Module 4.8

Excreta fertilisers in Agriculture

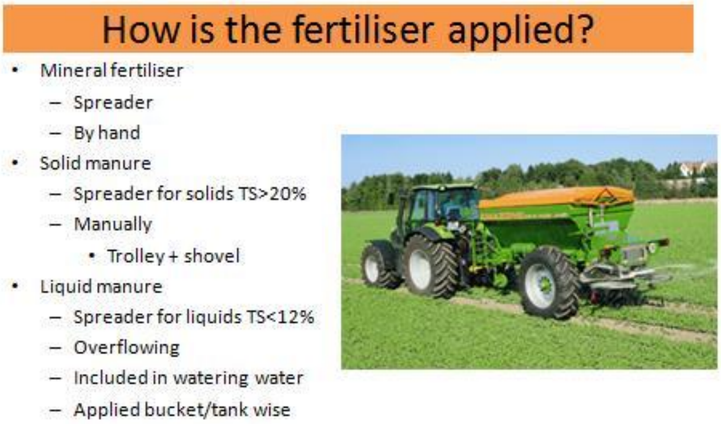
How can ecological fertilisers from excreta best be used?

When a farmer is producing food he start with an investment in the soil with the application of seeds. To improve the productivity of the applied seeds will he try to give the plants the best surrounding as possible. This is to 30% of all food production performed by application of mineral fertilisers, normally nitrogen, phosphorus and potassium, in some cases even other macro nutrients such as sulphur and calcium. The mineral fertilisers are focusing on improving the proportion of available macro nutrients, the nutrients that plants have the highest requirement of, these nutrients are most often the ones that limits the growth of the plants. However, there can also be other factors that limits the growth, e.g. temperature, sun light, water etc, and are these conditions not fulfilled the applied nutrients will not have any effect on the growth of the plants.

Animal manure is most often used in agriculture as fertiliser in agriculture. In some cases the manure is just dumped and not utilised but it is a good fertiliser and soil conditioner. In comparison to mineral fertilisers does the animal manure not contain as much readily plant available nutrients as the mineral fertilisers. On the other hand, the manure contain organic matter that will improve the soil quality, as it increases the organic content etc., this will among other things improve both the buffering capacity (better pH) and the water containing capacity.

Except from the nutrients, in some cases will the farmer need to apply water to improve the growth.

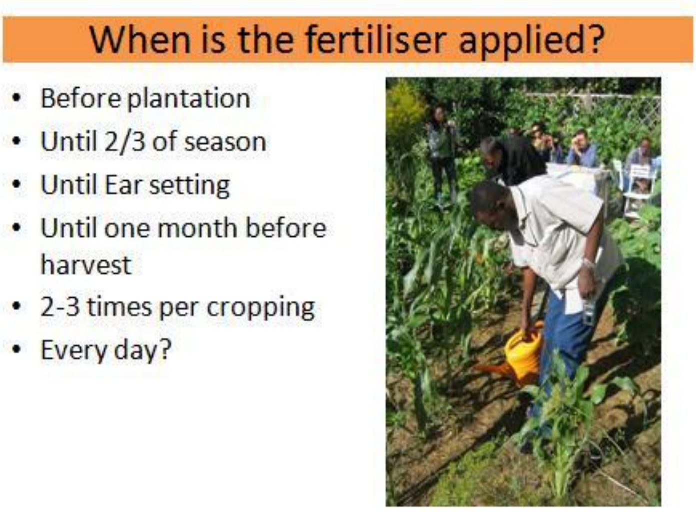
In all cases this work to improve the plant growth will need energy, it can be man power, animal power or from machines. Still, all this effort will require input of energy for producing a crop to be harvested.



Mineral fertilisers can be applied by hand, or by machine. The machine application can either be broad spreading onto the field close to sawing or simultaneously with sawing. Additional nutrients (mainly nitrogen) will also be applied some period into the growth to optimise the harvest. Mineral fertilisers are mainly applied as pellets with a diameter of a few mm.

Solid manure is either spread by machine or by hand using a trolley and a shovel. The manure need to be dry enough for spreding, this means that the minimal dry matter content need to be above 20%, i.e. maximum water content of 80%. If it is too dry there is major risk for dust during spreading, which can be seen as a threat to the health of the workers. Per hectare can between 10 and 50 tonnes of material be applied. The major factor regulating the application rate is the nutrient content as too much nutrients can harm both the crop and the environment.

