My Garden Laboratory

Experiments in technical approaches to rural water supply, sanitation and hygiene carried out in my garden and home and then in the world beyond

Peter Morgan

August 2020

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Peter Morgan

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Introduction

There is something about being an experimenter and a scientist that never quite fades despite ones age or the fact that, as the years pass, as one gets older, the brain and the body never quite functions as efficiently as it used to do. Having been a student of Zoology in my early years and trained in the scientific method of a bygone era (1960's) and later adapted to a completely different discipline, twice, the feeling of not finishing what one intended to do becomes stronger. There is an urge or at least an attempt to carry on, despite ones age or reduced physical energy and skills. With the technological era, the electronic world is upon us, it leaves those of us who had to think for ourselves, far behind. But in one sense, having to think for oneself with limited resources is a good thing. It leads to a lot of lateral thinking and deep thinking on the subject one chooses to study. And there is nothing to stop a self-imposed isolationist, which I profess to be, from holding views derived from the recollections of a long past and even writing what he or she may think. In this little book I have tried to put down my thoughts and those technical developments which I have played a part in developing. It has nothing to do with earlier studies in Zoology or the fishes of an African lake in Malawi, but studies made since I came to Zimbabwe (formerly Rhodesia), namely technologies related to reducing the spread of tropical disease, which date back to 1973. This book includes more recent studies made in the back yard when in my upper 70's. It is very possible that such studies and developments will never see the light of day outside my garden laboratory, although they have been developed for use, or at least further trials, in this country of ours – Zimbabwe, and perhaps beyond.

In my time I have been a dedicated zoologist, a marine biologist, and a limnologist (freshwater biologist), as well as an inventor of technology related to health for which I have no formal training or academic qualification. That is the evolution of technical methods which can contribute to reducing the passage of enteric disease in the tropical regions – mainly Africa. In simple terms studying and evolving technical ideas which can find a use in the world of what is now known as WASH. Water Supplies and Sanitation and Hygiene.

I have chosen to compile this little work privately, so that at least my family have access to it and perhaps a few close friends and colleagues. Some of it is new work (carried out between 2017 and 2019), but much built upon older work and some related work which may have been hidden from view as its significance was never realised by those who may have glanced through my written works before. At least I will know that I have done my best and put down my thoughts and developments in the printed form, knowing that in future years it may find its way onto a dusty shelf and be forgotten. This book will come along with a DVD attached to it. This booklet does not intend to go into the detail of each development, which can be found on the DVD, but to give an overview together with personal thoughts on the subject. It is up to generations of the future to chart their path forward. Whether they choose to be assisted by those who came before them, or not, is their choice and not mine. The wisest people do look back on what has been done before and build upon it. The book itself was first printed in May 2019 but much backyard development has taken place since then. It was updated and reprinted in May 2020. These developments have been added to an updated DVD.

I have written and arranged the chapters in a certain way to include simple on-site sanitation, starting with the tree toilet (*Arborloo*), hybrids been the *Arborloo* and Blair VIP, the Blair VIP and various chapters describing ecological and organic gardening and also the link to trees. In the water section I have described family wells, Bush Pumps and other hand pump developments, rainwater harvesting and rainfall patterns related to water table levels. Also on the home front, several developments I have made to help us in both the home and garden. In Zimbabwe the practice of self-sufficiency is very important. Zimbabwe lacks a reliable municipal water and electric supply.

Several books have also been written in the past, the most well know was called *Rural Water Supplies and Sanitation* published by MacMillan in 1990. This was updated in 2016. A few other books were written and published like *Toilets that make Compost* and a few other books which have either been produced as e-books or self-funded books like this one. Also a great deal of information has been placed on our website www. *aquamor.info.* Also a huge amount of material has been placed on DVDs. One such DVD is attached to this book when seen as a hard copy. Otherwise refer to our website. RWSN has kindly placed some of my works on their website.

I have made an introduction to the general topic as a first chapter in the series dealing with that subject. In certain subjects I have put more detail in this book and some less detail. These generally deal with more recent studies which have not appeared on the internet, although they, in their full length form, appear on the attached DVD. They mainly concern more recent developments of down-the-hole components of the Bush Pump, the hybrid BVIP/*Arborloo*, which one may call the ventilated *Arborloo* which is a type of VIP and also an update on the relationship between rainfall and ground water tables. This book is privately funded and has a maximum of 130 pages.

My work in our “backyard garden” has played a very important part in the development of many technical methods which I have given birth too over the years. This book deals in one sense with a more personal view of these developments. It does reveal that with a lot of effort and determination a lot can be achieved in “backyard” studies. This is possible in a country like Zimbabwe, because there are not the legal restrictions placed on those who live in more advanced countries like the UK or USA. I would have been heavily fined if I had carried out this work in such countries.

However it must be said from the start that many developments, whilst they may have arisen at first in the back yard, have evolved as a result of the help and encouragement of many others and also in sites which are more rural and well away from the back yard.
I have acknowledged the help of many friends and colleagues and made reference to work that was performed elsewhere and where significant progress was made.

All that we can do in a life is to be good parents, try to be friendly and helpful to others, appreciate the remarkable world in which we live, offer encouragement to others, and if the fates are kind leave this world a better place than when we found it.

Peter Morgan
Harare.
August.2020

My involvement in rural sanitation technology

Since I am neither a trained engineer nor a medical man, I was hardly the man to take on this field of endeavour. I had been invited to join the Blair Research Laboratory in Salisbury, Rhodesia, after papers I had written in the field of Schistosomiasis (bilharzia) undertaken on Lake Chilwa, Malawi, had been published in the Central African Journal of Medicine in Salisbury. I arrived in 1972. At first I was told to study the control of this disease in Lake McIlwaine (now Lake Chivero), but the late Dr Dyson Blair, a former Secretary for Health in federal days, and a walking Encyclopaedia, urged me to change my line and study the world of rural sanitation, water supply and hygiene from a technical point view, as he considered that this was the most practical way of reducing the transmission of a number of diseases in the tropics including Schistosomiasis. He was backed by Louis Oliver, who worked for the WHO at the time. I decided to take his advice, although a little reluctantly at first. This looked like a messy business. In those days (1973) pit toilets were common, messy, smelly and produced masses of disease carrying flies. It was a big challenge.

The work started at the Henderson Research Station in 1973 where I had a team of builders and labourers. The farm manager, Ron Evans and the director of the station were also supportive. The field team was led by Ephraim Chimbunde, and his three excellent builders, Fambi Gono, Joshua Mazanza, and Philimon Ndororo. At the Henderson Primary school, the flies from existing pit toilets were so numerous, that activities outside the classroom were unpleasant for the children. The same was true of the occupants of the so called "compound" where many of the staff lived. We worked as a team very well together, although working in the mid to late 1970's was tense due to the liberation war. Towards the end we had to have armed escorts.

My first attempt in the sanitary world came in the form of a tipping pan system called a "Watergate" which formed a water seal under a chute on which the users squatted. It was an original idea and was patented by the government and later manufactured. But it used water and that was a drawback. It was later made in South Africa and remarkably appeared in one of Bill Gates' sanitation shows in the USA.

More or less at the same time I decided to use some of my biological instincts to look more closely at the behaviour of flies. We made fly traps and fitted them to toilets and were able to count huge numbers flies (in their thousands) emerging from a single pit toilet in the rainy season. Some of the flytraps were fitted to vent pipes. Termites also build vent pipes and this principle was copied. And flies have distinct forms of behaviour. They enter a toilet pit being attracted by odour and leave it by being attracted to light. It is very possible that the biological and specifically insect orientation of these studies originated in the teachings of my mentor in the UK, Dr John Sudd, who was an entomologist, and specialized in ants and their relatives in the animal world.

Studies at Henderson continued with a series of experiments with fly traps and the use of vent pipes as fly traps. If a pit toilet was made with a concrete cover slab with two holes, one for the vent and one for the squat hole and the superstructure above it, and if the superstructure was covered with a roof, air would flow down the squat hole and up the vent pipe. If a fly screen was fitted to the top of the pipe, flies being attracted to the odours coming out of the pipe could not enter the pit via this route. Any flies that did enter the pit would be attracted to the light coming down the pipe and were trapped. A roof was essential to reduce the light inside the structure. At first doors were used on these structures, but these were replaced by spiral door-less structures, so that semi darkness inside (but not total darkness) could be achieved. Quite large numbers were built at Henderson and also some at Chikurubi where specific fly counts were made between ventilated and unventilated pit toilets. The results were very convincing. Large numbers were built in the “protected villages” and commercial farms at that time.

I named this toilet the Blair Privy after Dyson Blair, who had encouraged me to look at these things. The Blair Laboratory was also named after him. The concept was endorsed by the Ministry of Health in 1975. I had received enormous encouragement for my work from the Ministry of Health and specifically from the Environmental Health Department and also from the Provincial Medical Officers of Health. I wrote a paper was in 1975 for the Central African Journal of Medicine and it was first published in early 1976. Information of the work was given, in 1976, to those working in this field in South Africa and also Botswana, where the local World Bank people worked. Back in Washington, USA, the World Bank changed the name of the concept to VIP without my knowledge. Several thousand Blair Privies had been built in Rhodesia before Independence. And reports of these works had been published in international journals. But the name VIP stuck and our own toilet also became known as the Blair VIP after independence in 1980, and has been promoted ever since, both as family units and multi-compartment units for schools. The first of these multi-compartment units was built at Henderson.

We designed a series of Blair latrines after Independence from the ultra-cheap to the more substantial brick toilets with a brick chimney which acted as a vent pipe. The Environmental Health Department chose the “de lux” fully brick model as the standard. At the time the donors were very generous and offered large material subsidies to families who built the Blair Latrine. Over the next decade or two several hundred thousand Blair Latrines were built including the multi-compartment unit for schools.

Over the years, the VIP toilet entered the public domain and millions have been built throughout Africa and other parts of the developing world. Many variants have been designed and these will be described briefly in the following chapters.

The Blair VIP dominated the rural toilet program in Zimbabwe for many years. As donor funding became reduced after 2000, and rural communities became poorer, not richer, few could afford to build a standard Blair VIP without donor support. Only about one third of the rural population was served with this toilet, which also doubled as a washroom. A number of lower cost BVIPs were also designed and built during this era. I retired from the MoH after nearly 20 years of service, partly because I became senior and had to do a lot of administration and attend head office meetings, which I found tedious. The staff meetings were brief during this era! The MoH asked me to stay on as a researcher for another two years. Later in 1992 my small team moved to newly formed office of WaterAid, and I continued to assist them for several years independently. This NGO later became known as the Mvuramanzi trust and its first director was Anthony Waterkeyn. It also became involved in other developments linked to family wells which will be described later.

