

11. Urine diversion – how to build and manage a single vault composting toilet system.

Urine diversion

In a third range of latrine designs, the concept of **urine diversion** is used. This is a well established method which is being used successfully in many parts of the world. Countries in Europe like Sweden, use it a great deal in the new era of ecological sanitation which is taking off in the northern hemisphere. It is being strongly promoted by the Swedish EcoSanRes group and also GTZ. The concept of **urine diversion** is also being used widely and successfully in Mexico, Central and South America (El Salvador, Guatemala, Ecuador), India, Japan and also in China, where the recycling of human wastes has been practised for generations. It is also being promoted on a relatively large scale in South Africa (Austin and Dunker, 2002) and Uganda by the Ministry of Water, Lands and Environment (MoWLE, 2003). The use of this method is well documented. A book entitled *Ecological Sanitation* (1998) by Esrey et.al. is particularly valuable and the second updated edition will be available in 2004. For a list of suitable references see the bibliography at the end of this book.

Urine diverting toilets use a special pedestal in which the urine enters the front part of the pedestal and is then diverted through a pipe and is thus separated from the faeces. In China and a few other countries where the squatting position is favoured, urine diverting squat plates are used. These are very successful. The urine can either be collected in plastic or concrete containers of some sort, or it can be led into a soakaway system. Considering the value of the urine, to allow it to soak away, unless on to a mature tree like a banana, is somewhat wasteful of a valuable resource. The faeces fall down directly into a brick lined vault beneath the pedestal. Some dry soil and wood ash (or lime in some countries) is added to cover the faeces after every visit. This covers the deposit and helps to dry out the surface of the faeces and makes them easier to handle and transfer. The distinct advantage of this method is that the urine can be collected separately, making it available as a liquid fertiliser. Also the solid component, being in a semi dry state, is much easier to handle and is safer from the beginning, even if it does initially contain pathogens. Being semi dry, it does not smell so much and its potential as a fly breeding medium is much reduced compared to the mix of urine and faeces. Eventually the faeces become completely dessicated.

Semi dryness is essential for the success of the urine diverting system. There must be no malfunction of the urine diverting pedestal. In other words, urine must always go down the front and faeces down the back. If there is an error made in this use, the system can malfunction badly. Blocked pipes carrying urine need unblocking. It is possible that soil thrown down the pedestal may enter the urine pipe, and sometimes even faeces if used by children. Thus the pipes used must be wider rather than narrower, and easily washed out. Also if urine (or water) finds its way into the above ground “dry” vault, the result can be messy and unpleasant. Meticulous use is rather an essential component of the urine diverting concept. This is one reason why alternatives are also recommended in Southern and Eastern Africa, as they are simpler and cheaper, being more forgiving of misuse. The writer has used an above-the-ground single vault urine diverting toilet for several years in his garden and this experience is reported in this chapter. Both home made and commercially made urine diverting pedestals have been used. Initially urine was taken to a seepage area, but this was modified so that urine was collected in a 20 litre plastic container for use in the garden. This system has proved to be an excellent asset to the homestead and has given far fewer problems than the conventional water born system used in the house.

The “*Skyloo*”

The *Skyloo* is the name given by the writer to this particular version of a urine diverting toilet. It differs in several ways to the standard urine diverting method of building and processing the excreta. In the “*Skyloo*” faeces are collected in a single small vault built above the ground. Whilst faeces can accumulate directly in the single vault for periodic removal, the preferred method in this case, has been to contain them in a 20 litre plastic bucket (together with toilet paper, soil and wood ash). The bucket contents are held within the vault only for a relatively short period, until the bucket is nearly full. Then they are transferred to a “secondary composting site” for further processing. These sites may be in the form of cement jars or buckets or shallow pits or trenches and even garden compost heaps. In each case the formation of humus is encouraged by combining the various ingredients in the bucket with more soil and also some water to add moisture to the mix. Some leaves can also be added. The mixture of ingredients is converted into a pleasant smelling humus-like soil within a few months. This humus can be used to grow a variety of trees, vegetables and flowers. Nothing has gone to waste. Once again the recycling of human excreta is made as simple and convenient as possible. Natural processes are involved.

The humus resulting from composted human faeces makes an excellent soil conditioner and is rich in nutrients as the soil analyses revealed later shows. The important lesson that comes out of this experience is that human faeces, once composted into humus, have a considerable value of their own, not only in providing extra nutrients, but also by improving the texture of soil. The resulting humus can be used directly for growing trees, vegetables and flowers or it can be mixed with less fertile soils to improve the overall quality of the soil. The use of garden and leaf compost generated in the garden is also important so that a combination of these various plant growing media can be encouraged. Thus those practising ecological sanitation should also be familiar with the methods of making garden and leaf compost so that all these fertile materials can be mixed to form a good planting material. The human fraction enters the system and becomes part of it. Such humus when properly used in agriculture helps to improve food yields and also food quality and hence provides more food security and improves the nutritional status of the beneficiaries.

The *Skyloo* - a general description.

The *Skyloo* is built upon a base made of concrete cast on the ground. Above this concrete base is built a shallow “vault” made of bricks and cement mortar. The vault only needs to be a little deeper than the bucket which will be fitted inside it - that is less than 40cm deep. A concrete slab is laid on top of the vault with openings for a vent pipe and urine diverting pedestal. An additional slab is made to fit on the rear of the vault for easy access into the vault and removal of the bucket. A urine diverting pedestal is fitted over the hole in the concrete slab. The urine pipe from the pedestal can direct the urine into a soakaway or preferably through the wall of the vault into another brick built chamber which contains a 20 litre plastic container to receive the urine. Next, a suitable superstructure is built or mounted on top of the latrine slab. This can be made of wood, bricks, plastic sheets attached to a frame or in any way that affords privacy. All hardware in direct contact with urine should be made of durable plastic – not metal - urine is very corrosive.

