M4: Management: Planning, Implementation and Operation

M4-7: Agricultural Aspects

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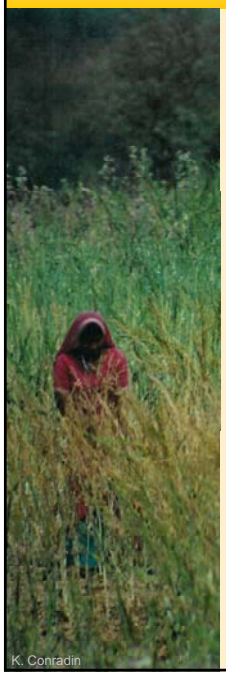

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We apologize in advance if references are missing or incorrect, and welcome feedback if errors are detected.

We encourage all feedback on the composition and content of this curriculum. Please direct it either to johannes.heeb@seecon.eu or petter.jenssen@umb.no , or use the feedback form.

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Note

Note: Guidelines must be adapted to local conditions (soil quality etc.)

Hygiene guidelines should be followed strictly: refer to M4-5 for more information on hygienization.

This module is adapted from the *Guidelines on the Use of Urine and Faeces in Crop Production* (Jönsson, H., Richert Stintzing A., Vinnerås, B. & E. Salomon). For more detailed information, please refer to this publication, accessible from the M4-7 Tutorial.

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Introduction

Concerning excreta, **faeces contain the largest amount of pathogens**

- ⇨ viruses, bacteria and parasitic protozoa, as well as hookworms and other parasitic helminths → diarrhoea, malnutrition etc.
- ⇨ **cross contamination with urine *must* be avoided**

Factors that affect survival:

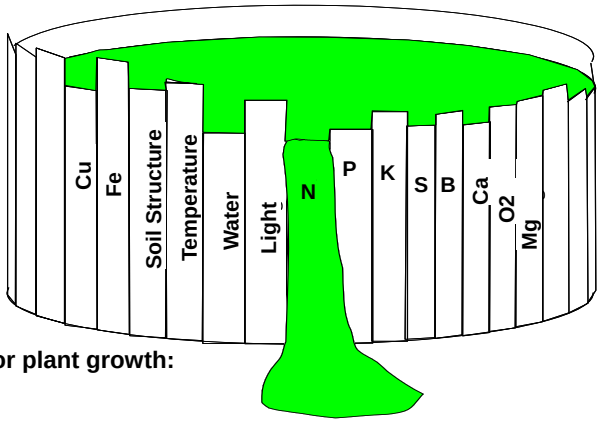
- heat
- pH
- moisture
- solar radiation/UV-light
- nutrient availability
- presence of other microorganisms affect survival

Avoid risk:

- ⇨ no exposure
- ⇨ sanitise excreta

Source: (1)

Requirements for Plant Growth



Source: Vinnerås (5)

Requirements for plant growth:

- light,
- Water
- structure for roots
- nutrients.

⇨ When supply of most limiting growth factor is increased, then other growth factors become important as limiting factors.

⇨ If factors other than nutrients are limiting, increasing nutrients will not help.

Source: (5)

Macronutrients & Micronutrients

Nutrients: essential elements

- Largest uptake: carbon, hydrogen and oxygen (in the form of CO_2 and water (H_20)
- Increase in: light, carbon dioxide, water and mineral nutrients → increased growth

Macronutrients:
Uptake is about 100 times that of micronutrients:

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Sulphur (S)
- Calcium (Ca)
- Magnesium (Mg)

Micronutrients
Uptake in very small (micro) amounts

- Boron (Bh)
- Copper (Cu)
- Iron (Fe)
- Chloride (Cl)
- Manganese (Mn)
- Molybdenum (Mo)
- Zinc (Zn)

Source: (5)

Composition of Human Excreta

Basically:

Amount of **excreted** plant nutrients / person = Amount of **consumed** plant nutrients / person

⇨ The amount of excreted plant nutrients can be calculated from the food intake (better data available)

⇨ If all excreta, biowaste and animal manure are recycled the **fertility** of the arable land can be **maintained**