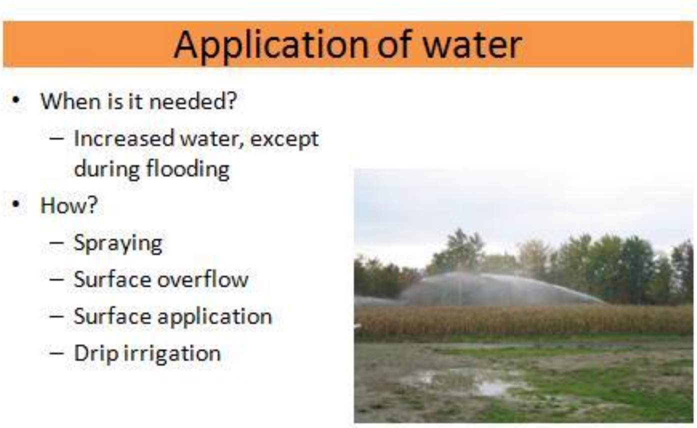
Liquid manure should be possible to pump, as a rule of thumb will this require at least 88% water, i.e. maximum dry matter content of 12%. The liquid manure can be spread with a spraying machine, preferably close to the ground to avoid aerosols and ammonia losses. Other techniques for application is overflowing of the fields, incorporation in regular watering water, or application by hand tank wise or bucket wise.



The fertilisation is mainly performed in close relation to plantation of seeds. This is the case when applying fertilisers that require incorporation into the soil, e.g. compost and solid manure. If fertilisation is planned to be performed only once, the optimal time is close to the plantation. When distributing the fertilisation over the growth season phosphorus and potassium are of most importance early in the growth of the plants while nitrogen is mainly required when the plants have started to grow and are visible over ground. SO if the fertilisation should be distributed, looking at excreta based fertilisers, faecal compost etc should be applied prior to sawing and urine should be applied after the plants have started to grow.

The plants will not utilise the nutrients all through the growth season if you are planting cereals. As a rule of thumb is that the plants will take up nutrients during the first two thirds of the growing season or until they are setting ears. If you plant leafy crops, e.g. lettuce, nutrients will be taken up all through growth. However, nutrients applied later than one month prior to the harvest will only be utilised to a very small extent.

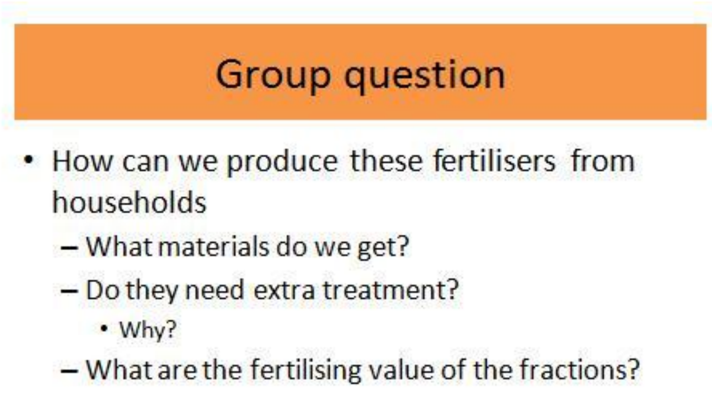
If distributing the nutrient application over the season the nutrient losses will decrease and the plant utilisation will be improved. However, if the nutrients are applied more than 2-3 times during the growth season no significant increase in yield will be noted compared to application 2-3 times per season.



Application of water will almost always have a positive effect on the growth. Still, there is not always economical to apply extra water if the existing water distribution to the plants does not significantly decrease the growth as water application also comes with a cost of infrastructure, energy and labour.

The application can be performed via spraying, either as single point or multiple points at one field, depending on systems available. Surface over flow is often used and with proper pre structure with canals etc. the effort for application is minimal.

Surface application and drip irrigation minimises the risk of aerosol formation and thereby spreading of diseases in the environment. Irrigation in systems with small holes, e.g. drip irrigation, tend to risk blockages if dirty water is applied as either the content of the water will block the holes or it will be blocked by growth in the pipes. The choice of system is mainly dependent of what is locally available and affordable.



This is a general question for discussion, the aim with this is to get the student to apply a reverse engineering approach, not looking at the conventional systems that we have in our houses today but rather try to look at the different waste fractions from a farming perspective. When doing so, the conventional waste and wastewater system can look a bit odd as the products here is not for farm use but rather pollution prevention out of a societal perspective.

If the students discuss this for 5-10 minutes in group of 2-3 people they can get interesting discussions around both existing systems but also about what do the farmer need for his food production.