Many years later, when the fully brick BVIP design became too expensive for the rural poor, I decided to restyle the method of construction of the BVIP and called it an upgradeable Blair VIP in which the substructure was built with a brick lining and fitted at the top with a concrete slab with a squat hole and vent hole caste into it. This combination could be built with a single bag of Portland cement. The superstructure design was optional, as was the addition of a vent pipe made with PVC pipe. The work was performed in my back yard. The government accepted this modification in 2011 and it was called a uBVIP, an upgradeable Blair VIP. I am not sure how many of these have been built.

Some years later I also looked at the problem of emptying Blair Latrine pits and using the contents in agriculture and tree growing. These were more advanced examples of the BVIP concept and were built and tested in Epworth. This work is described in more detail on the DVD and on our website.

In the mid 1990's Swedish Sida asked me to have a look at what is called Ecological Sanitation. I am indebted to Ingvar Andersson and his colleagues Rolf Winberg and Bengt Johanssen for supporting me in this work and later Arno Rosemarin and Madeleine Fogde who worked in the Stockholm Environment Institute, who also worked for the "Ecosan Project." During this era I investigated the link between toilets and agriculture and also what happened when one mixed excreta (the solids and the liquids) with soil, with the addition of leaves and wood ash. The study was biological and this interested me. Much of the work was performed in my garden and then tried out elsewhere. It added additional information to much that was already known, namely that the addition of diluted urine, which contains a lot of nitrogen could significantly enhance the growth of green vegetables and other plants, notably trees.

The initial work with three toilets - the *Arborloo* (tree toilet), the *Fossa alterna* (alternating pit toilet) and the *Skyloo* (an elevated single chamber variant of the already established urine diversion toilet), were all performed in my backyard. They were later tried at the Eco- Ed Trust (at Mutoroshanga) with the assistance of Jim and Jill Latham and also by staff of the Mvuramanzi Trust in various places in Zimbabwe. The same work was also promoted by Marianne Knuth and Annie Kanyemba at the Kufunda Village NGO in Zimbabwe, where the *Arborloo* was called the compost toilet and small kits were made up to promote it. Later they were tried out on a larger scale in Malawi and Mozambique in WaterAid projects headed by Steve Sugden in Malawi and Ned Breslin in Mozambique. This work was extended in Malawi by the CCAP (Central Church of Africa, Presbyterian, Synod of Livingstonia,) based at Mzuzu and headed by Jim McGill and the NGO COMWASH at Phalombe and Thyolo headed by Gary Holm. The simple idea of the *Arborloo* in particular spread through Kenya with the assistance of Rolf Winberg of Sida and also by Mayling Simson-Hebert of the Catholic Relief Services in Ethiopia, Kenya, Uganda and Tanzania. Its use has also spread widely in many other African countries.

Its popularity is based upon the fact that it is cheap and easy to build and use. When the shallow pit (filled with an ideal combination of excreta, soil, leaves and wood ash is nearly full, the slab and superstructure are moved to a new site on top of a new ring beam at the top of the pit. The old pit is topped up with good soil placed over the old pit contents. A young tree is planted in this soil. The tree if watered and cared for, grows very well in such organic pits, and depending on the tree chosen can produce large qualities of fruit, wood for fuel or construction – or simply beauty and shade. It is the simplest way of promoting an ecological approach to sanitation, especially in poor countries.

It has never been promoted by the government in Zimbabwe, but it is time that this simple and effective concept is promoted in this country. Current back yard retirement work has included the development of a hybrid of the *Arborloo* and the VIP, where simple shallow pit toilets, where the pit is unlined (as in the *Arborloo),* and superstructures of various types can be fitted with a vent pipe. Thus when the superstructures are suitably made act as both a VIP and an *Arborloo* at the same time. This important development is described in this book. I have cut back on the development and evolution of the *Fossa alterna* and *Skyloo*, as they are well described on the DVD which accompanies this book and our website. The next section deals in more detail with the *Arborloo*, as it appears to be very suitable for areas where rural folk are poor and cannot afford to build more sophisticated toilets. Spaces is required for this concept as the toilet on always on the move, leaving a series of organic pits in which trees can grow.

Some photos of the various toilets

The brick built Blair VIP, the multi-compartment Blair VIP and an upgrade of the uBVIP

The *Arborloo*, the *Fossa alterna* and a hybrid between the *Arborloo* and the VIP

The *Arborloo* and its variants

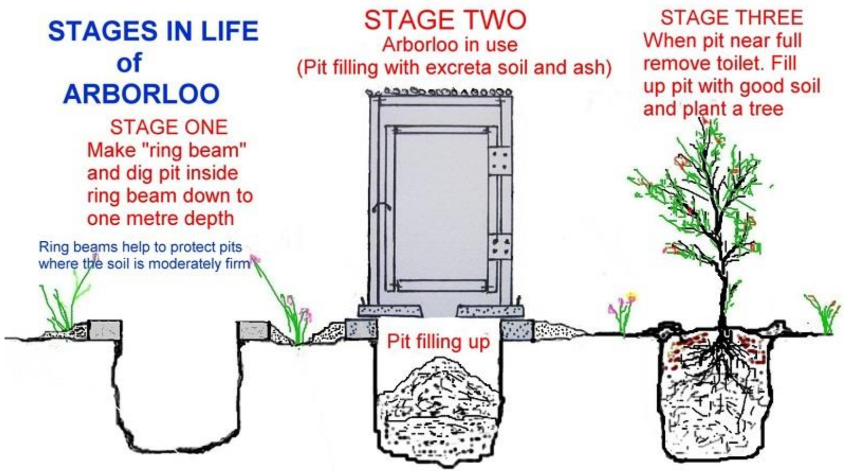
Once again a great deal can be found on the accompanying DVD or on our website which describes the *Arborloo* (tree toilet), and other ecological toilets like the *Fossa alterna* and urine diverting toilets like the "*Skyloo*." The *Arborloo, Fossa alterna* and a version of the already well known urine diverting toilet concept, I called the *Skyloo,* because one had to step up to get into it, were all first built in my back yard in the mid 1990's. Of these three designs, the *Arborloo* has been the most successful and many thousands have been built around Africa and in other parts of the developing world.

The *Arborloo* is the name given to the simplest ecological pit toilet. It is often called a "tree toilet.|" The pit is shallow and is not lined with bricks. Soil, ash and preferably leaves are added regularly to the pit as well as excreta. The toilet is moved from time to time, when nearly full, and the old pit is topped up with soil and a tree is planted in this soil. The name is derived from the word *Arbor* a Latin word for tree and loo – a toilet. The *Arborloo* is both easy to construct and is cheap to build. It is made up of 3 basic parts:

1. The **"ring beam"** to protect the pit
2. The **concrete slab** which sits on the ring beam
3. The **toilet house** which surrounds the slab.

The concrete slab is made first and allowed to cure. Then the ring beam is made in bricks and mortar or in concrete. The pit is then dug inside the ring beam to a depth of about one metre. The slab is added on top of the ring beam and then a simple structure is built around the slab, mainly for privacy. The *Arborloo* pit fills up with a mix of excreta, soil, wood ash and leaves. Leaves are put in the base of the pit before use and every day some soil and wood ash are added to the pit. Also leaves are added to the pit from time to time to make better "compost." When soil, ash and leaves are added regularly the excreta in a pit changes into a different type of material which trees can grow in. The daily small addition of soil and ash also help to control flies and smells. When the *Arborloo* pit is nearly full, the parts of the toilet (ring beam - if portable), slab and house are moved to another place and a layer of fertile soil (about 15cm deep) are placed over the pit contents. A young tree is planted in this soil and is watered and cared for and also protected against animals. It is usually best to allow the pit to settle and wait for the rains before planting a tree.

The ring beam is reassembled at a new site if made of bricks, or simply moved if made of concrete. The slab can also be re-used and the toilet house simply moved if it is strong enough or reconstructed in traditional materials. The new toilet is used again in the same way in the new *Arborloo* site. The same process takes place again and again to make an orchard or woodlot. The *Arborloo* has only been used on a small scale in Zimbabwe, but has been used widely in other countries like Malawi, Ethiopia and in East Africa and some parts of West Africa and Haiti. It is popular because it is very cheap and easy to build and the end result is a valuable tree. You could say it converts human excreta into vitamins, if a delicious fruit is the end result.



Planting trees near the *Arborloo* when the toilet is in use.

It is also possible to plant a tree near to the *Arborloo* when the toilet is actually in use. In this case the tree roots first tap nutrients in the soil under the tree but work their way into the pit later to tap the richer soil in the *Arborloo* pit.

On the left a very simple *Arborloo* made for children built in 2008 in my garden, with a young mulberry tree next to it. On the right the same tree in 2019. The *Arborloo* itself has long since filled up and been abandoned. But the tree has grown enormously provides much fruit.

Details of how to construct the *Arborloo*, and also the *Fossa alterna* and the *Skyloo* are available on the DVD provided with this book. But a few photos can be placed here to provide an overview of the *Arborloo*, which has spread widely across many countries of Africa and elsewhere. Trees can grow very large after the *Arborloo* pit has been filled, covered with soil and a young tree planted. So the *Arborloo* sites must not be placed too close together. The magic of the *Arborloo*, is that it provides a valuable facility for the family, as a toilet, uses natural principles to convert the offense excreta into a product in which plants can grow and provides a most valuable asset in the form of a tree, which can provide nutritious fruit, or timber for construction or fuel or simply shade, ground cover and stabilisation and beauty. A few highlights of the simple construction follow.

Basic steps in construction

The concrete slab

In its simplest form and the version most used in Africa, the slab is made of concrete with a single squat hole. In some projects the slab is mass produced in other materials also with a single squat hole. In Zimbabwe, variants have been made which include a vent pipe hole for a 110mm PVC vent pipe, if an upgrade to the BVIP is visualised.

Simple slab. Lay a plastic sheet on level ground and lay bricks in a circle 1.1m in diameter to make a mould. Add a shaped bucket or bricks to make the squat hole. Make a mix of Portland cement (10 litres) and river sand (50 litres) and add to the mould. Add half the mix first, then some wire like barbed wire to reinforce the concrete, then top up with the remaining concrete. Leave to cure and keep wet once hard for at least a week.

