The Ventilated Arborloo
What goes on underground?

Fungi mycelia have invaded human faeces in an experimental glass jar. Together with soil bacteria they convert human faeces into a medium in which trees can grow and thrive. This natural principle is used in the Arborloo and ventilated Arborloo – the "tree toilet."

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Harare. February 2024

Introduction

The *Arborloo* is a simple ecological toilet that was designed to recycle human waste within a shallow pit where the contents are transformed from a vile and disease forming material into a product which trees can tolerate, thrive and grow in without the user having to be in contact with the pit material. Many articles have been written by the writer about the *Arborloo* and other ecological toilets over the years from the late 1990's. More recently reports made in January and July 2023 and February 2024 have been written about the ventilated *Arborloo,* a hybrid between the *Arborloo* and the Blair VIP toilet which was first well documented in Epworth, close to Harare, in 2010. Both the Blair toilet (the forerunner of all VIP toilets) and the *Arborloo* originate in this country. So it may be obvious that a hybrid between the two would eventually emerge in Zimbabwe. More recently in January and February 2024 two more portable superstructure were designed and built in the writer's back yard - one of a huge range of structures that can be used on this toilet system. Many traditionally designed structures have also been built. It is now time to discuss again the important processes going on underground in the pit – and revitalize work performed by the writer decades ago. Such processes are natural and biological, which is of great interest to the writer who is a biologist. It concerns the reactions of our excreta to soil, soil bacteria, fungi and leaves etc. Such processes are going on in Nature all the time. The fungi live in a Kingdom of their own, they are neither plants or animals. The mushroom is the most well known part of the fungus being the spore producing reproductive body above ground. The main fungal components, the mycelia and hyphae lie under ground and out of site. The underground mycelia and hyphae have played a vital role in the life of our planet for millions of years. They still do. A great deal can be read about the amazing history and life and influence of the fungal empire viewed on the web. It is a fascinating story.

The original *Arborloo* controlled odours and fly breeding by the liberal addition of soil, leaves and wood ash to the pit contents. These additions assisted in the conversion of a smelly disease ridden material into a product which was not offensive and became acceptable for tree roots to grow in. The pit contents became an "organic plug" surrounded in a soil environment that was often sterile. The pit was shallow varying between one and two meters depending on soil conditions. The addition of soil, ash and leaves accelerate the filling of the pit, but often the users accepted this as the outcome could be the planting of a valuable tree more quickly. With the *Arborloo* concept the pit and its contents remain where it is. But the slab and superstructure move on a never ending journey through the lands to a site nearby. The trees which are planted and cared for can become part of an orchard or woodlot or planted individually for shade. With the ventilated *Arborloo*, far less soil is required to control odours and flies because this property is also controlled by a screened vent pipe. Additions may be added weekly rather than daily.

What goes on in the pit as its fills up still requires the participation of soil bacteria and fungi. There will be an invasion of soil bacteria from the side walls of the pit and some from the smaller amount of soil which is added to the pit during its use. Also there will be an invasion of fungi mycelium from the leaves which are added to the pit. The importance of adding leaves to the *Arborloo* pit was emphasized over 20 years ago in my earlier writings. In this document I wish to emphasis this point and describe in greater detail the importance of fungi, not only as a life form and its important history to life on Earth and how it forms an important symbiosis with all plants. Also how in combination with fallen leaves it can form a remarkably fertile organic soil called leaf mould. Leaves can also form leaf compost by the activity, mainly of bacteria. When leaves are added the *Arborloo* pit, both processes take place.

Fungi are neither animals or plants. They exist in a kingdom of their own and one which existed before either plants or animals came into existence, millions of years ago. The Fungi have a history which dates back over half a billion years and fossil fungi a billion years old have been discovered. This predates the plants. And also predates the animals by huge spans of time on the Earth. Much has been written on this fascinating subject on many websites. Most people know the fungi through the formation of mushrooms, but these are the fruiting bodies of the fungi which appear above ground level. The much larger component of the fungi are the strands of mycelium which exist underground and invade huge areas of the earth especially in woodlands and forests or where plant life is abundant. Flies which may also form part of this story (the Diptera) have a history covering 250 million years. By comparison, *Homo sapiens,* dates back a mere 200 000 years! The words of a biologist!