⇨ Differences in nutrients reflects differences in diet

⇨ Rule of thumb: Distribution of excreta on an area equal to that used for producing

Source: (5)

Composition of Human Excreta: Heavy Metals & Micropollutants

Heavy metals:

- generally low or very low in excreta
- depends on amounts present in consumed product

Hormones:

- excreted with the urine
- have long been excreted in *terrestrial* environments (mammals) → vegetation and soil microbes are adapted to and can degrade these hormones
- probably very low risk when applied on soil

Pharmaceutical substances:

- mostly derived from nature
- degraded in natural environments with a diverse microbial activity
- risks associated with them are small

Source: (5)

Plant Availability of Nutrients in Urine and Faeces

Nutrients in urine:

- mostly water-soluble → directly available to plants,
- rapid plant availability

Faeces:

- both water-soluble + non water-soluble nutrients
- slower plant availability
- as faecal matter is degraded in soil, nutrients (N + P) become plant available

Organic matter:

- ✓ improves soil structure
- ✓ increases water-holding & buffering
- ✓ supports soil organisms

Source: (5)

Urine as a Fertilizer

Urine:

- ✓ high quality & low cost alternative to artificial mineral fertilizer
- ✓ best used for N-demanding crops and leafy vegetables

⇨ Use crop- and region-specific recommendations for N fertilizers (urea, ammonium or nitrate) if available to translate the recommendations to urine.

Rule of thumb:
concentration of 3-7 grams of N per litre of urine

⇨ better effect on a soil with high organic content

⇨ beneficial for soil fertility to use both urine and faeces (possibly in different years)

Urine as a Fertilizer: Dilution

Urine can be applied neat (without dilution) or diluted with water.
Dilution level varies between approximately 1:1 to 10:1, and **3:1 seems common** in agriculture.

Dilution increases:
- the volume to be spread
- labour
- equipment needed,
- the energy use
- risk for soil compaction

Dilution decreases:
+ Risk of over-application
+ Risk of toxicity to plants

⇨ Diluted urine: → Handle the same way as urine

⇨ Work urine into the ground (no smells, no loss of ammonia, no generation of aerosols)

⇨ Avoid foliar application (on leaves)

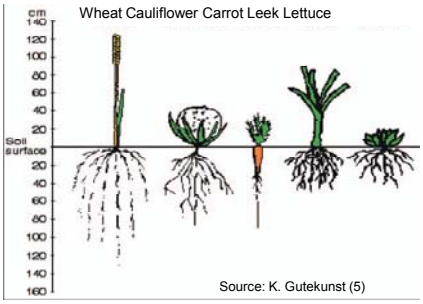
⇨ **Avoid dilution of urine during storage!**

Source: (5)

Urine as a Fertilizer: Application Time

- **Early stages of cultivation**: good availability of all nutrients important
- Applications:
  - ⇨Only 1 application: before sowing/at sowing
  - ⇨2 applications: 2nd application roughly ¼ of time between sowing and harvesting
  - ⇨**Continuous fertilisation possible when**: less concentrated
- Rule of thumb: **stop after** between 2/3 and 3/4 of the time between sowing and harvest.
- **Waiting period of one month** between fertilization and harvest
- Regions with heavy rainfall: repeated application

- Total applied amount depends on root size (small root systems: benefits from repeated application)



Source: K. Gutekunst (5)

Source: (5)

Urine as a Fertilizer: Application Technique

For best fertilizing:

- Incorporate urine into soil as soon as possible → avoids ammonia losses
- shallow incorporation is enough

Methods:
- small furrows that are covered after application.
- Washing the nutrients into the soil with subsequent application of water


Source: M. Johansson

Large Scale Application of human Urine in furrows (Sweden)

⇨No application on leaves: **foliar burning**!