How the urine diverting toilet works

SIDE VIEW

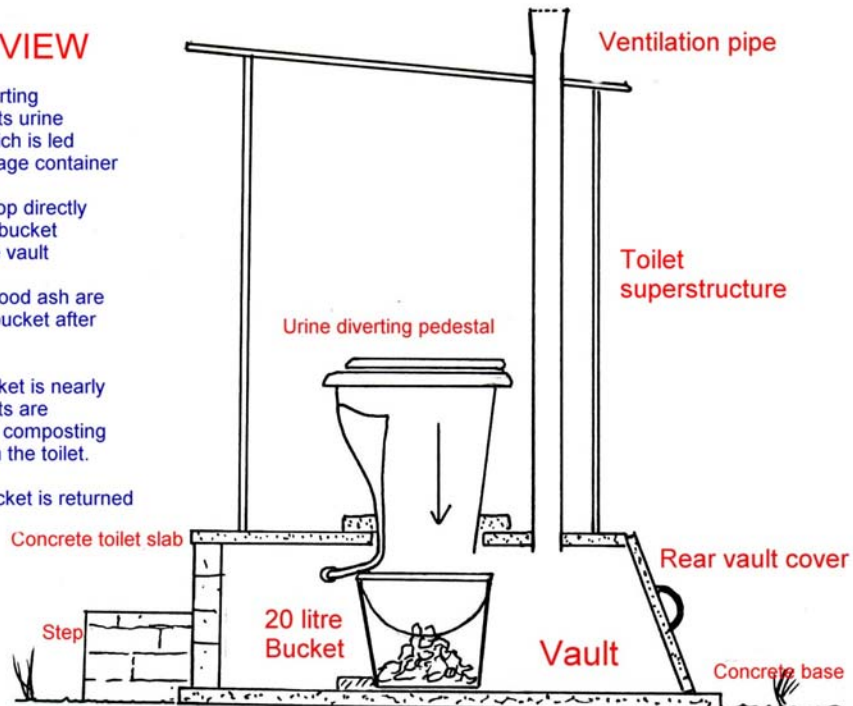
The urine diverting pedestal directs urine into a pipe which is led to a urine storage container

The faeces drop directly down into the bucket held within the vault

Dry soil and wood ash are added to the bucket after every visit

When the bucket is nearly full the contents are deposited in a composting site away from the toilet.

The empty bucket is returned to the vault.

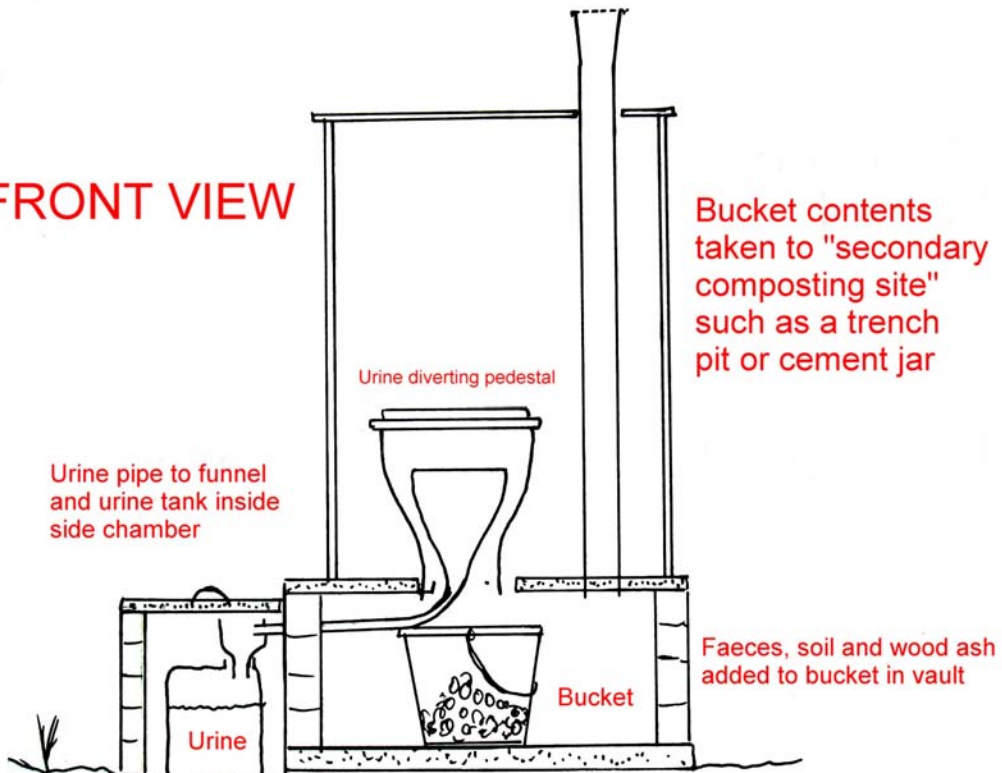


FRONT VIEW

Urine pipe to funnel and urine tank inside side chamber

Bucket contents taken to "secondary composting site" such as a trench pit or cement jar

Faeces, soil and wood ash added to bucket in vault



The “SKYLOO” - Stages of construction

Stage 1. Making the base slab

This is a concrete slab laid on level ground which will form the base of the *Skyloo*. This forms the foundation for the whole toilet. A concrete mix is made using five parts clean river sand and one part cement (or 3 parts river sand, 2 parts small stones and 1 part cement). The concrete is cast within a mould made of bricks, the dimensions being 1.35m long X 0.9m wide X 75mm deep. An area for the step is also made 450mm long and 335mm deep. Some steel reinforcing wires are placed in the concrete. It is left to cure for at least 2 days before any brickwork is built on top of it. It should be kept wet for several days to cure properly



On the left the brick mould for the *Skyloo* base slab. This is cast on level ground at the toilet site. The whole structure is built on top of this. On the right the mould for the toilet slab. This is cast with the same mix of ingredients as the base slab and is 1.2m long and 0.9m wide and about 40mm deep. Holes are cast in the slab for both the pedestal and the vent pipe. The exact method of making the concrete slab is described in the toilet construction chapter. In fact the same basic slab can be used to make an *Arborloo*, a *Fossa alterna* or this urine diverting “*Skyloo*.” Using the same slab it is therefore possible to upgrade the system over time. Money spent on making concrete slabs and other concrete structures is well worth while since they usually last for a lifetime and are a good investment in both money and time.

Stage 2. Making the latrine slab

This is made with a mixture of 5 parts of quality river sand and 1 part of cement or three parts river sand, two parts small stones and one part cement. It is reinforced with 3 or 4mm steel wire - 4 lengths in each direction. The slab is made 1.2 metres long and 0.9 metres wide and about 40mm deep. Holes are made for the vent pipe and the pedestal. The pedestal hole is made about 30-35cm from the rear end of the slab and the vent pipe hole (110mm in diameter) is made about 15cm in front the rear and side of the slab. The hole for the pedestal is made using a plastic basin or 20 litre bucket and this is laid in the final position. The hole size must match the pedestal being used. The vent hole is made using a short 75mm length of the pipe which will be used for the vent. This may be a PVC vent 110mm diameter. The slab is cast on flat ground on a plastic sheet. Bricks can be used as a mould, or timber. Half the mix is made first, then the wire reinforcing is added, followed by the remaining cement. The concrete work is made flat with a wooden float, then finished off with a steel float. About 10 litres of cement (quarter 50 kg bag) mixed with 50 litres good river sand (or 30 litres of river sand and 20 litres small stones) is a good mix. The slab is best cast in the late afternoon, left to harden overnight, then watered and covered with plastic sheet. It is kept wet for at least one week before moving. Whilst the slab is curing, the rest of the *Skyloo* structure can be built. Such a slab, well made will last indefinitely.