Leaves and fungi form a partnership in the formation of leaf mould. And leaf mould is very fertile and also makes good potting soil. Leaf mould takes longer to form than leaf compost where beneficial bacteria are involved in the process. Leaf mould can be formed separately in bags and containers. It is a combination of leaves and fungi which form under humid conditions. In the *Arborloo* pit there is time for leaf mould to form when leaves are added. And during the process the leaves condense in volume considerably during the process. In the *Arborloo* pit many natural processes are taking place. Nature is quite busy here.

I will first start off by attaching below a section of a book written in 2003 (An Ecological Approach to Sanitation in Africa), which describes work I carried out from 1999 on Ecological Sanitation. This included the value of adding leaves processed with fungi to pit material and was written with reference to the material processed in the *Fossa altera*, but applies equally to work done with the *Arborloo* and ventilated *Arborloo.* This work included the development and description of the *Arborloo, Fossa alterna* and "*Skyloo*" a version of the urine diverting toilet. Studies were also carried out on the effect of diluted urine on plant growth (vegetables, maize and trees). This book summarized much of the earlier work carried out by the writer on Ecological Sanitation. Four unpublished books were also written on this subject before this one was written.

Next I add below the contents of one of the chapters I wrote over 20 years ago which concerns the value of adding leaves and soil to the human waste. What happened then still applies today.

The value of leaves as an additive to *Fossa alterna* (and *Arborloo*) pits.

Constant reference is made to the considerable benefit which can be derived by adding leaves to ***Fossa alterna*** (and ***Arborloo***) pits. Leaves help the composting process considerably, by adding more air into the mix, and by adding a composting process undertaken largely by fungi to the already existing bacteriological process undertaken by soil micro-organisms.

During the first year of operation, the second pit of the ***Fossa alterna***, which must be built at the same time as the first pit, can be left empty and covered with a wooden lid. This will be the standard procedure. However it is possible to take advantage of the second pit during the first year of operation. One of the best methods is to make leaf compost (or leaf mould) within this pit for the first year of operation.

At one site in Epworth close to Harare, leaves were gathered and emptied into the pit interspersed with thin layers of the local topsoil. Water was added from time to time. After 12 months the leaf compost (mould) was excavated and proved to be much richer in nutrients than the original soil. In fact plants grew in this leaf mould far better than in the original soil. The second pit acted like a pit composter and was well worth the simple effort involved of adding leaves, soil and water. The following table shows the increase of nutrient levels in the leaf compost (mould) made in the second pit compared to the local topsoil.

The figures below show the pH and levels of nitrogen (after incubation), phosphorus, (ppm) and also potassium, calcium and magnesium (ME/100gms.) in the leaf compost formed in the second pit of a ***Fossa alterna*** compared to the surrounding topsoil which was added together with local leaves.

Soil source	pH	N	P	K	Ca	Mg
Local topsoil (Epworth)	**4.1**	**23**	**54**	**0.07**	**1.72**	**0.50**
Leaf compost from second pit	**7.7**	**81**	**130**	**1.86**	**9.31**	**1.88**

Composted leaves clearly have a considerable nutrient value of their own and no doubt greatly enhance the final quality of ***Fossa*** humus, if added. The results of four soil analyses of leaf mould (as it is best named when processed by fungi) formed in wire baskets and a variety of containers is given below. A description of these leaf mould makers is given later in this book.

Analysis of leaf mould.

Soil source	pH	N	P	K
Leaf mould in wire basket	**8.2**	**256**	**344**	**3.92**
Leaf mould formed in plastic bag	**7.8**	**267**	**294**	**8.50**
Leaf mould formed in steel drum	**7.6**	**239**	**255**	**0.60**
Leaf mould formed in brick moulder	**7.4**	**540**	**266**	**9.00**

Overall comparisons of soils and composts

Soil source	pH	N	P	K
Mean value (local top soils)	**5.5**	**38**	**44**	**0.49**
Mean value leaf mould	**7.75**	**325**	**290**	**8.00**
Mean value (*Fossa alterna*)	**6.86**	**273**	**278**	**4.22**

Physical properties of excreta, soil, leaf mixes.