⇨Spraying not recommended: **ammonia losses**


www.winetitles.com

Foliar Burning

Source: (5)

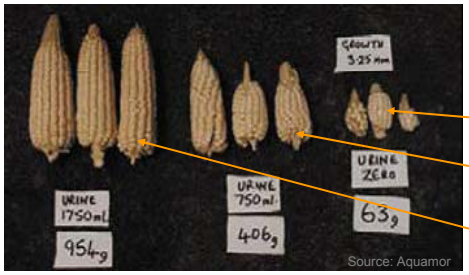
Urine as a Fertilizer: Application Technique

- **Drip irrigation possible**
  - avoid blockages (salt precipitation)
- Do not **simultaneously expose all the roots of the plant to urine**
  - Sensitive plants
  - Application prior to sowing/planting
  - Or application at a distance from the plant
- Spreading with **watering can**: easy application for small-scale gardens

Urine as a Fertilizer: Examples

Unfertilized spinach

- **Spinach fertilized with urine diluted with 3 parts of water to 1 part of urine**
- **applied 2 times a week**



Maize from Zimbabwe:

Growth period 3.25 months.

0 ml of urine

750 ml of urine

1750 ml of urine

Practical Recommendations: Safe Application of Urine


Source: GTZ

Urine: major recommendations

- direct use after collection or a short storage time is acceptable on the single household level
- longer storage necessary for larger systems
- at least one month should apply between fertilisation and harvest

Additional practises to minimise the risks :

⇨ precautions when applying: Hand washing

⇨ close to ground fertilising

⇨ incorporation into soil

⇨ Small-scale: urine preferably not diluted before application

Practical Recommendations: Safe Storage of Urine

Recommended guideline storage times for urine mixture[a] based on estimated pathogen content[b] and recommended crop for larger systems[c]

Storage temperature	Storage time	Pathogens in the urine	Recommended Crops
4°C	>1 month	viruses, protozoa	food and fodder crops that are to be processed
4°C	>6 months	viruses	food and fodder crops that are to be processed, fodder crops [d]
20°C	>1 month	viruses	food and fodder crops that are to be processed, fodder crops [d]
20°C	>6 months	probably none	all crops [e]

Concluding Recommendations: Urine

- ⇨ Urine: low risk for transmission of disease.
- ⇨ Dilution should be avoided.
- ⇨ Faecal contamination = highest risk!
- ⇨ At household level the urine can be used directly.

Large-scale systems:

Treatment	Criteria	Comment
1) Storage	Temperature >20°C during 1 month	Time should be extended at lower temperatures, pH should be >8.5
2) Additional Withholding[1]	Time > 1 month	Minimum requirement. Longer time needed if temperature requirement can not be ensured (see previous slide)

- ⇨ **Vegetables, fruits and root crops consumed raw**: Always one-month withholding period
- ⇨ In areas where *Schistosoma haematobium* is endemic, urine should **not be used near freshwater sources.**
- ⇨ Urine should be **applied close to ground** and preferably **mixed with or watered into the soil.**

Source: (2)

Faeces as Fertilizer

Source: GTZ

Faeces:

- lower total amount of nutrients than urine
- high concentration P and K,

Phosphorus (P):

- valuable for the plant in early development
- important for good root development

Organic matter:

- increases the water-holding and ion-buffering capacity of the soil
- food for the microorganisms
- better soil structure (aeration, pores etc.)

But: Higher risk for high pathogens → hygienization crucial!

Faeces as Fertilizer – Fertilizing Effects Depending on Treatment


J. Heeb


J. Heeb


J. Heeb

Faeces:

- fertilizing effect varies much more than the effect of urine
- fertilizing effect depending on treatment methods

Additives (ash, sawdust, etc.) influence:

- nutrient content
- organic matter content

Fertilizing Effects: Ash


Source: GTZ

Ash (Incineration)

- high contents of P and K + micronutrients.
- N and S are lost with the fume gas.
- high pH

Plant availability:

- good as long as the incineration temperature is not high enough for the ash to melt.
- With very high temperatures, nutrient content decreases rapidly

Depending on primary treatment:

- ash, soil or lime addition
- ash & lime: → increase pH (good for soils with low pH)

Fertilizing Effects: Compost

Compost:

- Often some 40-70% of the organic matter can be lost
- N is partially lost as well

Plant availability:

- Remaining **Nitrogen**: organic form → plant-available at the rate of degradation, (slow)
- **Phosphorus**: less than N bound in organic forms
- **Potassium**: mainly in ionic form and thus plant-available.
  - ⇨stable organic matter improves the water-holding and buffering capacity of the soil.