The slab can also be made to fit a vent pipe

This slab is also 1.1m in diameter and is made in the same way as the simple slab, but a short length of 110mm PVC pipe is also inserted as shown. .

The mould for the slab can be made from a ring of bricks as shown which will be the normal route. A special tool can be used to make a smart squat hole, measuring about 30cm X 15xm. This also uses 10 li Portland cement and 50 li river sand. About 10m of barbed or 3mm wire are used for reinforcing. Half the concrete mix is added first, then the wire then the final mix of concrete. The slab is left to harden overnight and kept wet therafter under a plastic sheet for at least a week before moving.

In larger projects where many *Arborloo's* may be built, steel moulds can be used to caste both the slab and the ring beam.


The ring beam

The ring beam helps to keep the top of the pit from falling in. It supports the concrete slab and soil taken from the pit is rammed in place around it to make the toilet safer. The soil must be moderately firm where the ring beam is used. It will not work in looser sandy soils. The ring beam can be made of bricks and cement mortar or it can be made from concrete made with a mix of cement and clean river sand. It is important to raise the toilet base above ground level.

How to make the brick ring beam in bricks and cement

Get some fired farm bricks and mark a circle on the ground 1m in diameter (radius 50cm). Lay the bricks around the circle.


Laying the bricks in a circle with the inside diameter of one metre. Make up a mix of cement and pit sand about 10 parts sand to one of cement. Using a trowel mortar the bricks together. Then add a second layer of bricks on the first layer. The upper layer of bricks should sit on the joint between bricks of the first course.

How to make a concrete ring beam

This ring beam was made for a 1.1m slab. Lay on ground with 1 metre for the internal diameter of ring beam and 1.3m for external diameter. If Portland (PC15) cement is used 10 litres of cement are mixed with 50 litres of river sand. The brick mould is half filled with the concrete mix. Then two lengths of 3mm wire are laid centrally on the concrete between the inner and outer bricks. The remaining concrete is added and levelled off. It is levelled with a wooden float and left to cure, being kept wet for several days after hardening. A handle can be added to the ring beam to help drag it to the next site, if required. Thus half a 50kg bag of cement, which holds at least 40 litres of cement can be used to make both the slab and the ring beam. These can be used many times in many sites to form part of many *Arborloo's.*

Dig down a hole within the ring beam to at least 1 metre below the surface. Place the removed soil around ring beam and ram in place hard. Add a bag of leaves to the pit base. This will help the contents of the pit to compost. Then lay the slab over the ring beam. It is best to lay the slab in some weak mortar placed on the ring beam. This mortar is important to seal the pit, make the slab level and also to stop the slab cracking.

A steel ring beam mould is being used to make the ring beam

Dig down the pit inside the ring beam

A hole is then dug inside the ring beam down to a depth of about 1m. The soil which comes out of the pit is placed around the ring beam and rammed hard in place. This will help to make the ring beam firm in its place. This ring beam and rammed soil helps to raise the toilet above ground level and stops rain getting into the pit. If the soil is firm the pit can be dug a little deeper.

School children digging the pit of an *Arborloo* at Chisungu Primary School, near Harare.

Full hole dug

Fitting the slab on the ring beam

The slab is placed over the ring beam on a layer of weak cement mortar. This helps to seal the pit and slab and also helps to make the slab level on the ring beam if not perfectly level. It also helps to prevent the slab from cracking if the ring beam is a little uneven.

Building the toilet house (superstructure)

The toilet superstructure is now built around and over the ring beam and slab and there are many ways of constructing this. This house structure is used to make the place private. It must be light weight and easily moved from one location to the next. It is best to make a roof to fit over the structure for shade and to keep the rain out. There are many ways of making the structure which can be made to look smart. Some examples of *Arborloo* houses are shown below.

There are many variants of the *Arborloo* house

Arborloo structures with vent pipes

Ventilated *Arborloo's* can be quite smart!

Other examples of ventilated *Arborloo's* – the smartness varies!

Using the *Arborloo*

The *Arborloo* is used like a normal pit toilet, but there are differences. A handful of soil is thrown down the pit daily to cover fresh faeces and this should include a hand full of wood ash if available. These help to cover the fresh deposits and also reduce fly nuisance. Leaves should also be added from time to time to help the composting process and allow air into the mix. An important thing is not to throw garbage down the pit as it is quite small compared to normal pit toilets. For a small to medium sized family the pit should fill up to near the top in about a year. Then the *Arborloo* must be moved to a new site and the parts reassembled. The used pit is filled up with good soil to about 150mm deep and left to settle.

Moving the *Arborloo*

Together with the concrete ring beam it is possible to move all the parts of the *Arborloo*

Planting trees

Good trees for this *Arborloo* pit are mulberry, guava, mango, avocado, paw paw and banana. But most species of tree can be planted and with thrive if cared for. Plant the young tree in the soil above the original pit contents. The tree must be protected against attack by animals and must be watered often. In time the tree will grow big and provide many fruits. Trees are best planted during the rains. Once the tree is established it can be further fed with manure or compost.

Trees growing on Arborloo pits

Banana and an orchard of fruit trees in Malawi

Banana, paw paw trees in Malawi and avocado planted on *Arborloo* pits in Ethiopia

Citrus tree planted in Kenya, mango and paw paw in Zimbabwe

The Compost Toilet Starter Kit

This kit was produced by the NGO Kufunda Village as a means of promoting the simple *Arborloo* concept in Zimbabwe. The *Arborloo* was called a Compost Toilet. It contained 8 litres cement to make a concrete slab, instructions for slab making, instructions for construction and use of *Arborloo* and tree planting and two young mulberry trees. The ring beam was made by using bricks and anthill mortar.

The compost toilet Starter Kit and its enclosures


Group of trainees at Kufunda village (Ruwa, Zimbabwe) being taught how to build a simple "compost toilet." Adding leaves to the pit.

Planting trees in *Arborloo* pits

A group of trainees planting a mulberry tree at Kufunda

The ventilated *Arborloo*

As we have described earlier, the *Arborloo* can also be built so a vent pipe can be fitted to it. If certain design principles are followed, it becomes one variant of the VIP toilet. In 2009 a series of trials were made with *Arborloo's* fitted with vent pipes (see earlier photos). It is curious that in the next chapter on the evolution of the Blair VIP a ventilated version of this technology was also researched independently. Whilst the *Arborloo* is widely used in several other African countries, it is not well known in Zimbabwe, although the concept was first researched here. Perhaps the authorities would find it more appropriate for the rural sanitation program if it had the potential to be upgradeable like the upgradeable Blair VIP (uBVIP) which is described in the next chapter. It is interesting that both the uBVIP and the *Arborloo* slab with vent are identical. Perhaps the designer did this intentionally!! This means that the standard concrete slab can be used in an upgrading process which includes a ventilated version of the *Arborloo* as well as the already accepted uBVIP. Time will tell.

Summary

Simple ecological toilets like the *Arborloo,* which were designed for use for those poorer members of our rural communities, which sadly in Zimbabwe are in the majority, can serve many important roles. They can act as comfortable toilets, they can be upgraded over times, they are cheap and easy to build and use. But perhaps most importantly, in addition to these other features, they can provide long lasting benefits in the form of trees, which can provide, fruit, fuel, building materials, as well as great beauty. The trees of our planet are amongst the oldest living things on Earth. They are indeed one of the greatest treasures of the living world. Anything that can promote their multiplication must be encouraged. The photo below taken in Kenya reveals that the concept of the *Arborloo* has been well accepted by Mother Nature.

An interesting photo of a tree growing out of an abandoned pit in Kenya. The tree was not planted there by humans. It grew naturally. The ultimate proof that Mother Nature approves of the method of trees growing on decomposed "so called" waste material.

Eco-sanitation and organic gardening

This chapter is not about gardening, there are plenty of learned books about that subject. It is about how excreta and gardening can be complimentary – an unlikely subject. At least for those who have access to fertilisers and who know about the soil and can make compost heaps. During my studies of ecological sanitation, the link between toilets and their products and the garden and the production of food or other plants formed an important part. As a biologist it was clear, after some thought, that our so called “waste products,” the soil, plants and leaves and the atmosphere in which we all live are parts of the natural world. I, like everybody else, finds excreta revolting, but Mother Nature does not, it appears. So in one sense they can all fit together in some sort of way. At first I made mixes of excreta and soil, often with leaves added. Once processed, the mix changed its form and was presentable and became more like a fertile soil. This was often processed in buckets. Then I added this mix to other buckets and jars and then grew vegetables and even trees in the bucket mix. They grew well. Over the years I performed many experiments in my back garden and even taught them at a school. Many of the same ideas were taught elsewhere in Zimbabwe and in some other African countries.

The simple facts were that when mixed with soil and leaves with preferably wood ash added, human faeces would change their form completely and become like a new soil, with a pleasant smell and in time all the pathogens would also die out. Urine too was useful. It is known to contain a lot of nitrogen, but not the sort of nitrogen that is acceptable to plants. It offers plants the nitrogen it needs only after the nitrogen in urine has been converted to nitrate by soil bacteria. So the living soil is essential, even for this process.

Most of my experiments in this subject have been written up and are included in the DVD attached to this book (and on our website), so once again there is no need to go into detail here. But some experiments and methods are worthy of mentioning here. First is the usefulness of a gardening technique which uses a small miniature garden enclosed within a ring beam. That is the same ring beam that is used on the *Arborloo*. Small in area that it is, even one unit can produce a respectable amount of food, mainly in the form of vegetables. So several units could be used to grow a variety of vegetables. The interesting point is that the soil within the ring beam can be dug out and replaced or mixed with an improved soil, humus or compost. Once the crop has been harvested, the soil inside the beam can be turned and replenished. Furthermore diluted urine can be added to increase the nitrogen content of the soil, which can greatly accelerate the growth of green vegetables.

Plastic buckets, cement jars and other containers can also be used to grow useful crops. But the same can apply to small patches of vegetable garden in the back yard. The importance of using garden compost and leaf compost (leaf mould) cannot be overemphasised. And animal manure too. Whether human or animal manure is added or not, plants grow at their best when the soil is alive – the living soil.

Ring beam gardens and the value of diluted urine application

For me the idea originated when I needed a base on which to place the concrete slabs of *Arborloo's* and the *Fossa alterna*. In these early days and in both cases the slabs and the ring beams were made of concrete and rectangular in shape. In both cases the concrete slab of the toilet had to sit on a firm base caste or built on the ground. This elevate the slab above ground level. In a short space of time, slabs and ring beams for the *Arborloo* became circular, but for the *Fossa alterna* remained rectangular. The circular slabs and ring beams possibly following the circular slab designed for the Blair VIP.