One interesting property of excreta or mixes of excreta and soil, both in jars and pits is that the volume is considerably reduced over time. Even with abandoned full latrine pits the volume may decrease considerably over time. In urine diverting toilets the urine is channelled away and the faeces dehydrate or compost and lose their initial volume due to loss of moisture. In shallow pits the combination of urine and faeces also loose volume over time with the urine being absorbed into the soil added to the pit, the leaves and also into the soil surrounding the pit. The bulk and volume of the faeces is also reduced over time with the liquid fraction of the faeces being absorbed into the soil added to the pit. It is known that the water content of the faeces is variable but always high. It is this larger water fraction of the faeces which can be absorbed into other ingredients added to the pit (soil, ash, leaves),whilst the remaining smaller solid fraction of the faeces is converted into “humus,” which forms part of the final total volume of the material humus formed in the pit or container..

But what are the fractions?

The following experiment was carried out to calculate the percentage water content of faeces by combining a known weight and volume of faeces with a known weight and volume of dry soil. Since the dry soil would lose neither weight of volume, any change in the final volume and weight of the mix would be caused by changes in the properties of the faeces.

A sample of faeces was collected in the ***Skyloo***. This sample weighed 357gms, had a volume of 340mls and a density 1.05 gm/ml. This was mixed with a near equal volume of dry soil with a weight of 352gms, a volume of 310mls and a density of 1.135 gm/ml. Therefore the total weight of the mix was 709gms having a volume of 650mls and an overall density of 1.084 gm/ml.

On the left, raw faeces and soil being mixed prior to composting. On the right a mix of leaves, soil and raw faeces prior to mixing and composting.

This was allowed to slowly "compost" over a period of 24 days. Fly larvae developed in the mix, which was also attacked by ants. Slowly the mix changed into a "new soil." Another mix was made with an approximately equal mix of faeces, dry soil and crushed dry leaves. This mix was also allowed to compost for the same period. After the period of composting both samples were laid out in the sun to substantially dry out, but not to full dessication status. The final weight of the dried soil/faeces mix was 420gms, with a volume of 405mls and a density of 1.037gm/ml.

Thus the weight of the "new soil" formed had increased from 352 to 420g (about 19%), compared to the original soil in the mix and the volume of the "new soil" had increased from 310mls to 405mls (about 30%) compared to the original soil in the mix. Since the volume and weight of the dried original soil cannot change, the faeces weight had therefore been reduced from 357g to 68g (420 - 352g) - 19% of original. So water content was 81%. The faeces volume had therefore been reduced from 340mls to 95ml (405 - 310ml) - 28% of original). So the final density of the mix was less than the original soil. The mix was also darker in colour. The overall initial combined weight of the combination was reduced from 709g to 420g) (59.23% of original). The overall initial volume of the combination was reduced from 650 ml to 405ml. (62.3% of original). The processed combination of "NEW SOIL" was very similar in appearance to original soil since 76.5% of its new volume and 83.8 % of its new weight consists of the original soil.

Samples of original soil (left), and "new soil" made from faeces and soil (centre) and from faeces, soil and leaves (right).

In the case of the faeces/soil/leaf mix a final weight of 270gms was measured with a volume of 405mls. This gives a density of the combination of 0.66gms/ml. This is a much lower density compared to the faeces/ soil mix. Clearly the addition of leaves lowers the density, a result no doubt of the less compaction and more air in the mix due to the presence of leaves. These properties would encourage far more efficient composting. Composting is far more effective as the air content increases.

Density trials on *Fossa alterna* humus

The results shown above would explain why a mix of excreta, soil and leaves appears to compost much faster than a mix of soil and excreta only. To test this theory the humus taken from a ***Fossa alterna*** which had a mix of excreta, soil and leaves was compared to the humus taken from another ***Fossa alterna*** which had a mix of excreta and soil only.