Stage 3. Making the vault, step and lintel

The vault is built up in fired bricks and mortar to the required height on the base slab. If a 20 litre bucket is used the vault should be about 40cm high. This will require about 4 courses of bricks built on edge or about 6 courses built normally. The walls are built so that the outer measurements of the top are 1.2m X 0.9m and the base 1.35m X 0.9m. This allows for the slope at the back of the vault over which the vault access slab at the rear will be fitted.

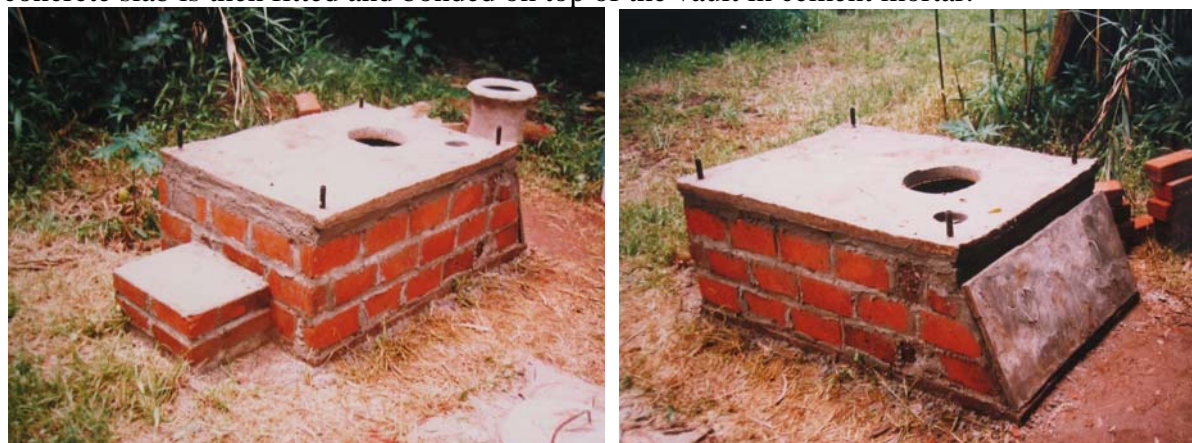


Stages in making the vault. The brickwork

Since the rear end of the latrine slab will not be supported on a brick wall it is desirable to make a reinforced concrete lintel which spans the rear end of the vault. This is made with 3 parts river sand and one part cement and reinforced with 3 or 4mm wire. It should be 0.9m long and be 225mm X 75mm wide. Once cured after 7 days it can be carefully mounted on the rear wall of the vault as shown in the photo above.

Stage 4. Making and fitting the vault access slab

This is made in thin high strength concrete using 2 parts river sand and one part cement with 15mm chicken wire as reinforcing and two wire handles inserted for lifting. The dimensions are about 90cm X 45cm high (the exact dimensions must match the vault). This is cured for a week and will be rested against the sloping rear side of the vault. A neat, almost airtight fit is required. This is made by applying strong cement plaster to the vault brickwork and grease to the adjacent cement panel side and bringing the two together. After curing the panel can be withdrawn leaving an exact impression on the vault. This is shown in the photo below. The concrete slab is then fitted and bonded on top of the vault in cement mortar.



The vault access slab and the toilet slab have now been fitted. The superstructure must now be made.

Stage 5. The urine diverting pedestal

Urine diverting pedestals can be home made (see chapter 13 for various methods of home made urine diverting pedestal and squat plate construction), purchased commercially or modified from commercial non urine diverting pedestals which are more commonly available. The “*Skyloo*” described in this chapter used a home made urine diverting pedestal at first. Later this was replaced by a urine diverting pedestal made from a commercially available non urine diverting pedestal. This was modified by adding a urine diverting wall and a urine outlet pipe.

Home made urine diverting pedestals can be made from off-the-shelf plastic buckets and cement. The photos below show one possibility. The plastic bucket forms the inner shell of the pedestal and it is surrounded with cement mortar. Another plastic bucket is cut and trimmed to fit inside the first. The urine is channelled down and led off through a pipe to a soakaway or preferably into a urine storage container.



Stages in making one “home made version” of a urine diverting pedestal. Urine in this case ran down through the hole into another plastic bucket held within the vault and then to a soakaway.



On the left the home made urine diversion unit is fitted over the slab. On the right the improved urine diverting pedestal, fitted with wooden seat. Note also the vent pipe fitted behind the pedestal to the right.

Stage 6. Mounting the pedestal.

Pedestals are mounted over the hole in the slab and cement mortared in position. It is important that this joint is watertight, so that any water falling on the slab (from rain or washing water) does not drip into the bucket below which must contain faeces, paper, soil and wood ash only – absolutely no water.

Stage 7. Adding a urine collector.

Urine is a valuable plant food and is best collected in a container. The best method is to build an extra brick side-chamber on one side of the vault. This will house a plastic container of about 20 litres capacity which will receive and store the urine. A plastic pipe is led from the urine outlet of the pedestal through the side wall of the vault into the brick side chamber so that the urine can be caught by a small funnel which directs it into the urine storage container. The brickwork of the side chamber is built up to enclose and protect the container and the piping. The chamber is covered with a concrete lid with handles. It is important to ensure that the plastic pipe leading from the urine outlet to the container falls continuously and does not pass through a loop which will act as a water trap or air lock. The side wall chamber must be big enough to house the container so that it can easily be withdrawn. Since urine is very corrosive, the piping and container must be made of stout plastic. Metal parts will corrode.



A plastic pipe is led down from the urine diverting pedestal through the side wall of the vault into a plastic container held within a small brick built side vault. A home made funnel is used to guide the urine into the container. The side vault is built up on soil so that any urine overflow can drain away.

Stage 8. Making the superstructure

Many types of superstructure are possible for urine diverting toilets. They are built in one location and thus can be made from bricks or timber, metal sheeting, asbestos sheeting, reeds, grass or of any material that offers privacy. In this case, the vent pipe is placed within the structure and the roof must have a hole made for the ventilation pipe to pass through. Structures are fitted with a door of some sort. A roof is essential as this prevents rain water entering the interior and the pedestal. Water must not be allowed to penetrate into the vault.

Skyloo superstructure



The superstructure in this case has been made from a frame of polyethylene pipe covered with plastic "shade cloth." This is not very robust, but has proved very adequate over a four year period. The urine diverting pedestal is smart and comfortable. A mixture of soil and wood ash (4:1) is stored in one container, with dispenser. Toilet paper is held in another container.



Finished structure with side vault for urine collection. The rear vault access door is neatly fitted. A 20 litre bucket has been fitted within the vault. Two bricks cement mortared to the floor locate its best position directly beneath the pedestal chute.