The concept of the *Arborloo* itself, was born by renaming a structure called a "tree pit" where the products of very early urine diverting toilets which I used in the back yard, fell into a bucket together with soil. The contents of the bucket were then thrown into a shallow pit and mixed with more soil and leaves. The ring beam was made to protect the head of the pit, and to allow it to be covered during periods when the pit was not being filled. It therefore seemed like a small step to put a slab with a squat hole over the tree pit and use it directly as a toilet. This process happened in my back yard. The name changed from "tree pit" to *Arborloo.* Early experiments with the conversion of human excreta were also taking place at the same time by mixing soil with the human materials in square ring beams made of brick and mortar. The texture and quality of the pit contents changed dramatically, thanks to entirely natural processes.

Once the concepts of these toilets and the use of ring beams had been established, it seemed obvious to use the ring beam as a site to grow vegetables and other plants as well as trees. In fact in some countries, like Ethiopia, I am told, vegetables like pumpkins are grown on *Arborloo* pits in place of trees.


It is remarkable how much produce can be grown in a small space if the soil is good and the plants are well cared for. On the left a ring beam of spinach in our own garden. On the right a photo sent to me of pumpkins grown on an *Arborloo* pit in Ethiopia.

Photos of ring beam gardens in our back yard

A fine production of spinach in a ring beam. Around 40 spinach seedlings were planted in this ring beam (internal diameter 1m) on good topsoil. Once established the plants were fed with 4 litres of a 3:1 mix of water and urine twice a week with intermediate watering when required. In 9 months 23kg of spinach had been cropped from this very small area (with 2 plantings)

On the left a rectangular ring beam with a variety of vegetables. On the right herbs like lavender can be grown on ring beams

Sweet potato on the left and covo on the right planted in ring beams

Rape planted on a ring beam and also pumpkin (centre and right)

Ring beam garden experiments at a school

This experiment was undertaken at the Chisungu School in Epworth with maize, spinach and covo planted in small ring beams to demonstrate the effect of diluted urine on plant growth. For each treated ring beam 2.4 litres of a 3:1 mix of water and urine was added twice a week with additional watering in between. The untreated ring beams were watered only. The increase in yield is very obvious as the photos show. Maize and green vegetables respond very well to the application of diluted urine.

Maize

Spinach

Covo

The school is an excellent place to teach the principles of ecological sanitation

The link between sanitation, soil, plants and nature

When we worked on the Blair toilet in the 1970's we had as our main goal the reduction of odours and fly nuisance for the users. In order to achieve this I had used natural principles in the design of this toilet, namely the behaviour of flies and also the effects of chimneys on air flow, beautifully demonstrated in the termite turret. These combined effects reduced the two problems associated with pit toilets used in rural sanitation, so much so that the toilets were often used as washrooms. But the weakness was, that when the pit was full, a process that normally took between 12 to 15 years, the whole structure had to be rebuilt. There are Blair toilets that were built in the mid 1970's at Henderson that were still working 30 years later, but these had big pits. To reduce costs, the recommendations for the pit size were reduced over time to save on the use of cement. Also, in more recent years I designed Blair toilets that could more easily be emptied and these have been mentioned very briefly in this book, under variants of the Blair toilet with information also placed on the DVD and on the website. A great range of Blair toilets have been designed from the cheap to the more expensive.

When the Swedes asked me to look at the subject of ecological sanitation, it opened up another way of looking at toilets, from a biological perspective. In fact this added once again to the use of both natural and biological principles to the subject. This resulted in the development of the *Arborloo*, the *Fossa alterna* and other models of the urine diverting principle. It also opened up ways of converting the rather unpleasant products of excreta into useful materials that could be used in agriculture and forestry. Excreta is a natural product of nature, as is the living soil and all plant life. And since all animals depend on plant life, the soil lies at the centre of everything. We, as humans, find excreta revolving, and I am no exception, but those who enjoy the natural world have come to value the living soil and the plants that grow on it. So it seemed to me quite natural to form more links between the toilet, excreta and the natural world.

The following chapters deal with this subject, which is important to me as a biologist. The first deals with the importance of a living soil, so well described in many early works by Balfour and others. The second deals with ecological and organic farming and how this can be linked to the formation of ingredients linked to excreta (converted faeces and urine). The third deal with an important subject for me. The link to trees.

Trees are wondrous living things of immense value and beauty. Trees can provide benefits like an income in cash, fuel, fruit or building materials and shade. They are able to convert the nutrients in the soil and even urine and converted faeces together with sunlight and carbon dioxide into vitamins and other health benefitting foods contained in fruit. Many can also provide valuable health benefitting substances. Trees can also benefit the health of our planet. The more trees on Earth the better. And trees have time. Amongst their numbers are the oldest living things on Earth. Long live the tree.

The answer lies in the soil

My own view, which is central to the theme of ecological toilets is the link between toilets and the soil. Soil with its complex makeup of living organisms and nutrients is essential for life on earth. Without the living soil, plants would find it difficult to grow and could not grow at all without carbon dioxide. It seems natural therefore that both soil and excreta which are both natural products, much as we find the latter rather disgusting, should have some sort of relationship. When a mix of soil and excreta are combined and left to react biologically, the organisms in the soil help to break down the excreta to form a product which is like a “new soil” and quite acceptable to handle. The excreta in return offers additional nutrients to the soil. Even the recycling of urine is linked to the soil, for soil bacteria are essential for the conversion of urea and ammonia contained in urine to the nitrate - a salt of nitrogen which can easily be taken up by plants. So adding urine to the soil increases the nutrient content further. So the living soil is central to the process.

The various ecological toilets systems and recycling methods described in this book have been so designed that the excreta which accumulates in the pit or container is converted into a product by the addition of soil, leaves and wood ash. The ash helps to reduce fly breeding and provides potassium. The leaves provide fungi and when biologically converted by themselves produce an excellent product, known as leaf compost.

These various products are readily used by a great variety of plants – whether they be vegetables, food crops or trees. In the case of the *Arborloo,* a shallow pit latrine in which soil, leaves and wood ash are added to the excreta deposited in the pit form an ideal medium, once processed, for the growth of trees. Once the pit is almost full, the structure and slab are removed and placed on top of another shallow pit and ring beam nearby. The used pit is topped up with fertile soil and a young tree is planted in this soil, watered and protected. It is planted in the soil – not the excreta – plants do not survive when planted in fresh excreta. If the fates are kind, the young tree grows, at first in the topsoil, whilst the excreta below is turning into a “new soil” as it would in Nature. In this way the nutrients held within the pit contents are utilised by the growing tree, and when the tree matures, can produce fruit, fuel or building materials. Much of the urine is absorbed into the mass of pit soil and leaves held within the pit, provide more air spaces to assist the biological processes, as well as providing additional biological breakdown processes by the action of fungi. The *Arborloo* structure thus travels on a “never ending journey” through the “lands” followed in their wake by a series of trees which may eventually form a woodlot or an orchard – or just simply shade trees scattered here and there. Sometimes a young tree will hesitate as it starts to grow. A few may die, but most grow strongly right from the start if well cared for. Thus the nutrients we call waste are converted into something very useful, and out of site!

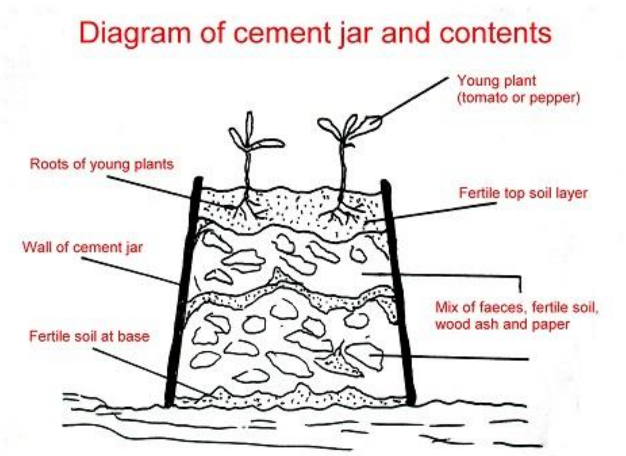
In the case of the *Fossa alterna*, the second simple eco-toilet developed in our garden laboratory, a similar process takes place in the shallow pit, with soil, wood ash and leaves being added as well as excreta. But the structure, which is portable, alternates between just two pits, which are permanently sited. Once the first pit is nearly full, the superstructure is moved to the second pit and the first pit topped up with a good layer of leaves and topsoil. After one year the contents will have changed their form into a nutrient rich product which can be dug out and used on the garden. The structure is moved back on to the original emptied pit. It moves from one pit to the other once a year, every year – a process which is fully described on the DVD or on our website.

In the case of urine diverting toilets where the urine and faeces are separated, the faeces normally accumulate in a vault beneath the pedestal and the urine collects in an offset plastic container. There are many descriptions of urine diverting toilets in the international literature (see bibliography at the end of this book, notably Ecological Sanitation by Esrey et al. 1998). In the example described in this book, known as the "*Skyloo*" the faeces accumulate together with soil and wood ash in a basin held within the vault. The soil and wood ash (if available) are added after every visit made to deposit excreta. This mix of faeces, toilet paper, soil and wood ash held in the basin is deposited in a "secondary processing site" where more soil and leaves are added. Here the mixture changes its form into a fertile soil like material for onward passage to the garden at a later date. Human faeces readily turn into a soil like material if they are in close contact with a fertile soil – and are kept moist and are well drained and aerated. The aim is to enable the soil to form layers within the accumulation of faeces to effect the change. The mix of faeces, soil, ash and paper and preferably leaves can also be added to shallow pits, trenches or containers such as cement jars and covered with layers of fertile soil. The change in form from a most obnoxious, foul smelling mass into pleasant smelling soil like material is quite remarkable. It takes place in nature all the time, in the forest, for instance, where the wastes produced by animals turn into humus on the forest floor together with leaf litter formed from the trees. All the nutrients formed are recycled back into the forest.

Photos. Left: An *Arborloo* in Malawi. Centre: The first *Fossa alterna* in my back yard. Right: a *Skyloo* in my back yard. Descriptions of all these toilets can be found on the DVD accompanying this book and on our website.