This can either be further discussed in the full group or that the students present this material by shortly summarise what they talked about. This gives the teacher an opportunity to reflect back during the further lecture to what the students were discussing.

The following nutrient fraction is the faecal matter. The volume of the faeces varies and depends on the diet. A general food consumption in the western world contain low amounts of fibres that result in smaller faecal volumes compared to a traditional African and Asian diet that contain more fibres which result in larger volumes. Still, the total faecal volume is small and vary between 40 and 100 kg per person and year of which the water content are approximately 80% and thereby the excreted solids are between 8 and 20 kg per person and year.

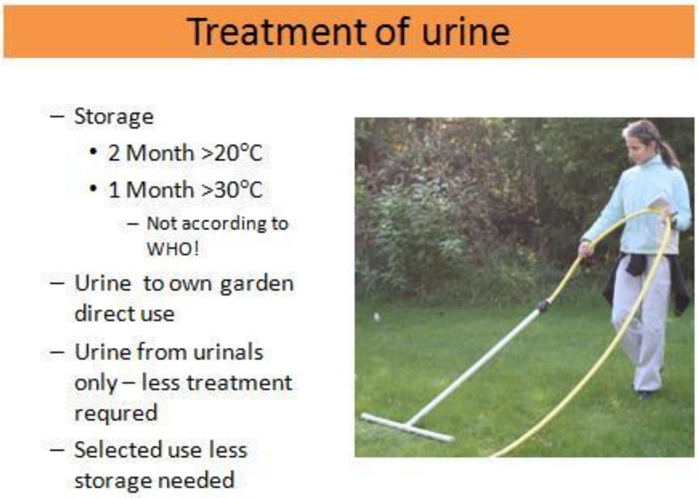
The nutrients in the faeces are mainly organically bounded and thereby not as plant available as the nutrients in the urine. The content in the faeces are mainly material and substances that is not metabolised by the body and the faeces can be more seen as a soil conditioner than a fertiliser.

In the faeces will the main part of the disease causing microorganisms, pathogens, be found that end up in the different streams of wastewater. How much you can find is described more closely in chapter 3 and how to manage the pathogens in the faeces to produce safe fertilisers are presented in Chapter 4 module 2.

In human urine will you find the majority of the plant nutrients coming out of one household. It is, in comparison to mixed wastewater, a small volume as the average person urinate between 1 and 1.5 litre per day. This urination is distributed on approximately seven occasions. In the urine you will find 3-3.5 kg nitrogen per year 0.3 kg of phosphorus and potassium. Additionally you find all micronutrients needed for biological activity, such as iron, copper, zink etc. All of these substances are higly plant available and the urine can be compared to a mineral fertiliser. While the levels of non-essential metals, such as mercury and cadmium are extremely low, often as low as they are impossible to detect in the urine. The substances we find in the urine reflects what is metabolised by the body, therefore is the pollution levels low.

The exception is hormones and pharmaceuticals that are excreted in the urine to a relatively high concentration as they are metabolised by the body, most often are these substances excreted in their active form. However, the organic substances from hormones and pharmaceuticals do less harm in the soil compared to the harm they can do if they end up in the water streams.

The exact content of the urine collected from one person vary a lot depending on the diet, as the nutrient content are reflected in the urine by the diet as well as the volume will be dependent of the water consumption together with the transpiration.



The most common treatment of urine is storage. At storage above 20°C it is enough with 2 month of storage for unrestricted use of the urine as fertiliser, if the storage temperature is even higher, above 30°C only one month of storage is needed. This is not in line with the recommendations presented by WHO but based on later research further detailed studies have shown that this is enough.

The main source of pathogens in the urine is from faecal contamination and if the urine only is collected from urinals the risk for faecal contamination does not exist and lesser restrictions on the time of storage can be used.

When using the urine collected in one household in the own garden no restrictions are applied on the use of the urine as the risks for other routes of transmission for diseases are consider to overshadow the risk of disease transmission via the urine.

If other barriers are applied in the use of urine, explained further in chapter 3, such as restrictions in where the urine is applied, e.g. processed crops, non food crop.

Further description on how to treat urine and what functions that regulate the inactivation of pathogens can be find in chapter 4 module 2.

As the risk of pathogen content in the faeces are high a more advanced treatment is required for decreasing the risk of disease transmission upon fertilisation.

Composting is the most common treatment of faeces, the composting itself will not inactivate all pathogens present but if the process reaches a temperature above 50°C the potential pathogenic content will be inactivated. The WHO recommendation is composting above 50°C for at least one week. To be sure of enough inactivation of potential pathogens all material needs to be treated at this temperature. Easiest to do this is to mix all material during the high temperature process, as a rule of thumb, reactors should be mixed 3 times and piles/windrows should be mixed 5 times.