Additions:

- Additions of organic waste influence amount and characteristics of: compost

Fertilizing Effects: Desiccation/Biogas/Alkaline Treatment

Desiccation

- fast drying with a low moisture level:
- only small losses of both organic matter and N
- recycles more organic matter compared to composting
- but the organic matter is less stable

Residues from anaerobic digestion (Biogas Production)

- 40-70% of organic matter degraded
- mineralized N is not lost
- 40-70% of the N found in the residue is in the form of ammonium → readily plant-available.
- well-balanced, quick-acting and complete fertilizer
- mostly, animal manure and household waste are added → affects characteristics

Chemical treatment with urea

- ammonia content is elevated to high levels
- through large content of P and K → still well-balanced and complete fertilizer.
- applied according to content of mineral N.

Practical Recommendations for Faeces: Application Time

Application prior to sowing or planting (Irrespective of treatment)

- ⇨ large amounts of P very important for good development of small plants and of roots. T
- ⇨ application so that contact with soil solution is secured → dissolving and transport of the nutrients
- ⇨ incorporation into the soil is important

Pathogens in faeces → barriers needed:

1. secondary treatment of faeces.
2. application and thorough covering of the treated faeces before sowing/planting
3. avoid adding faeces as a fertilizer to vegetables eaten raw

Practical Recommendations for Faeces: Application Technique

Largest benefits of faeces: content of P and organic matter

- ⇨ Thus: applied at a depth where the soil stays moist → P only plant-available at the rate that it dissolves in the soil liquid.
- ⇨ water-holding and buffering capacity of the organic matter only fully used in moist conditions.

⇨ **The faecal product should always be well covered and placed in such a way that is within reach of the roots but not their only growing medium**

Practical Recommendations for Faeces: Application Technique

Digestion residues:

- high **ammonia content**
- Minimize ammonia loss through storage, handling and application
  - → storage in covered containers
  - → rapid incorporation into the soil.

Ash

- concentrated fertilizer
- careful distribution
- spreading may be difficult → mixed with a bulking agent (sand, soil)

Photo: A. Richert Stintzing, VERNA

Sabtenga, Burkina Faso. Mango tree fertilized with faeces at planting and doses of urine regularly during the growth season.

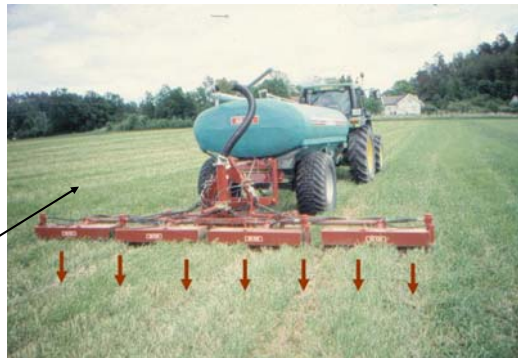
Practical Recommendations for Faeces: Application Rate

Applied according to Phosphorus content:

Depending on the amount of P excreted (i.e., ultimately, on the diet) and removal rate of the crop → faecal matter of 1 person enough to fertilize some 200-300 m2 of wheat at a yield level of 3000 kg/ha per person.

Many soil are devoid of Phosphorus: higher recommended application rate – faecal matter of 1 person enough P to fertilize 20-40m2.

⇨ **SEE M4-7 TUTORIAL FOR DETAILED INFORMATION**



Direct Ground Injection system, practiced in Norway

Source: P. Jenssen

Practical Recommendations for Faeces: Application Rate

Application rate according to organic matter content

- higher rates of application are needed to achieve effects on the soil system
- depending on soil state

High and stable organic matter content is only accomplished over longer periods of time.

Organic matter of dried faeces or compost → not as stable as the humus of the soil → degradation occurs:

+ plant nutrients are mineralised and become plant-available

- content of organic matter decreases

→ continuous application necessary

++ Risks of Applying High Rates of P or Organic Matter

Little risk with applying large amounts of P or organic matter to the soil.