Stage 10. Finishing off

Make sure the rear access door fits well at the rear of the vault. The vent pipe will function better if the vault is well sealed. Two bricks can be mortared on the base slab to locate the best position for the bucket which is directly under the pedestal. The vent pipe is fitted into the toilet slab and through the roof. A latch is fitted to the door to hold it closed. A mix of dry soil and dry wood ash (4:1) is provided in a container. It is best to mix bulk dry soil and ash first and hold in a sack, or dust bin, then bring to the toilet in small lots.

Use and management of the *Skyloo*

Since the faeces from the *Skyloo* will be used to make humus, it is essential that soil and wood ash are added after every visit to the latrine. The bucket then fills up with a mixture of materials which compost easily - faeces, paper, soil and wood ash. It is wise to premix the soil and the ash first (mix of four parts soil to one of ash), when these materials are in the dry state. This can be stored for use in a larger container or sack and brought and stored in smaller containers within the toilet. The ash and soil can be applied down the chute using a small cup or home made dispenser – the one used on the *Skyloo* is made from the upper part of a plastic milk bottle. Half a cupful of the mix is added after every deposit made. When the bucket of contents is nearly full, its contents are transferred to a “secondary composting site” for further processing. The rate of filling obviously depends on the number of users and the amount of soil/ash added. Weekly transferral may be required for a family of about 6. For a single user, the bucket may take 4 – 6 weeks to fill up. The urine accumulates in the plastic container until it is nearly full. This urine can be used in various ways (see Chapter 10).

Processing the faeces

The faeces (without urine) fall directly into the bucket, and it is wise to put some humus or leaves in the base when it is empty to avoid sticking and to help start the composting process off. In this unit the bucket is removed and its contents transferred to a “secondary processing site” quite regularly. The frequency of moving the bucket and its contents depends on how quickly the bucket fills up and this is related to the number of users. In the *Skyloo* fresh excreta does not remain in the toilet system itself for long. It may be just a few days or a week or two at most. However, at the ambient temperatures found in Harare (the temperature of faeces held in buckets hovers around 18 degrees C.), the combination of faeces, paper, soil and wood ash does start to degrade. Thus in practice the toilet can be considered the “primary processing site” (in so far that the ingredients are placed together and start to change their form) - but the period is brief. When the bucket is nearly full, the rear vault access slab is removed and the bucket withdrawn and its contents tipped into a “secondary composting site” nearby. Some soil is placed back into the empty bucket and then it is placed back in the vault beneath the pedestal. The rear vault slab is replaced and the toilet can be used again. This transferral of materials from primary to secondary composting sites is quick and easy.



The bucket is withdrawn from the vault and its contents tipped into a shallow pit composter or a split cement jar as shown above. The 30 litre split cement jar is ideal for processing human faeces. Fertile soil is added on top of the excreta and a strong lid placed over the top for protection. More deposits are made when the bucket fills again. After 3 or 4 months the contents are pleasant to handle. Naturally it is always wise to wash hands after handling humus of any type – including this variety. The conversion is a *Miracle of Nature*.

Secondary composting sites.

Several “secondary processing sites” have been tested over the last three years with the *Skyloo*. These are sites where the raw excreta is converted into a product which is best called humus. The humus has the appearance of loam like soil and smells pleasant. These sites include shallow pits (tree pit or fertility pit or twin shallow pits), trenches, compost heaps and also buckets or split cement jars where the composting process can take place. Plastic bags have also been used. The tree pit is a shallow pit covered with a lid into which the bucket contents are placed and then covered up with fertile soil. When the pit is almost full it is topped up with a good layer of topsoil and a young tree is planted in the topsoil. This works like the *Arborloo* – in fact this method preceded the *Arborloo* which evolved from it. A similar method is used with a trench, which is filled up in stages with buckets of the mixed composting ingredients.

What system to use as a secondary composting site?

This will depend on the number of users. If the number of users is small, a series of small jars described later is ideal. If the family is medium to large say between 5 – 10 persons or more it is best to build a twin pit composter where the contents of the bucket are added to one shallow pit until it is nearly full, then to a second shallow pit which fills whilst the contents of the first pit are composting. A composting time of at least 6 months should be allowed.

A single user will completely fill a 20 litre bucket with a mix of faeces, paper, soil and ash in about 4 - 6 weeks. Thus a family of about 6 persons will fill a 20 litre bucket in approximately one week. This means that the bucket must be removed and its contents placed in a “secondary composter” every week. The actual rate of filling will be quickly established. In this case the best composter is the double shallow pit type. This can be built near the toilet.

Amongst these various techniques the writer has predominantly used the method of processing the faeces in split cement jars. This is a very effective and adaptable method and has the advantage that the forming humus can be exposed by dividing the split jar – taking off one of the two jar shells. Over the years this has been one of the best demonstration tools for promoting recycling and ecological sanitation - visitors can see the humus – it is very convincing.



Tipping the contents of the bucket from a *Skyloo* into a small shallow pit for processing. The shallow pit is covered with a concrete lid with hole which is itself covered. On the left three cement jars are shown. The one actively being filled is covered with an attractive painted concrete cover.

Stages of building a twin pit composter for single vault urine diverting toilet



Stage 1. Choose a level site near the toilet and cast two ring beams from concrete on the ground. The internal measurement is variable but in the case shown here the internal measurement was 0.8m X 0.8m. The width of the ring beam was 15cm and the depth 7.5 cm. A mix of 5 parts river sand and 1 part cement was used. The two ring beams were placed about 0.75m apart. The concrete was allowed to cure for a period of 3 days under plastic sheet. In the photo on the right the bricks and timber shuttering have been removed from the ring beam and each filled with water to loosen the soil beneath.



After a day and night soaking the soil is easier to dig. The photo on the right shows the two pits dug down to about 0.5m metres. The removed from the twin pits has been laid around the ring beams and rammed in place. This makes the pits more stable. The pit which will not be used first can be filled with leaves to compost, whilst the other pit will be filled with a mix of faeces, paper, soil and ash from the toilet. The area around the ring beams is smoothed down and made neat.



A wooden lid is made for the twin pit composter and placed over the pit which is being filled with excreta, soil, paper and ash. The almost full bucket is removed from the toilet vault and tipped into the shallow pit. The deposit is covered with more soil.



On the left a motivated pensioner tips his bucket of contents into the shallow pit. The photo on the right shows the first deposit made into the pit. Many more will be added until the pit is almost full. Since the excreta is close to the soil and is surrounded by soil and the additions are made in “small lots,” the composting process is quite efficient. The pits are called secondary composting sites because the actual composting process starts off in the bucket itself and the process continues in the shallow pits. Leaves can also be added to the shallow pit. These add more air into the system and also further organisms which help to break down the excreta. The final humus is more crumbly in texture if leaves have been added.