The importance of soil rich in nutrients and living organisms called humus

Humus is the dark crumbly material formed from decayed matter formed in nature from a constant supply of residues from animal and plant life. These residues are constantly converted in nature by the organisms present in the soil and also in the residues themselves. Moisture is required during the whole period during which the humus is being made and also abundant aeration is essential. Even in Nature, if too much water is present, the aeration of the forming humus is impeded and the process slows down or stops. If too little water is present, the activity of the micro-organisms slows down and then may cease altogether if the mass becomes desiccated. Desiccated leaves can remain unchanged for decades or even centuries – but when they are moistened they decompose readily, especially if they are thin. The conversion of the various natural products into humus is a result of activity by beneficial bacteria and fungi and also by a myriad of other micro-organisms and small animals. Bacteria are essential to this process. Most bacteria present in nature are beneficial to life and present no health threat. In fact by far the majority of bacteria are essential to the natural process of breakdown, and thus life on Earth. Without this process of breakdown, followed by re-growth, life on this planet could not exist. The soil is the home of millions of beneficial bacteria. Early work on this subject in our garden was carried out in cement jars and buckets.



In the mid 1990's cement jars and buckets were used to observe the conversion of a mix of excreta, soil, ash and leaves into a product which could be handled and became a good growing medium for plants of many types.

Humus is essential to soil fertility and adds an important physical condition to the soil, making it more crumbly, more moisture retaining and physically capable of greater oxidisation, which is essential for the growth of all living organisms including plants. The best humus is derived by mixing the soil formed from excreta with other humus like soils and leaf compost. Thus good humus can be built up, in a series of generations by adding and mixing. The earth worm, the bacteria, the fungi, and a myriad of other micro-organisms of a benevolent character whose habitat is the soil are important actors in this process. The only way to farm or to manage a successful garden is to maintain the fertility of the land by adding humus – thereby preserving the living content of the soil. That living content of the soil is best maintained by the constant refreshment of further supplies of life in the form of humus.

Everything we see in nature shows the greatest use of every type of waste. In fact nothing anywhere in nature is allowed to go to waste. Recycling is a central theme in Nature. Ecological sanitation also promotes this ideal. These views, well expressed by Friend Sykes in his book "Humus and the Farmer" and other promoters of the humus theory (Howard, 1943 and Balfour, 1943) make a lot of sense (see bibliography). Others promote the use of chemical fertilisers as the best means of obtaining adequate crop yields on the land. The probable truth lies somewhere in between, in striking a balance between using natural and artificial fertilisation (Hopkins, 1945). This wise concept is also discussed by Louis Bromfield in his book Malabar Farm. In his studies of the land, Bromfield found that chemical fertilisers were of very little use on soils devoid of organic material and of great immediate value upon soils high in organic content. Studies revealed in this book also show that the same holds true for the application of urine to the soil. Urine adds only chemical nutrients to the soil and no living material. Bacteria in the soil are essential for the conversion of the urea present in urine into forms of nitrogen (nitrate) which can easily be absorbed by plants. So the use of urine as a plant food, depends very much on the soil and its living content to be effective. Soil containing humus is far more effective at processing urine than soil deficient in humus, such as very sandy soil. So once again, the soil plays a central role, even in the use of urine.

The capacity of chemicals to burn out crops or to destroy bacteria, earthworms and other living organisms in the soil, Bromfield found, was largely determined by the amount of organic material present and of the moisture content which accompanies its presence in the soil. Nothing was so effective in trapping and holding rainfall and moisture as organic materials in every stage of decay. Thus it would appear that the value of humus holds true, whether or not artificial fertilisers are added, in whatever form they are used. This must also hold true even where diluted urine is the source of liquid feed. Plants will respond better to urine if the urine is diluted and if the soil is more humus like and has water holding properties. Thus the recycling of both solids and the liquids of human excreta much depends on the presence of humus - the living soil.

One major difference between the process taking place in the garden compost heap and that seen in our shallow pit eco-toilets or the production of humus from excreta in bags, buckets, jars or shallow pits, is the relatively larger proportion of "manure" (human faeces) and the smaller proportion of vegetable matter. Vegetable matter in abundance is vital to the "Indore Process" of composting promoted by Sir Albert Howard. With less vegetable matter being present in the humus formed in shallow pits and jars containing human excreta, there is little rise of temperature – as compared to the compost heap where significant rises of temperature occur. The conversion of excreta into humus in this case does not depend on the activity of heat loving (thermophilic) micro-organisms (bacteria and fungi) but rather those bacteria and fungi which thrive at ambient temperature (mesophilic) - that is close to the temperature of the surroundings. All manner of other beneficial organisms, including insects, worms, and many other life forms also thrive best at ambient temperatures. Not only do these animalcules and microbes digest the excreta but also inhibit, compete with, consume or otherwise antagonise those pathogenic organisms, such as bacteria, that carry disease. The process is an entirely natural one leading to the formation of humus. The addition of fertile soils and leaves to excreta also help to absorb much of the moisture content of the excreta itself – a process which is associated with a reduction of the volume of the mass. The end result of this process is friable darkened humus like material, which when mixed with topsoil makes an excellent soil conditioner and nutrient enhancer.

The conversion of raw excreta into humus, in the presence of adequate volumes of soil, leaves and ash, reveals a change of colour, odour and texture of the original faecal matter, which becomes pleasant to smell and handle. The activity of insects and their larvae may also be important in breaking up the faeces as well as bacteria, fungi and earthworms where they are present. Roots from trees and other plants also invade the highly organic layers in the eco-pits or containers where excreta is converting, and are very visible when the pit is being excavated or the jar is opened. Where plants grow into the organic materials held in pits or containers, their roots also convey oxygen into the body of the material, which greatly assists the decomposition process. In Nature, all living organisms and their products eventually end up in the soil and become part of it, only to be recycled again and again within a never ending process of building up and breaking down.

These descriptions of the humus and the important part it plays in the fertilisation of the land, together with the capacity of urine to increase the amount and availability of some essential nutrients, are in my view, central to our own promotion of the eco-sanitary process. Since the soils of Africa are so deplete in nutrients there is an overwhelming case for using all methods available to restore both nutrients and fertility. The use of animal manure is widely used in those areas where cattle are kept and this technique forms part of a long standing traditional practice. But the great majority of people do not own cattle. In a world where commercial fertilisers are becoming increasingly unaffordable, there is an even greater need to harness any other form of humus or nutrient suitable to enhance crop growth.

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. This is because the excreta has a very high water content. In urine diverting toilets the urine is channelled away and the faeces dehydrate 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 and also into the soil surrounding the pit (as in unlined pits like the *Arborloo*). 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 the final product held in the pit or jar.

But what are the fractions?

The following curious and messy 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 nor 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.

This was allowed to slowly compost over a period of 24 days. Fly larvae developed in the mix, which also attacked by ants. Slowly the mix changed into 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.


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

After the period of composting both samples were laid out in the sun to substantially dry out, but not to fully dessicate. 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 the water content of faeces 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 weight of the combination was reduced from 709g to 420g (59.23% of original). The overall volume of the combination was reduced from 650 ml to 405ml. Thus the composting process of soil and faeces reduced the volume to 62.3% of the original combined volumes.

The processed combination of "NEW SOIL" was very similar in appearance to the 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 (1.037gm/ml). Clearly the addition of leaves lowers the density of the mix, a result no doubt of 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. This is a very important finding.

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 for weight and volume 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 (excreta & 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. Thus leaves are an important ingredient in this process, not only because they provide extra nutrients, but also because they lower the density of the mix and provide extra air, thus increasing the efficiency of composting. They also 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 in programmes of implementation.

Conclusions

These various results show that a mix of faeces, soil, and leaves**,** when well managed, can provide a valuable material for the garden and for growing trees. The addition of wood ash to the mix also provides extra potassium and in a pit can reduce fly breeding and odour. The formation of a healthy mix of excreta, particularly by animals together with soil and leaves or other vegetable matter was invented by Nature itself.

Abundant growth of green vegetables in backyard garden enriched with the contents of a double-pit compost toilet (*Fossa alterna*).

Trees and Toilets

As recyclers of nutrients present in human excreta

Hundreds of years ago, the Pilgrim Fathers planted trees on their abandoned pit toilets, and Nature also chose the same method when seeds dropping from trees fell into toilet pits which had filled and been abandoned. Planting trees like bananas became common practice in many townships in Malawi and other countries in East and Southern Africa. In almost every case it was noted that the tree growth could be accelerated considerably when its roots could tap the nutrients in toilet pits and the same held true for trees planted near soakaways linked to septic tanks connected to flush toilets. The resulting fruits were large and tasty. Despite the obvious fact that tree and fruit production could be increased considerably by this simple method, very often the production of fruit in this way was often concealed from view, perhaps by some form of embarrassment, or perhaps for fear that the Health Authorities may have condemned the method on grounds of food contamination.

This same principle was adopted within the discipline of ecological sanitation in the form of the *Arborloo* – or tree toilet. In the last few years tens of thousands of *Arborloo's* have been built in Africa. The *Arborloo* uses the same principles found in Nature. Combine human faeces and urine with soil and it turns into an enhanced soil. The soil adds soil microbes which accelerate the decomposition process. If ash is also added, this reduces smells and flies and also adds potash to the mix. The reaction also turns slightly alkaline, which can accelerate the biological process. If plant material is added as well, in the form of leaves or plant cuttings, an improved composted product is formed. The addition of leaves adds the activities of fungi to the biological process and also adds carbon and air. In the *Arborloo*, excreta is added to the pit in combination with soil and ash etc. When the pit is almost full the toilet slab and structure are moved to another site. The pit contents are covered with a generous layer of soil. If water is available a young tree can be planted protected and watered straight away. The roots grow at first in the topsoil whilst the material beneath is changing its form. Root invasion proceeds, as the materials in the pit are found more acceptable to the roots of the plants or trees.

Early experiments involved the use of the "tree pit" which became known as the *Arborloo* and also experiments using dog manure in 1 cu. m. pits topped up with soil where a variety of tree species were grown, both exotics and indigenous. Experiments with the *Arborloo* were initially tried in the EcoEd Trust, Mtoroshanga, Zimbabwe. And later by the Mvuramanzi Trust in several locations around Zimbabwe, including Porter Farm. Later trials and promotional work were carried out at Kufunda Village Training Centre, Ruwa.

