –** ~ 100% of tot K, S has been lost

Urine vs chemical fertiliser barley, Sweden



After discounting for loss of ammonia:
90% effect of NH_4NO_3
Same effect as ammonium-N (NH_4^+-N)

Urine vs chemical fertiliser & slurry

Barley & ley in Germany (Simons & Clemens, 2004)

Field exp – barley

- Urine better yield than chemical fertiliser
  - Better N-availability: urine 72% - CAN 54%
- Probably irrigation effect

Field exp - Ley

- Yield & availability of urine tended to be higher (not significant) than for slurry

Greenhouse exp – grass

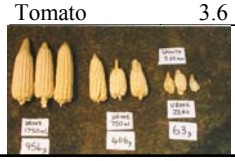
- Yield – no difference between urine & CAN
- Yield – no difference between pH 8 & pH 4 urine
- N-availability: urine 91% - CAN 72%

Urine vs organic fertilisers

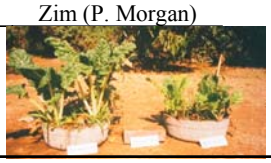
- **Winter wheat & spring grain, Sweden 1997-99**
  - Doses 40, 80 & 120 kg N/ha
  - Urine: +750, +1500 & +2000 kg/ha
  - Dried chicken manure: +600, +1100 & +1500 kg/ha
  - Dried meat+bone meal: +400, +800 & 1200 kg/ha.
- **Amaranth, Mexico**
  - Dose: 150 kg N/ha
  - Urine + chicken manure: 2350 kg/ha
  - Chicken manure: 1900 kg/ha
  - Urine: 1500 kg/ha
  - Unfertilised control: 875 kg/ha

Relative yield - Urine fertilised

Crop	Urine	Where/who
Spinach (	6.7	Zim (P. Morgan)
Swiss Chard)		Ethiopia (A. Sundin)
Covo	4.0	Zim (P. Morgan)
Lettuce	2.9	Zim (P. Morgan)
Onion	2-3	Zim (P. Morgan)
Maize	≤35	Zim (P. Morgan)
Leeks	3	Sweden (Båth)
Tomato	3.6	Zim (P. Morgan)



Photos: Peter Morgan



Field use in Sweden

Hedge & lawn, Sweden 2002

Garden Sweden 2002




Nyckelviken, Nacka municipality

- Urine used as fertilizer in demonstration garden of municipal nursery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Squash at Nyckelviken, august 2004


Unfertilised Urine fertilised

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Mexico, EcoSanRes pilot project

- Tepoztlan, urban setting with 35 000 people
- Urine diversion integrated with conventional solutions
- Reuse aspects emphasized



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Spreading

- **Urine –** in growing crop or before sowing/planting, preferably incorporation
- **Digestion residue –** incorporation before sowing/planting, if safely sanitized also in growing crop if not too thick
- **Compost** - incorporation before sowing/planting
- **Ash –** incorporation before sowing/planting preferred

Risk of phytotoxic substances

- **Urine –** ammonia and nitrite can be toxic ⇒ not too close to small plants
- **Digestion residue –** ammonia, nitrite and fatty acids can be toxic ⇒ not too close to small plants
- **Compost** – no risk if mature – risk of fatty acids if not mature ⇒ fresh compost not too close to small plants
- **Ash –** risk of too high pH if too much too close ⇒ dose carefully

Crop nutrient removal

Crop	Yield, kg/ha	Dry matter	N, kg/ha	P, kg/ha
Cereals				
Maize	4000	88%	51	9
Rice	4000	88%	45	11
Sorghum	4000	88%	56	9
Wheat	4000	88%	73	13
Wheat straw, crop above	5300	85%	21	3
Tubers etc				
Cassava root	20000	36%	32	1
Potatoes	25000	23%	83	13
Sweet potatoes	10000	59%	49	12
Others				
Banana fruit, ripe	25000	31%	67	8
Ground nuts, peanuts	1000	94%	37	4
Soybeans	1000	91%	54	5

Urine as fertiliser

- Prior to EU allowed in ecological farming in Sweden
- Allowed in conventional farming by EU
- Allowed in ecological farming by IFOAM but not by EU
- Allowed in conventional farming in Sweden, Denmark, Norway etc., but not allowed in Austria and Germany.

Urine - recommendations

- **Unique – quick non-chemical N-fertiliser** - for N-demanding crops paying well.
- Apply **from prior to sowing until 2/3-3/4** through vegetation period.
- Apply **neat or diluted, on soil & incorporate or water down.**
  - No dilution simpler
- **Do not soak whole root** – some plants (seedlings) sensitive.
- **Total amount applied important** - apply all at once or divide.
- Dose – **recommendations for chemical N-fertilisers** - if lacking urine from **one person during one full day to one m²,** but can beneficially apply 4-6 times more
- **Suffices to 300-600 m²/pers, yr**

Photo: Peter Morgan

Photo: Håkan Jönsson

Urine - unique organic fertiliser

- **Well balanced complete fertiliser rapidly available**
- **N-effect** - 70->100% of chemical fertiliser (NH_4NO_3)
- **P-effect** - similar to chemical fertiliser
- **No toxic effects** seen (cereals), but NH_3 & NO_2^- toxic
- **Ammonia emission** at application <1%-10%, (**5%**)
- Application in 20-30 cm high cereals works fine
- **Heavy metals - very low**, *hormones, antibiotics?*
- **EU** - conventional but not in organic farming