The initial comparisons (for volume, weight and density) were made in crumbly (not dried) ***Fossa alterna*** humus. These samples were then dried out in the sun to obtain new parameters.

***Fossa alterna* soil (crumbly, not dried)**

Soil /humus type	Vol. ml	Wt.gm	density
FA kia (excreta,soil,leaves)	410 (jam jar)	370g	0.90g/ml
FA FF (xcreta,soil only)	410	402g	0.98g/ml
Garden soil	400	443g	1/10g/ml

***Fossa alterna* soil (sun dried)**

Soil/humus type	vol. ml	Wt.gm	density
FA kia	325	278	0.85g/ml
Fa FF	370	338	0.91g/ml
Soil	368	392	1.06g/ml

These results reveal that where leaves are added to the ***Fossa alterna*** pit the resulting density of the humus is lower. The density of the humus is related to both the moisture content and the air content. The more air (with some moisture) the better the conditions for composting. Thus a mix of excreta, soil and leaf in the Fossa alterna pit is more effective and leads to a faster and more efficient composting process than the mix of excreta and soil alone. Interestingly it was this mix of excreta, soil and leaves which was tested in the initial ***Fossa alterna*** trial in 1999.

Leaves are an important ingredient in this process because the leaves provide extra nutrients to the mix, they provide extra air and improve soil texture. They add a process of fungal decay in the mix as well as composting based on bacteria. They also provide a larger surface area for the composting process to take place and allow for better pit drainage. All these combined beneficial effects of leaves enhance the composting process considerably.
Consequently the addition of leaves to the shallow pit composting process in both the ***Arborloo*** and ***Fossa alterna*** has been greatly encouraged. Similarly leaves are now added to the buckets holding faeces, ash and soil in the ***Skyloo*** and subsequent jar composters.

Adding leaves to shallow pits

Adding dried leaves to shallow pits used in the *Arborloo* and *Fossa alterna* helps the "composting" process considerably.

Adding leaves to *Fossa alterna* pits. On left at Woodhall road, on right at Epworth.

Adding semi composted palm leaves to the base of a Fossa alterna pit in Mombasa, Kenya (left). Two sacks full of leaves at the base of a concrete lined pit in Maputaland, South Africa.

Conclusions

These various results show that the ***Fossa alterna,*** when well managed, offers the family a valuable asset, and well worth the initial investment. It is not only an effective toilet system, controlling both flies and odours, but also offers the family a simple and effective unit for making nutrient rich humus. The annual production of humus, when mixed with poor local topsoil can enhance back yard vegetable production considerably (see plant trials later). By combining these advantages with its low cost and relative ease of use and management, the ***Fossa alterna*** may hold much potential for future use in many parts of Africa.

But it must be remembered that the annual output of humus from the family owned ***Fossa alterna*** is not large, possibly about 500 litres per family per year. So its value lies in enhancing food production on a small scale on the family vegetable garden and not on extensive fields. However such improved fertility will improve year by year and thus the back yard vegetable crop can be sustained. The next chapter describes the importance of the various nutrients to plant growth and this is followed by a chapter on how best to use the rather limited and precious supply of humus formed in the ***Fossa alterna*** pit every year.

The current experiments

Since I am a biologist, things which relate to biology fascinate me. We are fortunate to have a well treed garden and I have been recycling fallen leaves for years. And the tree is an amazing and beautiful product of Nature. Leaves can be processed by bacteria to produce a product called leaf compost and by Fungi to produce a product called leaf mould. In *Arborloo* pits I suspect that both processes are taking place. Leaf mould is richer but takes longer to process than leaf compost – but in the pit there is time. With all ecological pit toilets which I have been involved with leaves are always added to the pit first and then during the filling process. When leaves are left to decompose in the pit or in containers the mycelium of fungi penetrate the medium and react with the pit contents and process them. Unlike bacteria, mycelia are visible and much easier to observe their reaction with faeces. These experiments record these observations.