Tree trials at the EcoEd Trust (Mtoroshanga)

Trials at the Friend Foundation with both exotic and indigenous trees

Trials at Kufunda Village Training Centre, Ruwa, and Porter Farm Zimbabwe

From there the method was transferred to Kenya in the Kisumu area. The method was then transferred to Malawi (along with the concept of the *Arborloo* and *Fossa alterna*) where many thousands of units have been built. The method has been used widely in Africa, notably in Ethiopia where over 50 000 *Arborloo's* have been built.

Because it is simple and cheap to build the *Arborloo* is popular in areas where people are poor and may lack wood for fuel, nutrients from fruit and even shade and stability for the soil. The *Arborloo* pit acts like an "organic pit." This maybe valuable in areas where the soil is poor and where plants may not grow easily. However leaves and organic matter added to the pit helps the conversion process and also wood ash. The final trees produced may be used for heating water and cooking food. The concept is versatile and uses the forces and mechanisms found in nature.

Trials with *Arborloos* and trees in Kenya and Malawi

Trials in Epworth.

Between 2008 and 2010 *Aquamor* supervised a 3 year study of Ecological Sanitation in Schools supported by the EcoSanRes, a project supervised by SEI, Stockholm, Sweden. This pilot study included the construction of a variety of simple toilets built by the school pupils, the planting of trees around the toilets, the use of urine to increase production of vegetables, maize and trees. Several other aspects were also studies including hygiene and hand washing and simplifying toilet construction methods. Methods of upgrading traditional wells and collecting urine from school urinals were also studied. Woodlots were also planted using urine as a plant food. Much of this work has already been reported in a series of manuals produced under the title of Teaching Ecological Sanitation in Schools. (*Peter Morgan and Annie Kanyemba).* The schools study ended in December 2010, but the work is still being undertaken by the staff of the school. A large amount of basic research has also been undertaken at the school, and in the surrounding environment (the schools outreach program). Various other reports, manuals and power points describe this work.

The story of the trees in the Epworth study

Large numbers of trees were planted around toilet structures in Epworth and also a woodlot was planted in the Chisungu school grounds. These were mostly gum trees (*Eucalyptus grandis* and *E. tereticornis*) and also mulberry. Whilst the gum tree does not rank highly on the tree specialists' category, it has many uses. These include fuel and construction. The growth is rapid and the tree can be coppiced up to 5 or 6 times. Once mature it can provide valuable fuel for cooking. It responds to urine treatment very well and is very tolerant of high nutrients levels when planted next to unlined pits filled with raw excreta. There is also a distinct possibility that its tolerance of high nutrient levels and its ability with withdraw water and liquors from high water table areas may have a positive effect on reducing the effect of underground water pollution caused by pit toilets in shallow ground water areas, The mulberry has also been used also responds well to diluted urine treatment and grows well near to toilet pits. The banana has also been used in trials and responds well to urine treatment. The Australian Red Cedar, *Cedrela Toona* has also been tried. This tree is commonly grown in Zimbabwe.

Planting single trees near shallow eco-pit toilets

Experiments were carried out in my backyard and also in Epworth at the Chisungu Primary school using a method where the trees were planted in pits or drilled holes next to a toilet.

Single trees grown next to toilet in the school grounds



A hole is drilled with an earth auger about 1m away from the toilet pit. It is filled with rich well composted soil. The tree can be planted when it is very young, but it is often best to grow the tree first in a bucket so it gains strength and produces a strong root system. Then it is transplanted at the head of the drilled hole. In this case diluted urine was added occasionally to the soil around the tree. The mulberry is a delicious fruit filled with vitamins. Here it grows next to a simple Blair VIP.

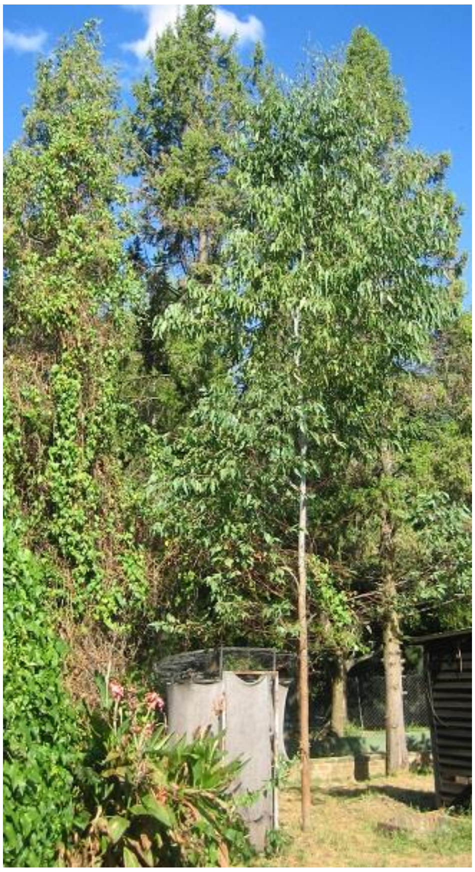
The effect of urine on tree growth.

The growth of most trees planted around or near toilets in this study was accelerated by the application of diluted urine. Thus a combination of urine application and the roots tapping nutrients from the pit was taking place. Earlier back yard trials had established that urine could have a significant effect of the growth of gum trees as described below.

1. Effect of urine on gum tree *Eucalyptus grandis*


Gum trees planted in two 10 litre buckets on the 20th March 2009. One of the trees was fed 125mls urine + 275mls water (400mls) with extra watering once a week after the trees had become established. Right photo on 19th April 2009.

Effect of urine treatment becomes more apparent. Left photo 6th May 2009 and right photo 30th August 2009.



Left: Gum trees growing near brick lined *Arborloo* in Epworth 2010. Right: Gum tree near *Arborloo* at the Friend Animal Foundation. Harare. Note considerable growth of trees, a combination of toilet compost below ground and diluted urine treatment above ground.

Toilets and banana

The banana is perhaps the most commonly used fruit tree which is used to recycle human excreta in traditional practice within Eastern and Southern Africa. Most commonly placed on used and abandoned toilet pits, it is also planted around soakaways attached to septic tanks. It freely accepts a high concentration of nutrients present in human excreta.

Valuable trees in recycling human excreta also include the gum tree, the mango, paw-paw and avocado. Citrus trees are less tolerant but popular nonetheless in countries like Malawi, Kenya and elsewhere.

Banana growing vigorously – at end of a pump water run off fed by urine and near a BVIP (tank version) each showing vigorous growth linked to feeding from human excreta.

Bananas planted on *Arborloo* pits in Malawi

Planting a woodlot of gum trees and accelerating the growth with diluted urine

The rapid growth rate of gum trees treated with diluted urine weekly, in both the school and the outreach environments provided sufficient evidence for extending this concept to woodlots. Fuel is in short supply in Epworth, as it is in most parts of Zimbabwe and an effective and simple method of growing more timber, using excreta as a source of nutrients seemed like a viable and practical concept. Many species of gum trees are available for this type of work. The project had used the fast growing *Eucalyptus grandis* in its first trials. This had proved very successful. However another fast growing and drought resistant species *Eucalyptus tereticornis* was more easily available at the time of planting and was chosen. Whilst gum trees are known to take up large amounts of water from the soil, they are valuable in many ways – not least for building and for fuel.

School staff chose the most suitable site for planting and holes were drilled with the 170mm diameter earth auger used to drill other holes for trees. Holes were drilled 0.6m deep and 1.5m apart.


The earth auger fills up with soil and this is removed after each filling and placed back in the hole to drill deeper. Soil is removed by knocking the auger with a bar to loosen the soil then emptying by hand or with a stick. Each hole is filled with rich soil or a mix of compost and excavated soil. This helps the plant roots penetrate more quickly into the soil.

Tree planting, urine application and watering

Each tree is carefully taken out of its planting bag and placed in a hole made in the soil within the drilled hole. The soil is pressed down around the tree. The tree is thoroughly watered. It is a good idea to place a "mulch" of leaves or grass over the soil around the tree to reduce the loss of water by evaporation after watering.

The trees are watered regularly if there is no rain. Gum trees in woodlots like all other planted trees are best planted during the rainy season, especially if sources of water are distant or scarce. In this case water is taken from the school well, fitted with a hand pump. Urine application starts about 2 weeks after planting to allow the trees to establish.

In this trial urine was collected from a urine tank connected to the boys urinal. A modified plastic "Blair pump" is used to pump out the urine. Large amounts of urine can be collected from the tank and one of the best ways of using this is to dilute it with water and feed trees. Urine is diluted with water before being applied to the trees. 2 litres of water are diluted with 8 litres of water in 10 or 12 litre bucket or watering can. This is a 4:1 dilution and is enough to treat two trees. Thus each tree is given one litre of urine. The urine is applied once a week. After the urine has been applied each tree is given a further 5 litres of water.



Liberal watering helps a lot in the first few weeks and in the dry season of the first year. Later the trees formed a healthy woodlot at the school.

The Toilet and the Tree







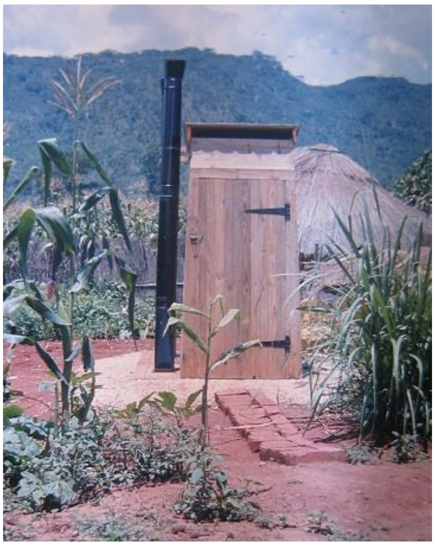


Trees are wondrous living things of immense value and beauty. Trees can provide benefits like an income in cash, fuel, fruit or building material. Trees benefit the health of our planet. And trees have time. Amongst their numbers are the oldest living things on Earth.