Photo showing first addition (left pile) and second addition a month later (right pile) in the composter. The conversion to humus is already well advanced in the first pile. Note how the toilet paper has disintegrated. The new additions to the shallow pit are covered with a layer of soil and the wooden lid is laid over the pit for protection and safety. Water is added periodically to keep the composting ingredients damp. The two pits are used alternately. Once the first pit has filled up which should take rather more than 6 months, the second pit is used. When the second pit is full, the first pit can be emptied. And the process started again on the original pit.

Routine maintenance of the *Skyloo*.

Routine cleaning and maintenance of the *Skyloo* is important for the best functioning of the unit. This is not an arduous task and can be carried out quickly once every month or two. Urine diverting pedestals have no means of flushing down the sidewalls and it is inevitable that some fouling will take place. Whilst the vent will carry any odours down into the vault and up the pipe, periodic cleansing of the chute is desirable. During normal use, the dry soil/ash mix will cover any side wall fouling, dry it out, and make it less objectionable.

The great advantage of the *Skyloo* system described here, where the faeces are contained in a removable bucket and not a static vault, is that the system can be washed down completely once the bucket and the urine container have been removed. It is desirable that the vent pipe, pedestal and urinal pipe are washed down and cleaned from time to time. First the bucket and urine container are removed and put to one side. The vent pipe (which will normally be made

of PVC) is also pulled out. Cobwebs which may have developed in the vault can then be cleaned out with a small tree branch. The whole unit can then be thoroughly washed down and cleaned out. The pedestal is cleaned entirely from top to bottom including the side walls. The urine pipe is also flushed out with water. The toilets floors and vault can also be washed down with water.

The ventilation pipe must also be washed down and cleaned out from time to time to retain its efficiency. This is because spiders weave their webs inside the pipe and this seriously disrupts the air flow inside the pipe. Efficient ventilation is important and helps to reduce odours and also maintains a constant flow of air through the vault which reduces moisture.

The toilet and its parts are then allowed to dry out and are all put back together (put back bucket, urine container and vent). The dry soil/ash container inside the toilet is constantly being recharged from a larger stored stock elsewhere.

During the wet season, it has been found that Culicine mosquitoes (which do not carry malaria) can hide in the vault and emerge up the pedestal chute during use. Attempts at controlling these mosquitoes have been made by introducing sprigs of the wild basil *Ocimum canum*, which is known to be a mosquito repellent. No flies have ever been seen.



The interior of the Skyloo can be completely washed down once the urine container and the bucket containing the faeces, soil and ash have been removed. In the middle the wild basil, *Ocimum canum*, can be used to chase mosquitoes away. On the right a spider – fortunately they rarely travel up the pedestal!



Flies have never been seen in the Skyloo system, but spiders and mosquitoes do invade during the wet season. Spiders do no harm but can block vent pipes. Mosquitoes in this case are the culex type and not malaria carrying. They look for dark places to hide – they do not breed there – there is no water.

A study of humus formation in jars, soil analysis and re-use of the humus

The formation of humus derived from human excreta using soil, wood ash and leaves in shallow pits has been described in some detail in the *Fossa alterna* chapter. In the *Fossa alterna* the urine and faeces together are combined with soil and ash etc to form the humus. In the case of urine diversion methods, e.g. *Skyloo*, the urine is separated off and the deposits of faeces are combined with dry soil, wood ash and the paper (used for anal cleansing) and dropped into the bucket held in the vault. This “bucket of contents” is then transferred to another “secondary composting site” like a shallow pit or trench or, as in the case described below, a 30 litre split cement jar.

Use of split cement jars as a “secondary composting site”

When nearly full, the bucket of contents (faeces, toilet paper, dry soil and wood ash) are tipped into the jar, levelled off with a trowel and covered with a layer of good fertile soil. The soil is full of life forms which digest and convert the excreta into humus. Two or three bucket loads may enter the jar before it is nearly full. After the last filling the excreta is levelled off again and topped up with about 5 cm layer of soil. This jar of contents should be watered, then covered with a lid and left to decompose. The various ingredients will decompose within three or four months to form humus which can then be removed and used much in the same way as the eco-humus taken from the *Fossa alterna*. Tomato growing is the best option. The empty jar can then be reused time and time again.

When made properly, the cement jar can be used time and time again - being made of concrete. It is also cheap. The jar has a wider base than top so the contents held within it are well drained. That is important if a good conversion from excreta to humus is to be effected. During the period when the faeces are converted into humus, which may be as little as three or four months with this method, there is no (or very little) temperature rise within the jar. The conversion is rapid because the conditions seem to be ideal. There is a relatively high ratio of soil to excreta, and the conversion is made “in small lots” where no pocket of excreta is large and all excreta is relatively close to some living soil. As the mass is converted, it also contracts as the water content of the original excreta (which may be as high as 70%) is absorbed into the soil within the jar or drains away under the jar. In practice the level of the plug of soil held within the jar drops as its volume decreases. Also the diameter of the “plug” is reduced and this can leave a gap or small air space between the soil and the jar, which obviously retains its original dimensions. The soil near this air space is very active biologically. Thus the core of converting matter is moist, well drained, well aerated and close to the living soil - all ideal conditions for an effective conversion of faeces into humus.

Biological activity within the jar

The contents of the jar are biologically very active during the conversion stage and thereafter. The process is aided by adding a layer of fertile topsoil to the container and planting young plants of various types into this upper layer. The conversion process whereby faeces are converted into humus is the result of the activity of bacteria and fungi present in the added soil which thrive under ambient temperatures (that is temperatures which are close to the surroundings). Many other beneficial organisms, including worms, insects and many other life forms also thrive at their best at ambient temperatures. These animalcules and microbes appear to digest the excreta and may also considerably reduce the number of pathogenic