Recent experiments in the Woodhall garden

Mushrooms indicate the presence of fungi and mycelium in the soil below.

There is a shaded area of the garden lying underneath a large Mexican Apple tree and Bougainvillea tree where leaves have been "composted naturally" on the ground and also processed within containers (bags and containers of various types). When the leaves have been added to bags or containers and left to decompose, the end result is leaf mould. This process may take a year to two or more. The leaf mould is particularly rich in nutrients and also good as "potting soil" and for growing cuttings of trees like Mulberry (see description later).

Mycelium just below the surface of the soil on the ground (left). On the right a container ("tank") in which leaves alone have been placed and left to process naturally. The material has been kept moist. The end result is leaf mould

The mycelium in the larger "tank" container can be dug out with the leaf mould and transferred into other containers.. The material is dark and crumbly. It is formed by the action of fungi mycelium on leaves. It can be used as a potting soil for trees and other plants. And also for experiments to observe its effect on human excreta.

Effect on human faeces

I also decided to perform some experiments to reveal if the leaf mould had any effect on human faeces. These were carried out in plastic containers and glass jars and ventilated pit toilets. The experiments were unpleasant but brief. What actually goes on down in the pit will always be a bit of mystery. The main benefit is that the process of conversion takes place by a combination of natural processes. The growth of trees roots within these pits is perhaps the ultimate proof. At first human faeces were added to plastic containers where the leaf mould was added first, then the faeces and topped up with more leaf mould and left to process. The affect of the leaf mould on the faeces could not be seen directly. After this a set of 4 experiments were carried out combining the faeces with leaf mould in glass containers in which the interface between leave mould and feaces could be observed, thankfully behind a glass barrier! In one experiment leaf mould was added to a glass container and some human faces added on top of the leaf mould. The following photos record the reaction of the leaf mould and particularly the mycelium to the human faeces.

These photos were taken on 26th January 2024. Leaf mould and human faeces in glass jars.

Left. A detailed photo taken on the larger glass jar on 26th January 2024 from the top.

Right. The same jar photo on 28th January.2024

The same jar on 31st January 2024. The fungi mycelium have completely invaded the human faeces.

Left:February.14.2024. Right: February 16.2024. Mycelia still active.

Left. Human faeces surround by leaf mould. Placed in jar 26th January 2024.

Right the same view on 31st January. Mycelium invading the faeces.

Left: A close up view taken on 31st January.2024. Leaf mould mycelium invading faeces. Right: the same jar and the same angle taken on Feb.23. The human faces have been completely converted. Later experiments (see below) also confirm this. Like this they are a combination of Leaf mould and human faeces. Since leaf mould is a mix of leaves and fungi mycelia only, it suggests that in addition to all its other remarkable properties, fungi can also digest and convert human faeces. Indeed Fungi and their extensive network of mycelia and hyphae beneath the ground develop symbiotic relationships with most plants on Earth including trees. The fungi have been evolving on Earth for between 500 million to a billion years and preceded plants which developed the process of photosynthesis. Without plants the animals could not have developed and that includes us.

Affect of fungal mycelium on faeces in a toilet pits with leaf mould added to bucket placed in the pit.

Left. A deposit made on 31st January.2024. Right, Growth of fungal mycelium early morning 3th February 2024.

Left. Growth of fungal mycelium evening 3th February 2024. Right. Fungal mycelium covering the deposit 4th February 2024.

Fungi mycelia active in the ventilated *Arborloo* designed for children and used by the writer.

Observations on a combination of faeces and leaf mould in a plastic container (24th January to 17th February).

With transfer of mulberry cuttings to the resulting medium. Experiment one .February 17th 2024.

In this experiment some leaf mould was added to a plastic container and faeces on 24th January and another deposit on 25th January 2024. The container was topped up with more leaf mould and closed and left. The container was reopened and examined on 17th February 23 days later. All the faecal matter had changed and was left exposed on a plastic sheet to see if any flies were attracted to it. No flies were attracted to it, which is a good sign the excreta was full converted. The experiment continued by moving the contents into another plastic container (with drainage holes and inserting a mulberry cutting which had itself been planted on 24th January in a bucket of leaf mould (that is leaves watered and left to "compost." The aim being to see if the mulberry would thrive and grow in this new mixed medium.