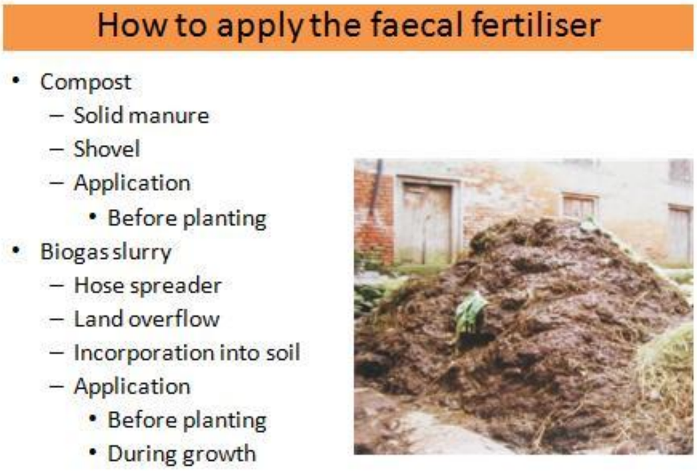
Another treatment alternative is anaerobic treatment (biogas process), neither this process will inactivate the pathogens in the material. Here you will not get the process to heat up by itself, the reduction of pathogens are improved by long residence times, both the minimal time in the reactor as well as the average residence time. One alternative could be post process treatment that for example could be performed with chemical treatment.

The traditional chemical treatment is by application of lime or ash. These processes will increase the pH to inactivate pathogens. To inactivate all potential pathogens a pH above 12 will be required. Another alternative is ammonia treatment, mainly performed by addition of urea, this treatment will be performed at pH 9 and have good effect on potential pathogens. The nitrogen can after performed treatment follow the faecal matter to the field as fertiliser and there improve the fertilising value for the faeces as the nitrogen will be direct plant available.

The urine can be applied from small scale to large farm scale. In all scales it is important to avoid ammonia losses. This is easiest performed with application close to the ground and incorporation into the soil close after application. In large scale the application should not be performed with sprayers or splash plates that produce large amounts of aerosols but rather with hose spreaders, drip irrigation etc followed either by secondary tillage for incorporation or application of water that transports the urine into the soil. In small/garden scale this can be performed by application into furrows that are covered after application or by watering after application.

In large scale the application can be performed by using conventional farm equipment for liquid manure application. In small scale the application can be done by pumps and hoses or by simple watering cans.

The time to apply the fertiliser is before planting and during the growth. The application rate will be limited by the nitrogen content, and a good application rate is to apply 100kg nitrogen per hectare of soil (10g nitrogen per square metre), this will give an application of 10-50m^3 of urine to apply per hectare depending of the nitrogen content of the urine. As a rule of thumb is that the urine collected from one person during one day can be applied to one square metre per growing season. Still up to the urine from five persons collected during one day will have good effect on the soil and not lead to over-fertilisation, but the optimal fertilisation levels are less.



When using treated faeces as fertiliser, the treatment method will affect the choice of application method.

Compost will be applied as solid manure, either with a solid manure spreader, or by hand. The compost should be incorporated into the soil after application so the optimal fertilisation is prior to planting.

The biogas slurry can be applied as a liquid manure, using hose spreader or other local suitable application techniques. For optimised use and less smell the material should be incorporated into the soil as soon as possible after application, e.g. by secondary tillage. The biogas slurry contain higher concentrations of plant available nitrogen that are easily utilised by the plants. Therefore, the slurry can be applied during growth.

The greywater contain large amounts of easily degradable carbons that are degraded rapidly after collection, and if no further treatment are planned but field application, storage should be avoided as the greywater start to smell fast. Short piping systems allow for direct use in the own garden, open water surfaces should be avoided, so the water should either be infiltrated directly in a mulch bed or similar.

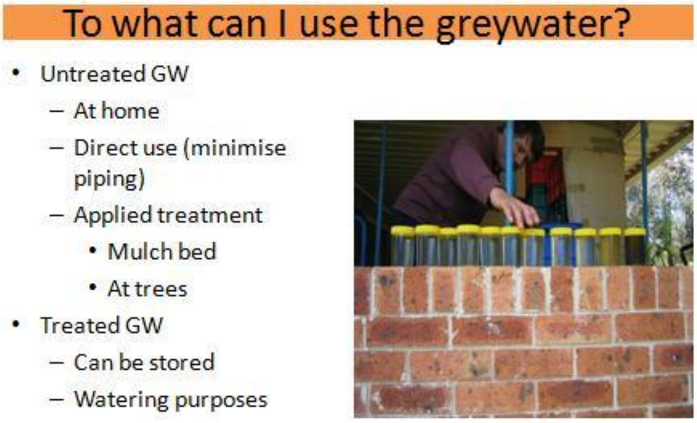
Treated greywater (Chapter 4 module 5-7) can be stored and applied using conventional watering equipments.