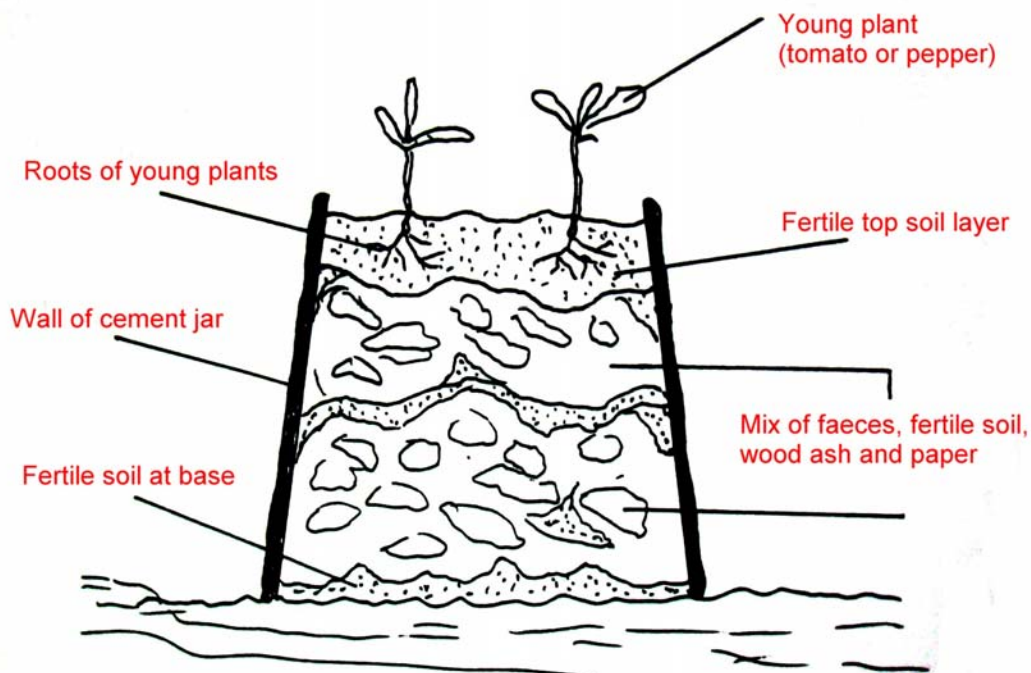
organisms, such as bacteria which carry disease. In tests carried out on jar humus, pathogenic bacteria such *Escherichia coli*, *Salmonella sp*, *Shigella sp*, and *Staphylococcus sp*. were absent after only 3 months of composting (From tests carried out by Clinical Laboratories, Harare - Frank Fleming. pers.comm.). This aspect is further discussed in the chapter on Health. Care is obviously required when handling any compost of this type.

The process is an entirely natural one leading to the formation of humus. The process may best be described as “*Ambient Temperature Composting*” since it takes place at a temperature close to the natural surroundings. The soil added should ideally be fertile and contain living organisms for the process to take place at its best. These fertile soils and leaf moulds also absorb much of the moisture content of the excreta, and the process is normally associated with a reduction of volume of the mass. Remarkably however the process still takes place where poor soils are added to the excreta, albeit less efficiently, and the final product may lack the texture of the best humus – but it certainly is high in nutrients, which come from the faeces.

In addition, the roots of the plants invade the body of the container as the plants grow and this provides an extensive biological structure within the decomposing materials which assists the process of converting the faeces into a friable and acceptable humus like soil. The extent of the root invasion depends on the plant type. Not all plants will send their roots down the entire depth of the jar. Certain types of flower are very effective at invading the contents of the jar (or bucket) and penetrate the entire space occupied by decomposing matter. The giant “*crackerjack*” marigold is a good example. Within 3 months its roots invade the entire contents of the jar or bucket and provide an extensive biological surface which assists in converting the faeces into soil. Obviously in doing this the flower is taking nutrients away from the humus.

The absorbing root-soil interface is called the rhizosphere. It is within this thin microscopic layer that surrounds the roots and root hairs that much biological activity takes place. There are many living organisms present in soil and around the rhizosphere - bacteria, fungi, protozoa, slime moulds, algae, soil viruses which together with nematodes, earthworms, millipedes, centipedes, mites, snails and other small animals, compete for water, food and space. The roots provide a multitude of surfaces for microbial colonisation. The roots also provide oxygen, essential for effective biological processes and also other nutrients that the micro-organisms require. These include carbohydrates, organic acids and many other substances essential to the life within the rhizosphere. The abundance of life in this active biological zone form micro-cavities where the micro-organisms live. In nature, decomposing vegetable matter within the soil helps to make conditions optimal for these organisms. The plant itself takes up water, nitrates, phosphates, potassium, sulphates, and many trace elements. Thus as the roots of plants invade the decomposing materials in the bucket, they greatly assist in the natural processes which lead to the conversion of faecal material into humus simply by generating enhanced biological activity throughout the root zone.

Diagram of cement jar and contents



The final texture of the humus formed very much depends on the type of soil added. If the soil is a lifeless sandy soil, the final texture of the humus will be more sandy. If the soil added is fertile and humus-like itself, then the final product will be more crumbly and humus like. Thus the texture of the end product depends on the soil added. It is also possible to add leaves to the mix and this will greatly improve the texture of the humus. In all cases the combination of soil and human faeces considerably enhances the level of nutrients in the final soil produced. The increase in nutrient levels is dramatic and can transform even the most barren soils into soils which are fertile and able to sustain plant growth. The following charts show the levels of major nutrients in the 30 litre “secondary composting jars” combining human faeces, wood ash and soils.



View of composted humus derived from faeces, soil, ash and paper held in jar

Nutrient levels in 30 litre jar humus - an analysis of soil

Soil analyses reveal that humus formed in cement jars which act as secondary composting sites for the *Skyloo* is rich in nutrients and well above levels found in naturally occurring top soils. Soil is enhanced by the addition of faeces alone as can be seen in the jars used to compost humus faeces following separation in the urine diverting system.

The figures below show the pH and levels of Nitrogen (after incubation), Phosphorus, (ppm) and also Potassium, Calcium and Magnesium (ME/100gms.) in samples of humus excavated from jars used to process faeces derived from the *Skyloo*. These results are compared with soil analyses carried out on various naturally occurring soils in Zimbabwe and also *Fossa alterna* humus.

Examples of nutrient levels of soil formed 30 litre composting jar (*Skyloo*)

Soil source	pH	N	P	K	Ca	Mg
Jar 1.	7.1	211	351	2.22	30.89	14.11
Jar 2.	6.8	230	272	4.40	46.71	30.3
Jar.3.	6.2	308	274	0.96	34.60	14.22
Jar 4.	6.8	141	204	4.64	32.56	11.79
Jar 5.	6.1	148	347	1.38	29.36	6.90
Jar 6.	7.1	328	350	5.76	15.30	7.25
Jar 7.	6.7	246	194	3.24	63.80	9.68
Jar 8.	7.0	249	387	1.95	4.56	2.29
Mean value (composting jar-Skyloo)	6.72	232	297	3.06	32.22	12.06

Comparisons

Mean value (local soils)	5.5	38	44	0.49	8.05	3.57
Mean value (<i>Fossa alterna</i>)	6.75	275	292	4.51	11.89	6.14
Mean value (composting jar-Skyloo)	6.72	232	297	3.06	32.22	12.06

These figures show clearly how human faeces when mixed with soil can produce a product with significantly more nutrients than most naturally occurring soils. Enough nutrients in fact to mix in equal proportions with existing top soils to enhance the final product sufficiently to make viable vegetable production possible without further fertilisation.

Whilst in most cases good fertile topsoil taken from the garden was added to the jars and wood ash had also been added in the toilet itself in combination with dry topsoil to help the composting process, in some cases the soil added was deliberately poor and added without wood ash, to assess the importance of the faeces in providing nutrients to the final product. The following figures show these the dramatic elevation in nutrient levels.