The Blair VIP and its variants

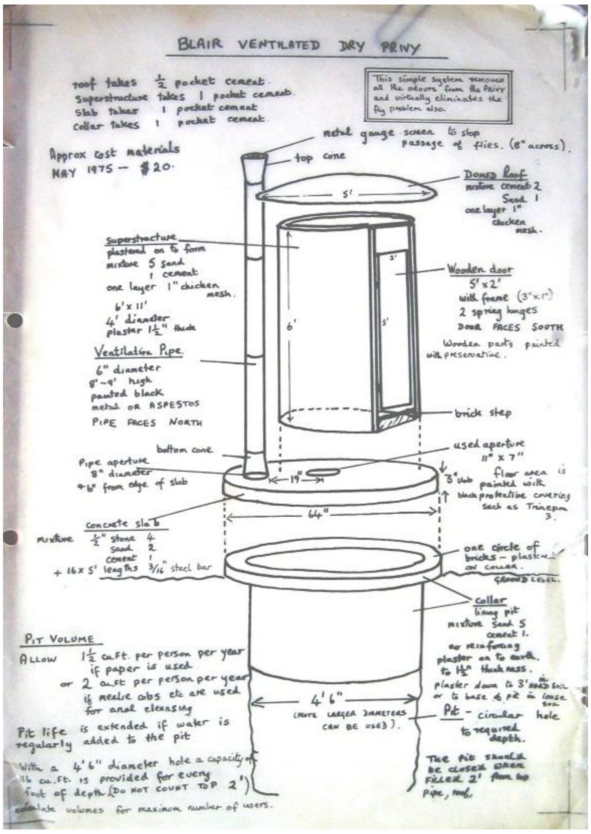
The early history of the Blair toilet has been described briefly in the introductory chapter to this section of the book and a huge amount of addition data is available on the DVD which accompanies this book or on the website. The BVIP toilet, as it became known, and its variants was also well described in my earlier book of 2016. The BVIP was also fully described in my first book also called Rural Water Supplies and Sanitation published by MacMillan in 1990. So there is little need to repeat these writings here.

However some of the developments of this toilet system were first developed in the back yard and subsequently tried in the field. Some of the early fly trapping equipment used in the early 1970's to test the output of flies were built at home, and even tested with vent pipes as fly traps. But most of the further development of this toilet system evolved at the Henderson Research Station in the early 1970's.



In early experiments the lower part of the vent pipe was fitted with a perspex window.

Fly traps were also fitted to the tops of vent pipes. The photos show early experimental Blair toilets built at Henderson Research Station during the early 1970's. Fly behaviour and toilet design were studied in detail during this period.



Fly control expts at Henderson. The photo show my assistant and later Field Officer, the late Ephraim Chimbunde at work with the fly trap. In 1975 the drawing on the right was made.

By 1975, the MoH had accepted the system and by 1976 the spiral version had been perfected and was made using a corrugated iron mould to form the ferro-cement superstructure. These early "Blair's" were fitted with a huge mass produced asbestos vent pipe 6 inches in diameter with a coned upper section. Some were still used and working 30 years later. Some toilets were fitted with pedestals. Once this early standard design had been perfected it was built in thousands before 1980.

The photo on the left of an early spiral Blair toilet was taken at Henderson in 1976. The photo in the middle was taken of the same toilet in 2010, over 30 years later and still working. The photo on the right was taken in 2010 and still working in 2010. It was also built in 1976. It was fitted with a pedestal.

Experiments with fly control

In a series of controlled experiments carried out at Chikurubi, 2 pit toilets fitted with screened vent pipes were compared with 2 pit toilets without vent pipes. All four toilets were identical apart from the presence or absence of a vent pipe. They were used for 6 months prior to the experiment. From October to December 1975 weekly counts of fly output were taken from one pair of toilets (vented and unvented) whilst the other pair were in use. The traps over the squat holes were moved from one pair of toilets to the other pair at monthly intervals. The following fly counts were made and reveal how effective at controlling flies the screened vent pipes were. It should be noted that during the brief counting period from October to December 1975 nearly 14,000 flies were trapped in the pair of unvented toilets - 7000 per toilet. Further fly counting experiments in Henderson revealed that most flies were released from December to March, during the main rainy period in any year.

Trapping period	No. flies trapped in unvented toilets	No. flies trapped in vented toilets
Oct.8. to Nov.5.1975	1723	5
Nov.5 to Dec.3.1975	5742	20
Dec.3 to Dec 24.1975	6488	121
Total	13,953	146

Blair Toilets fitted at the Henderson Primary School, benefitted from this new design. Before the toilets were fitted pupils could not work outside the school classrooms due to the abundance of flies in the environment. After ventilated toilets were fitted for the teachers and students significant drops in the number of flies in the enviroment were noticed and students could play and study in the school grounds without fly nuicance.

The period after Independence in 1980

After 1980, the work on the Blair toilet continued. At this time it was not known how the model which had been the standard could be introduced into the rural program which was now being funded largely by donors through the departments of government.

As a result a range of experimental Blair toilets were designed at various costs. These included simple toilets built using traditional materials and sometimes weird vent pipes.

Two low cost Blair toilets

At the top of the range a series of all brick Blair toilets were built some fitted with asbestos pipes and others with brick chimneys. The brick chimney idea dominated since most of the materials (like bricks and sand) were available in the rural areas. Both round and square spiral structures were designed. The brick pipe was not as efficient as the original tubular pipes but could be built locally. Initially PVC coated fibreglass screens were used on the vent pipe, and later stainless steel followed by cheaper but effective aluminium screens. The screens had to be corrosion resistant, as the gasses coming up the pipe were very corrosive. Hundreds of thousands of these units were built in family homesteads and a popular feature was the use of these toilets, which were virtually odourless and fly free as bathrooms. This program is described on the DVD and on the website.

The round and square spiral design built by families with government and donor support during the first two decades after 1980.

Multi-compartment school toilets

The multicompartment school Blair toilet was also designed at Henderson Research Station, initially as single units, which were then combined into a single unit. Each pit had to be aerodynamically separated from the next. Many of these structure are in use to the present day. The concept of the Blair toilet was also encorporated into the school curriculum and became well know country wide.

Many thousands of multi-compartment Blair toilets have been built coutry wide in Zimbabwe. Many are fitted with hand washing tanks. Hygiene after toilet use has always considered to be most important.

Further developments of the Blair VIP toilet – 2009-2019

With the demise of the national rural water supply programe after 2000 something had to be done, as donor support was reduced, especially for family units. During this period until 2010 I was involved with the study of ecological sanitation, supported by the Swedes. It was clear some revisions had to be made to the way the BVIP was built at much less cost. This work started in 2009 and after 2010 all the developments were self funded without research funding. This has remained the case till the present day in 2020.

Lowering the cost of the Blair VIP toilet.

Pit corbelling and smaller slab (2009)

This work was deemed necessary as the national sanitation program had shown signs of collapsing since 2000, when many donors who supported the programe left Zimbabwe. Also the concept of funding family facilities was fast loosing appeal amongst the donors and the government did not have the resources to fund such programs. Many lower cost models had been designed before, but these were generally temporary structures. In 2009 I started work on revising the design so the BVIP so it could be built in stages at much lower cost. I called it the upgradeable or uBVIP. This work was carried out in my garden.

This work was based on being able to line a pit with bricks and make a slab with a single bag of Portand cement. The technique chosen consisted of making a brick lined pit which was corbelled, that is narrowing in at the top. This meant that a smaller concrete stab could be made and fitted on the top of a lined pit. The standard BVIP slab has been 1.5m in diameter. The new slabs were either 1.1m or 1.2m in diameter and used much less cement (between 10li and 12li). Thus there was a saving of cement. Also experiments were tried using a much weaker mix of pit sand and Portland cement to mortar the brick work together. The pit was shallower (2m), but wider at the bottom than at the top and had almost the same capacity of the original Blair pit, as it had evolved which had been 3m deep. Over the years the pit volume of the standard BVIP had also been reduced to save costs by reducing the diameter of the pit, and thus its working life time. The pit structure and slab lined in this way in 2009 is still stable and working over 10 years later in 2020. The mortar mix appears to be weak, but time has shown that it works when applied in this application.

The first corbelled BVIP pit structure

A hole was dug with a diameter of 1.75m to a depth of 2 metres. This pit was then lined with bricks so the internal diameter at the bottom was 1.5 metres. At this diameter about 19 -20 standard bricks are required per course and 12 courses are required for each metre of depth. Thus approximately 240 bricks are required to line each metre of pit depth. The internal diameter of the pit lining is maintained at 1.5m up to 1.3m from the base of the pit. Then the corbelling begins. The diameter is reduced as extra courses are added. Corbelling from an external diameter of 1.75m to an external diameter of 1.1m takes about 10 courses to achieve which is around 0.85 m of height. 0.7m of this is below ground level and an extra 0.15m can be above ground level. Each course of bricks is stepped in by around 25mm. About 500 brick should be allowed for this type of lining. Using a 20:1 mix of pit sand and Portland cement mix, a single 50kg bag of cement should be sufficient to make cement mortar (30 litres) to line the entire pit and also make a 1.1m diameter slab (10 litres). Fired bricks should always be used to line toilet pits.

Stages of construction of the brick lined corbelled pit


The hole for the Blair VIP is dug 1.75m in diameter and 2+m deep. If one bag of Portland cement is to be used for making mortar for bonding the bricks in the pit lining and making the slab, the pit is dug down to 2m depth. The pit is lined with cement mortared fired bricks using a mortar mix of 20 parts pit sand to 1 part cement. The cement can be mixed inside the pit.


The diameter of 1.5m internal is maintained until the brickwork is 0.7m from ground level. Then the brickwork is stepped in about 25mm per course so the diameter is reduced as the pit lining gets higher.


The corbelling continues until the brickwork is above ground level and reduced in diameter so it can support the concrete slab. Where the 1.2m diameter slab is used the external diameter of the brickwork should be 1.2m. The number of bricks used is reduced by about half a brick per course.

The space between the brickwork and pit wall is backfilled with soil from the excavation. A very weak cement mortar can be used for brick work mortaring in this case because the conditions for mortar curing are ideal. The slab is fitted on top of the brickwork as soon as the backfilling has been completed. The slab is mounted on a bed of very weak cement mortar placed on top of the upper ring of bricks. Thus the mortar is not exposed to the direct sun and cures slowly under ground level. This curing process is also aided by wetting the bricks before they are used for building the brick wall.

Some practice may be required with the corbelling technique. And some calculation is required to get the right point of starting the "stepping in" process. The upper course of brickwork should have an outer diameter the same as the slab, which is 1.1m in diameter.

Views of the corbelling from inside the pit. This is a valuable technique which had seldom been used to line toilet pits but has several advantages. The pits and their linings must be round to provide the structural strength using this technique.