Left: Bottom filled with leaf mould and first dropping made. Right: second dropping made.

Left: The plastic container topped up with leaf mould.25th January. Right: the container opened and placed on a plastic sheet and left exposed on 17th February. No flies were attracted to the medium – an indication that the medium was fully converted. The medium was then transferred to another plastic container with holes cut in the base. Then a mulberry cutting first planted on 24th January 2024 and sprouting leaves was inserted in the medium and watered.

The plastic container filled with the combined medium with mulberry cutting pushed into it. Photo taken 17th February 2024. The trees have survived and grown since then.

Observations on a combination of faeces and leaf mould in a plastic container (24th January to 19th February).

With transfer of mulberry cuttings to the resulting medium. Experiment two .February 19th 2024. Always best to back up one experiment with another.

Another combination of faeces and leaf mould was prepared on 24th January 2014, similar to the one described above. On the same day a mulberry cutting was prepared and planted in leaf mould. The left photo below shows these two containers.

Left: Mix of faeces and leaf mould made 24th January and a mulberry cutting placed in leaf mould also on 24th January. Right: the mix of leaf mould and faeces on 19th February after 26 days. The combination was completely converted.


Left: The combination was placed in another container (clear). Right: the mulberry cutting.


Left: Some of the contents of the container in which the cutting was planted were also transferred to the new container to top it up. Right: the cutting was transferred to the new container.


The new container with mulberry cutting.19th February.2024. In both these experiments the faeces were fully converted into a medium in which tree cuttings could grow within a month. Since then the tree cutting has continued to thrive.

A further experiment to confirm fungal mycelia invasion of human faeces.


Left: Fungal mould was placed in a clear plastic container. A fresh dropping was placed on top on Feb.22. 2024. The container was sealed and placed in a semi dark location.


Left: Photo taken.February23.2024. Right: photo taken on Feb.26th showing invasion of mycelia.

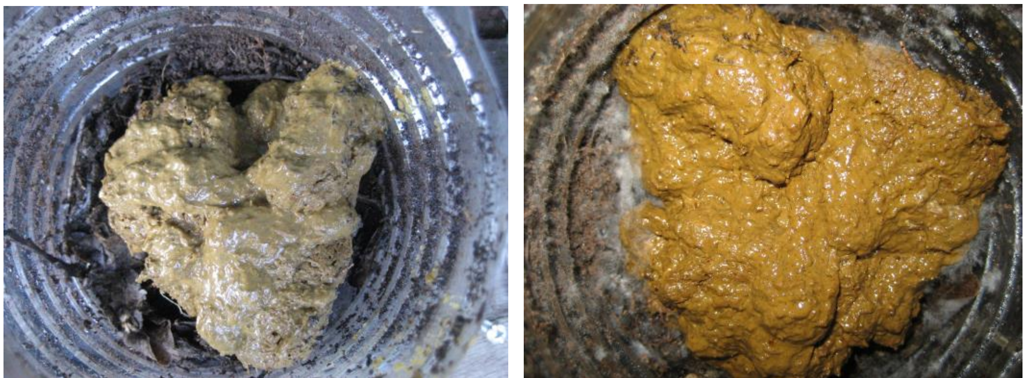
The fungal mycelia are clearing visible invading the human faeces. Photo 26th February.