The effect of human faeces on soil fertility

Example 1.

Soil source	pH	N	P	K	Ca	Mg
Nutrient level of soil added.	4.0	18	9	0.08	1.46	0.32
Nutrient level of final soil in jar.	6.1	148	347	1.38	29.36	6.90

Example 2.

Soil source	pH	N	P	K	Ca	Mg
Nutrient level of soil added.	5.5	27	5	0.29	10.23	4.11
Nutrient level of final soil in jar.	7.1	328	350	5.76	15.30	7.25

Example 3.

Soil source	pH	N	P	K	Ca	Mg
Nutrient level of soil added.	6.2	27	32	0.63	9.68	2.30
Nutrient level of final soil in jar.	6.7	246	194	3.24	63.80	9.68

In each of the three cases cited, the resulting soil was derived from a combination of poor soil and human faeces only. These results reveal the value of nutrients available in human faeces. There are dramatic increases in nitrogen, phosphorus and potassium in the resulting humus compared to the original soil. The writer cannot explain some of the high figures reported for calcium, but they are recorded directly from laboratory analysis. The overall picture however is clear enough.

Comparing the formation of humus in jars and shallow pits

It is interesting to discuss how the processes which take place within small 30 litre jars compares to the processes which takes place within the shallow pits used with the *Arborloo* and *Fossa alterna*. In the *Arborloo* and *Fossa alterna*, the pit volume is about 600 – 800 litres in a 1 – 1.2 metre deep pit. The most significant difference between humus formation in jars and shallow pits is that in the latter, urine is added in combination with faeces. The urine diverting pedestal is not used in the *Fossa alterna* to simplify the construction and use of the unit and also to reduce cost.

However, this does not appear to make a significant difference to the final product as the following figures for eco-humus show. The soil added to both pits was the same.

Soil Source	Ph	N	P	K	Ca	Mg
Soil added to pit	5.5	27	5	0.29	10.23	4.11
<i>Fossa alterna</i> (urine included)	7.6	355	258	7.14	8.97	6.26
<i>Fossa alterna</i> (urine diverted)	6.9	305	230	6.65	12.00	10.32

There is a slight increase in nitrogen as one would expect from humus enriched with urine. Levels of phosphorus and potassium are about the same. Most of the nutrient available in urine is nitrogen (ratio NPK for urine about 11:1:2).

There are several other differences to be noted between the environment of a jar converting human faeces and that of a shallow pit converting human faeces and urine in combination. These can be listed as follows:

1. **Volumes.** The jars are of 30 litres capacity, the pits about 600 – 800 litres capacity depending on depth. The process of conversion is more efficient, the smaller the volume.
2. **Faeces/urine mixes.** The excreta content of jars is faeces only, that of pits a mix of faeces and urine. Thus the moisture content may be higher in pits.
3. **Excreta volumes.** Small lots of faeces are added to the jars and interspersed with soil whereas excreta may build up in larger volumes in pits without being interspersed with soil.
4. **Soil/excreta ratio.** The ratio of soil to excreta in jars is quite high. The volume of soil may be the same as the faeces or even higher. This will promote rapid conversion. This will rarely be the case for shallow pits. It will depend on the nature of management. Soil content in shallow eco-pits will normally range between 30% and 50% by volume. It will be very variable however. Some users may add little soil, thinking that the pit will fill up more quickly and unnecessarily. Others may be more generous. If no soil is added, the unit will act just like a normal pit latrine and the conversion into humus may take several years. People may only be convinced when they have seen the humus being excavated from pits in which meaningful amounts of soil have been added.
5. **Type of soil added.** There may be little choice of the type of soil added to shallow pits. Ideally fertile soil should be added, as this will hold a wider variety of living organisms, but this may not be available, or if it is, it may not be used. As a rule of thumb, the final product of an excreta/soil combination will take the texture of the soil added - the resulting colour will be darker. If sandy soil is added - the resulting eco-soil will be sandy in texture. The combination of poor sandy soil and excreta will not form into a humus-like crumbly soil. That will only happen if leaves are added as well, or if the soil added is humus-like. However the nutrient levels of the eco-humus will always be significantly higher than the soil thrown down the pit.
6. **Distribution of soil and excreta.** In jars, small lots of excreta and soil are added and there is a good mix of ingredients. In pits, when the soil/ash mix is added, a pile of excreta may build up directly under the squat hole or pedestal and added soil may be diverted to the sides of the pile. This forms a core of excreta with a lower percentage volume of soil present, surrounded by material which may have a higher content of soil. The distribution of soil to excreta in the pit will therefore be uneven. It is best to redistribute the various pit materials with a pole.
7. **Drainage.** The jars are well drained. They are mounted above ground with the base having a larger diameter than the top. By comparison, pit drainage will vary, depending on soil type, pit lining type, volume of fluids added (urine and washing water), partial sealing of the pit base with raw excreta etc. Fully brick lined pits will not drain as well as partially lined pits or pits with “ring beam” or no lining. Seepage properties of the pit will also vary depending on factors such as soil area available for drainage and also soil type. Sandy soils drain better than clay soils. When pits are brick lined, some cement may fall to the base and not be removed. This will also slow down drainage. Raw excreta, if spread over the pit base can also form a type of plug also reducing the drainage of the liquid fraction (urine and water) from the pit. None of these conditions apply to the jar. It is advisable to add humus, leaves or compost to the base of shallow pits to assist in drainage. Humus formation is inefficient if the ingredients are too wet. An important challenge is to absorb the urine into the soil added to the pit as this will retain some nutrients in the soil, which will improve the overall quality and usefulness of the resulting humus.

8. Aeration. This is related to the volume and type of soil and other organic ingredients added (such as leaves) and its dispersal within the excreta. Generally shallow pits will be less well aerated than jars. The addition of leaves and other vegetable matter will help break up the pit contents. Good aeration is important to humus formation.

Thus the conditions found within the jars and the method of application of the material components of jars favour a more efficient process than is found in shallow pits. It would be expected therefore that the conversion of excreta into humus would take longer in pits. And this is always the case. However, excreta conversion can be efficient within pits if the conditions are right. These will include good drainage, and regular addition of soil/ash/leaves. The higher the ratio of added ingredients like soil, ash and leaves the better the outcome. The urine must either be absorbed into the added materials (soil, leaves, ash) or should be allowed to drain away. Higher temperatures also favour a more rapid conversion. In Salima, Malawi, humus is formed after about 2 months in a very warm climate and well drained sandy shallow pits (Mbachu Msonphora pers. comm). In fully brick lined pits built in soils which drain poorly, the conversion is much slower. In such pits, if the soils are not regularly added, the conversion may take much more than one year. In such cases much more added soil will be required to absorb the urine. Thus the best conversions take place in pits which are only partly lined.