- If large amounts of lime or ash are used as additives pH might get **too high (>7.5-8)**
  - ⇨ **Only a risk at extremely high application rates, and if pH of soil was already high**
- **Ammonium application might too high**: Base application rate on knowledge of the ammonium concentration of the product and the desired application rate for N.

→ High application rates are not resource-efficient

The application rates in the examples stated above are in the approximate range of 20-150 tons of faecal product per hectare. Normal application rates for farmyard manure in agriculture re in the range of 20-40 tons per hectare

Practical Recommendations for Faeces: Safe Reuse of Faeces

Agricultural use practises dependent on the preceding treatment.

→ **Treatment may not render an absolutely safe product!**

Additional safety measures to minimise risk for disease transmission:

- ⇨ special equipment for sanitized and un-sanitized products
- ⇨ handling: wear protective clothing (i.e. gloves) and wash afterwards
- ⇨ work treated faeces into soil rapidly
- ⇨ do not use improperly sanitised faeces for vegetables, fruits or root crops that will be consumed raw, excluding fruit trees.
- ⇨ incinerated faeces are hygienically safe – but some nutrients are lost

Concluding Recommendations: Faeces

- Faeces must be treated before it is used as fertilizer.
- Primary treatment: includes storage + alkaline treatment by addition of ash or lime.
  → Small-scale systems (household level): faeces can be used after primary treatment if the criteria in the table below are fulfilled (2).
- The treatments in the table below (+incineration) can be used as secondary treatment at household level:

Treatment	Criteria	Comment
Storage; Ambient temp. 2-20°C	1.5 – 2 years	Eliminates bacterial pathogens; re-growth of *E. coli*/*Salmonella* possible; will reduce viruses and parasitic protozoa below risk levels. Some soil-borne ova may persist in low numbers.
Storage (only treatment) Ambient temp. >20-35°C	> 1 year	Substantial to total inactivation of viruses, bacteria and protozoa; more or less complete inactivation of Ascaris eggs will occur within a year.(21)
Alkaline treatment (= pH >9)	pH >9 during >6 months	If temperature >35°C and moisture <25%, lower pH and/or wetter material will prolong the time for absolute elimination.

Source: (20)

Concluding Recommendations: Faeces

- **Secondary treatments** for larger systems (municipal level) include alkaline treatments, composting and incineration.
- **Composting:** as a secondary treatment at large scale (difficult process)
- **Storage:** less safe (see previous table). Shorter storage possible for systems in very dry climates → moisture level <20%
- **Sun-drying** or exposure to temperatures above 45°C will substantially reduce the time.

Treatment	Criteria	Comment
Alkaline treatment	pH >9 during >6 months	Hypothesis: If temperature >35°C or moisture <25%. Lower pH and/or wetter material will prolong the time for absolute elimination.
Composting	Temperature >50°C for >1 week	Minimum requirement. Longer time needed if temperature requirement can not be ensured
Incineration	Fully incinerated (<10% carbon in ash)	
Storage	as in the table above (preceding page)	Time modification needed based on local conditions. Large systems needs a higher level of protection. Than at household level. Additional storage adds to safety

Source: (2)

END OF MODULE M4-7

FOR FURTHER READINGS REFER TO M4-7 TUTORIAL

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++ Glossary and Abbreviations

ACTS	Agriculture, Crafts, Trades, Studies
GTZ	German Agency for Technical Cooperation
IRC	International Water and Sanitation Centre
N	Nitrogen
K	Potassium (Lat: Kalium)
UNICEF	United Nation's Children's Fund
P	Phosphorus
PHAST	Participatory Hygiene and Sanitation Transformation
SSHE	School sanitation and hygiene education
WASH	Water, Sanitation & Hygiene
WELL	Water and Environmental Health at London and Loughborough
WSSCC	Water Supply and Sanitation Collaborative Council

See glossary for unknown terms & definitions!

ECOSAN GLOSSARY

ABBREVIATIONS