A close up of part of the growing mycelia

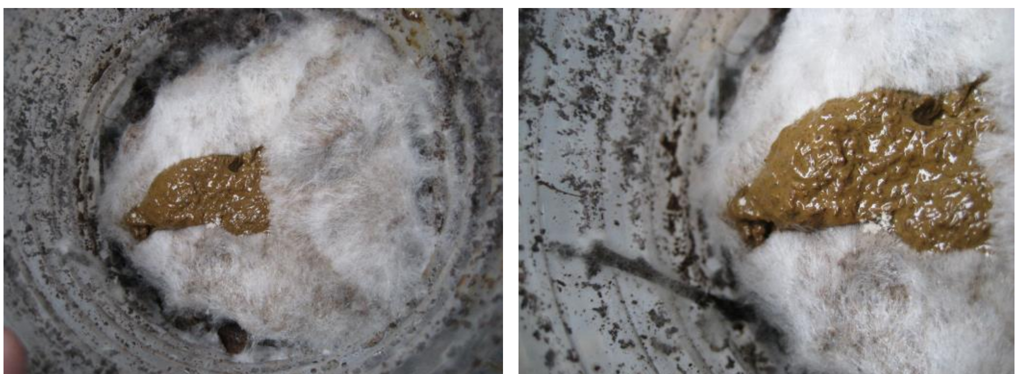
Another close up - a remarkable photo. Fungal mycelia invading human faeces. The mycelia and possibly fine hyphae are visible. What more proof is required to reveal that fungal mycelia can invade and convert human excreta as well as plants of many types, trees, And even termite colonies. Soil bacteria are also active. The Fungi are a remarkable Kingdom indeed.

Further experiments

Further evidence that fungi mycelia can invade and consume human faeces was derived from another experiment carried out in a plastic container on February 24th.2024.



The fate of the faeces. Left: the initial dropping 24th February. Right: 26th February 2024



A massive invasion of fungal mycelia. 27th February.

Full invasion of mycelia. 28th February.2024. Such evidence provides good evidence that fungal mycelia can invade and consume human faeces.

Conclusions

In these simple (and sometimes messy) experiments I wished to demonstrate that fungi, through their mycelia and hyphae and their association with leaves to make leaf mould, can invade and have a dramatic affect in reducing the smelly and dangerous human faeces into a product in which trees can grow and thrive. If leaves alone are thrown down the pit then the fungi will also act on them. The process also involves the action of soil bacteria in the pit. These bacteria are derived from the side walls of the unlined pit, the soil which is added during the filling process and the soil which is added to the near full pit before tree planting. These processes take place when the pit is moist and dark. Urine is also added to the *Arborloo* and ventilated *Arborloo* pit. This also adds moisture and also nitrogen. Experiments carried out many years ago with the *Fossa alterna* revealed that if soil, leaves, and wood ash together with faeces, urine and anal cleansing material were added to a partly lined pit, then the final contents, after a year of processing could be dug out and used on small vegetable gardens which benefitted the growth of the plants. During the process the volume of faeces is reduced, as much of their volume is made of water. These studies have been undertaken to indicate that fungi as well as soil bacteria can play an important part of the decomposition of human faeces. Unlike bacteria the fungi and their mycelia are visible.

The benefit of adding a screened vent pipe is that the additions (soil, leaves, water etc) can be added less frequently compared to the original *Arborloo*. Perhaps once a week rather than after every visit (or a visit when a "poop" was dropped. This will prolong the life of the pit before the above the ground components need to be moved to another site. In the latest vented *Arborloo* superstructures (which have been described elsewhere), the interior is not dark enough to operate like a VIP toilet. So a loosely fitting lid must be placed over the squat hole or pedestal, whatever is used. This means the pit itself will remain dark. Experiments reveal that the vent will still draw air if a lid is fitted loosely over the squat hole or pedestal. Smaller screened vent pipes (75mm and 63mm) have been tried on an experimental basis. 110mm PVC is still the best. Pedestals can be home-made or now commercially available. I prefer a pedestal for comfort. The vented *Arborloo* does not smell and is pleasant to use. The pit contents are humid which benefits the biological processes taking place in it. Biology and natural principles play an important part in the *Arborloo*, vented *Arborloo*, as well as the Blair VIP toilet. As a biologist myself, the biological component, including the action of Fungi are of great interest.

Three of the several demo ventilated *Arborloos* recently built in my garden. The central photo is a smaller toilet designed for children. The right photo one designed for my "Urban Forest Garden," filled with trees which provide privacy. Note the simple hand washers – an essential partner to any toilet.