Growing plants directly in the jars

These jars are an excellent way to start off young trees and other plants. Banana, mulberry, guava, paw paw and eucalyptus do exceptionally well. In each case the young plant seedling is placed in the soil layer above the excreta/soil layer. Water is added regularly to keep the jar contents moist. Flowers like “busy lizzie”, canna, and marigold will also grow well in these jars. If the jar is watered regularly, tomato seedlings will grow spontaneously from the humus. Jar humus is an excellent medium for growing pepper and tomatoes – see later.



Spontaneous growth of tomato seedlings on left are growing on a 30 litre jar with mixed ingredients, including human faeces. Tomatoes often germinate spontaneously in humus derived from human excreta and from organic kitchen refuse. On the right a “busy lizzie” growing on 30 litre jar, also with human faeces and soil mixed. Most plants enjoy growing on this type of soil.

Growing tomatoes in *Skyloo* humus

The most obvious use for the humus formed in jars or other containers where the *Skyloo* humus has been processed is to grow tomatoes. When the *Skyloo* humus is watered, tomato seeds present in the mix germinate freely and form into excellent seedlings and later into healthy plants. It is assumed that the seeds are derived from tomatoes consumed months before by the toilet user. The seeds are passed out in the faeces into the bucket and there lay dormant until the humus is processed and watered. Then the seedlings appear in large numbers. If the seedlings are just allowed to continue growing in the jar, they become overcrowded and do not provide a good crop. So the best procedure is to move the seedlings from the jar and transplant into other containers in preparation for placing in buckets.

Tomatoes grow very well in the *Skyloo* humus, especially when mixed with an equal volume of garden compost or leaf compost. Bumper crops of tomatoes rely on adequate levels of phosphorus at an earlier stage, and then later sufficient quantities of nitrogen and potassium. Potassium is particularly important for the best yields. Potassium can be supplied in the form of wood ash added to the soil or to liquid feeds. The careful application of diluted urine (5:1) can also help, provided wood ash is also applied to improve the balance of nitrogen and potassium. Leaf compost liquor (see later) also helps to increase crop production. An excess of nitrogen gives a lot of leafy growth at the expense of tomato production, so a careful balance of nutrients is required for tomatoes. For more information on the technique of growing tomatoes using recycled human excreta look at the chapter on gardening techniques.



A tomato planted on a bucket of humus collected from the *Skyloo* jar. Once watered the humus produces large numbers of tomato seedlings which can then be transplanted into other containers.



The seedlings can first be transplanted into seed trays and then into small pots or tins.



Here an established tomato seedling is transferred to 10 litre bucket full of neat *Skyloo* humus.



On the left a tomato seedling planted on a 10 litre bucket of neat *Skyloo* humus on 10th Jan 2004. On the right the same plant about 5 weeks later on 16th February. It was irrigated with water only. The plant is healthy. Lower shoots and the shoots growing in the axils of larger shoots have been removed. Bumper crops of tomato rely on adequate amounts of potassium being available. The addition of wood ash to the soil or in the liquid food or water can increase production. But tomatoes do require a lot of care and management. The tomatoes shown on this page succumbed to a fungus disease called late blight. For more information see the chapter on techniques that assist eco-san supported vegetable gardening.

Growing tomatoes on mixes of *Skyloo* humus and composts



The best soil for growing tomatoes under the umbrella of ecosan is a mix of humus from the toilet and leaf or garden compost. A 50/50 mix is ideal. Similar seedlings planted on 10th January growing in 50/50 mix of *Skyloo* humus and garden (80 litre jar) compost after 5 weeks of growth (left photo). Right photo: 5 weeks of growth on tomato seedling grown on a 50/50 mix of *Skyloo* humus and leaf compost. Photo taken 16th February.

Feeding tomatoes growing on neat *Skyloo* humus with liquid feed



Similar seedlings planted on 16th January growing on (left) neat *Skyloo* humus fed with a 5:1 mix of water and urine (0.5 litres) once per week and on (right) neat *Skyloo* humus fed leaf compost liquor, twice a week. See details on leaf compost liquor later. Photo taken 16th February, 2004. The plant on the right had 44 flowers at that time, each one with the potential to become a tomato weighing 100 gms.



Healthy tomato grows from 30 litre jar filled with *Skyloo* humus. On the right green pepper grow in jar of composted faeces with soil and ash. The jar humus is perfect for tomatoes and peppers.

Starting young trees on *Skyloo* humus

Young trees of all sorts grow very well in these split cement jars. Once the contents have been changed to humus and the young tree is well established, the two halves of the jar can be removed and plug of soil bearing the tree can be removed by cutting through the base with a flat spade, thus separating it off from the ground. The tree and the “organic plug” can then be transferred to another site where the tree can continue its growth. The jar is then used again. Alternatively, if the jars are placed in a suitable place, the jar can be removed and re-used and the tree can continue to grow on the original site. This seems to work well.



This young guava tree was grown from seedling stage in the jar. It was planted in the topsoil placed above the faeces/soil/ash/paper layer. In a few months all the faeces have been converted and the young tree can then grow in rich humus. It is later moved to its final growing site. This is like a miniature version of the *Arborloo*. The same method can be used for shrubs and perennial flowers.

The jar method is also very valuable as a teaching aid. The contents can be closely observed at any time by removing one of the jar halves (shells) temporarily. The two halves are held

together with a loop of wire. I have shown many people these jars in my garden and all of them have been most impressed when the jar is opened and the contents are handled and sniffed! It is possible to take out a handful of “soil” from the jar, after 6 or more months of composting. This demonstration is most convincing.

Bacteriological analysis of the soil has revealed it to be free from pathogenic bacteria like *Escherichia coli*, *Salmonella sp*, *Shigella sp*, and *Staphylococcus*, that had been artificially added two months before. This is very remarkable since half the volume of the original contents were raw faeces only a few months before analysis. Nonetheless care is always required when demonstrating and handling converted faeces, whatever they look or smell like. A period of at least 4 months should elapse before the jar humus is handled. It is a good idea to show the hand washing device too and get participants to use it. In the writer’s garden plenty of soil was added and the jars kept moist to encourage composting. The ingredients taking place in this remarkable transformation are human faeces, fertile soil, wood ash and toilet paper. Leaves are also being added and help a lot. The pH is about 7.0 and the temperature of the jar contents less than 20 degrees Centigrade. This conversion, from a harmful and most offensive material into pleasant and valuable humus is nothing short of a miracle of Nature. Every visitor who views the transformation is both surprised and convinced. It is perhaps the most compelling evidence that transformed human excreta can be both relatively safe and valuable too. To sum up, the conversion of faeces into fertile humus is a remarkable process which is entirely natural. It is truly one of Nature’s marvels.



YES- raw faeces can change into fine humus!

BUT CARE IS REQUIRED IN THIS IMPORTANT DEMONSTRATION