Urine, either if treated correctly or used in own garden can be used without restrictions. The user should be aware that the urine contain salts and in situations where there is no downward movement of water in the soil over the years, e.g. monsoon rain or rainy seasons etc, there is a risk for salt build up. However this is only in extremely dry areas, where all cropping is performed by irrigation. The urine containes high concentrations of ammonia and should not be applied on the leaves of the plants as the foils of the leaf are destroyed and the plant is killed. Additionally the ammonia will be lost as air emission.

For untreated urine in large systems restriction are needed for usage and how to apply to avoid disease transmission. This urine should not be applied to crops to be consume raw but to other crops that have other barriers for the disease transmission, more about this in Chapter 3.

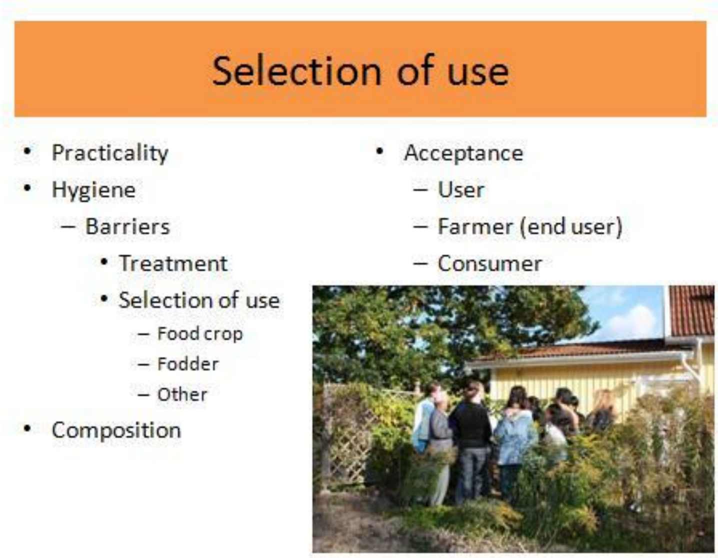
The fertiliser usage of faecal based fertiliser will have a close connection to the level of treatment performed on the raw faeces. If the treatment is of high quality regarding the removal of pathogens the usage can be without restrictions. However, if the treatment level is uncertain restriction in the use should be applied, as well as in the application, assuring that workers health will not be affected.

Choices of restricted use can be application of the fertiliser to crops with long growth period, where the application of fertiliser and the harvest can be differentiated by years, examples of such crops are pineapple, banana coconut etc. Another alternative is to use the fertiliser for non food crops, if assurance of no zoonotic diseases can be made the fertiliser can be used for fodder. It can also be used for energy crops and ornamental crops assuring that no one will consume the produce.



The hygienic risks with greywater are less compared to faeces and urine. The application of untreated greywater is mainly restricted to that it is not possible to store or transport long distances due to the large bacterial growth and the following smelling problems. Untreated greywater can be used in the own garden. If the system is performed with minimised piping no grease trap is needed as the water will hold such temperatures that there will be no coagulation in the system. The greywater can then be directly applied to trees etc. and also to grass, if particles such as food scrapes are removed prior to the application.

Treated greywater can easily be stored and used for wateringpurposes.



When, where and how to use the different fraction are limited to mainly local factors. Is the system practical for all involved persons?

Is the hygienic quality assured? Here it is important to involve all parts of the system, such as workers, inhabitants in the area, animals in the area, consumers of the produce etc. The different barriers for disease transmission need to be assessed and evaluated regarding the treatment, the distribution system and the use of the fertiliser.

Additionally the composition of the fertiliser need to be evaluated, will the farmer understand how and when to apply and will he/she have the proper equipment for application. Substrates that do not full fill the standard of existing fertilisers and fertilisation equipment will be hard to find a receiver/market for as no-one will be able to apply the fraction into the cropping system.

For a successful recycling scheme of excreta based fertilisers the acceptance of the different products need to be evaluated. This involves the user of the system, the farmer and the consumer of the fertilised produce. If the system fails in any of these steps it will be tuff to get it to succeed.