The brick work should rise at least one brick course above ground level. In this case it rose several courses above ground level with soil excavated from the pit being used to backfill the annular space between brickwork and original pit excavation and also to build up soil around the raised brick work. The concrete slab is fitted directly to the brick pit lining. However because the slabs are rarely completely flat, they are placed in a bed of weak mortar placed on top of the brickwork. This also ensures an airtight fit between slab and pit brickwork which is essential for the aerodynamics of ventilation in VIP toilets. There must be no air leaks at the joint.

The upgradeable Blair VIP (uBVIP) - (2011)

This technique was tried in the field after 2009 and since 2011 forms the basis on what became known as the upgradeable BlairVIP (uBVIP). The method uses about 500 bricks, pit and river sand, some wire for reinforcing the slab and a single bag of Portland cement. As it turns out only the poorest or most vulnerable families are given a bag of cement as a material subsidy and are trained by various NGOs and Health Clubs in the technique and supported by surrounding villagers.

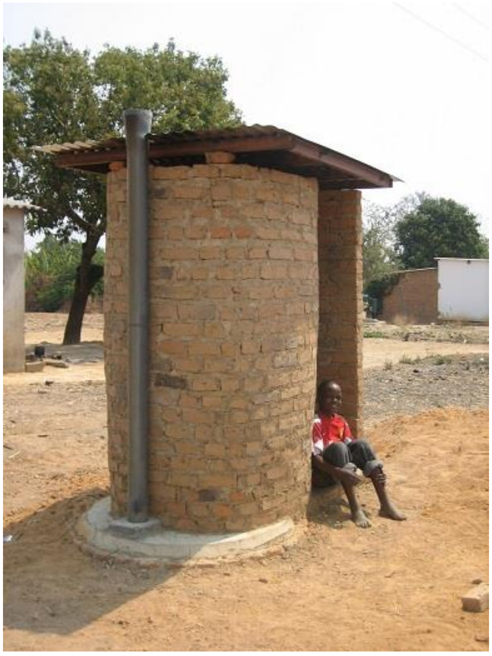
The unit, which initially consists of a brick lined pit capped by a versatile concrete slab (with provision for a squat and 110mm vent hole – intended for a 110mm PVC pipe), requires the use of a single bag of Portland cement and fired bricks for its construction. This is the starting point of an upgradeable series of toilet technologies which can lead to the construction of a standard brick BVIP. Once the pit has been dug, lined and capped with a concrete slab, the owner is responsible for the construction of the superstructure which it can afford and suits its requirements. A step by step process of toilet upgrading and improvement is possible.




The stages: dig and line the pit, make the slab, make a simple superstructure or make the Blair BVIP direct. The type of structure depends on what the owner can afford.

The toilet ascends up a sanitation ladder which can lead to the standardized brick BVIP. This means that the initial cost is low, but a range of upgradeable structures can be built on top of the pit. Various methods of recycling the organic and constructional components of this unit are also possible. Various manuals related to this and also the construction of the standard BVIP are available on the DVD or website. The acceptance of this new approach in Zimbabwe is a bold new move to make sanitation technology more flexible and sustainable with the aim of attaining a much broader coverage for a wide range of recipients. Structures can range from low cost to medium cost to high cost.

Types of toilet in the range of options



Economy brick BVIP structures

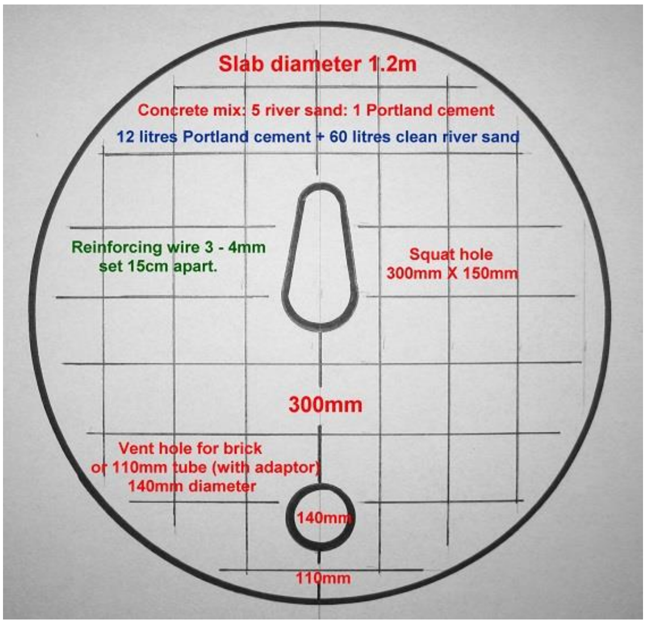
Standardised BVIP structures can all be built on the standard pit structure and slab

Stages of construction in brief

Stage 1. Dig the pit

The pit is dug 1.7m wide and 2m deep. Walls are straight and bottom flat

Stage 2. Making the concrete slab

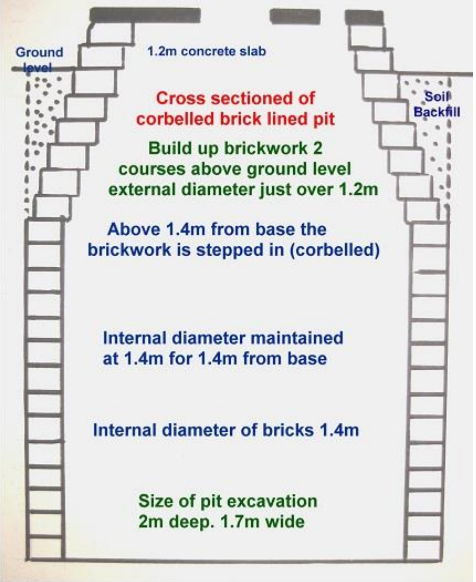


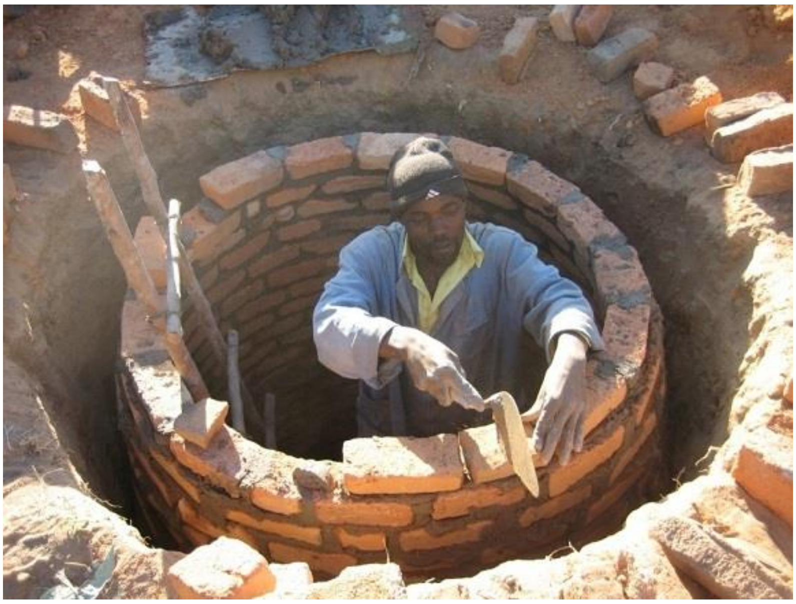
Dimensions of the 1.2m diameter concrete slab

Making the concrete slab for the uBVIP. Half the concrete mix is added first. Then the wire reinforcing (about 14m) is added in a grid formation. Then the remainder of the concrete is added and smoothed down flat. The slab should be around 50mm thick. It is left to harden overnight and then watered daily under a plastic sheet for at least a week before being moved.

Stage 3. Line with pit with bricks

A technique known as corbelling is used where the upper courses of brickwork are stepped in, so the diameter of the pit is reduced nearer the top of the pit. This allows a large diameter pit to be used together with a smaller concrete slab which fits over the pit. The pit is shallower (2m) and wider (1.4m internal) compared to earlier Blair VIP pits (3m X 1.1m) which makes it easier and faster to build, whilst keeping the close to the same pit volume as earlier BVIP pits.



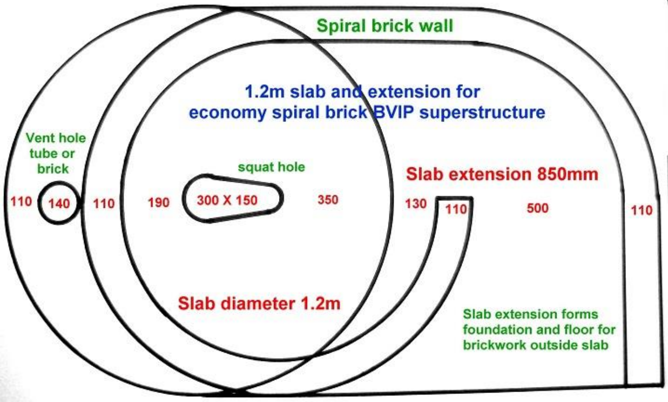


Cross section of lined pit. 20 parts of pit sand (100 litres) and 1 part Portland cement (5 litres) are thoroughly mixed first and then water added to make the mortar mix. About 5 mixes (25 litres) are required to mortar all the bricks. The mortar is laid thin between bricks


The space between pit wall and brickwork is filled in with soil and rammed hard. The 1.2m diameter slab is carefully raised and washed and then rolled on to site. A bed of weak (20:1) cement mortar is laid on the brickwork, so that the slab can be bedded in it. The slab must be level. The slab is lowered down on to the brick work in the correct orientation that will suit the structure. The slab is made level by adding small stones under the slab where it is low and filling with cement mortar. This forms the starting point on top of which a large number of superstructures can be built, from the ultra-low cost to the standard BVIP. When built in bricks, this becomes the new standard of construction of the BVIP.

Building an economical spiral brick superstructure

In order to economise on bricks and make the construction easier and faster, the orientation of the slab within the structure has been changed. The vent can be made with bricks or a 110mm PVC tube. The roof area is also smaller. The unit has been specifically designed so that it can be built and taken apart more easily than the original BVIP. In other words the parts can be recycled. The original pit as described in early manuals will take 10 or more years to fill, in a family situation, especially if garbage is not thrown down the pit. Once filled, the pit can be abandoned or used to grow trees, and a new pit dug and lined at minimal cost. The slab, roof, pipe, and even bricks can be taken apart and rebuilt on the new pit. After some years, and if left, the contents of the original pit can be dug out, but a more effective method may be to recycle pit nutrients by planting trees on the old pit. The pit contents will decompose faster if soil and some leaves are added to the pit periodically, by ramming with a pole.



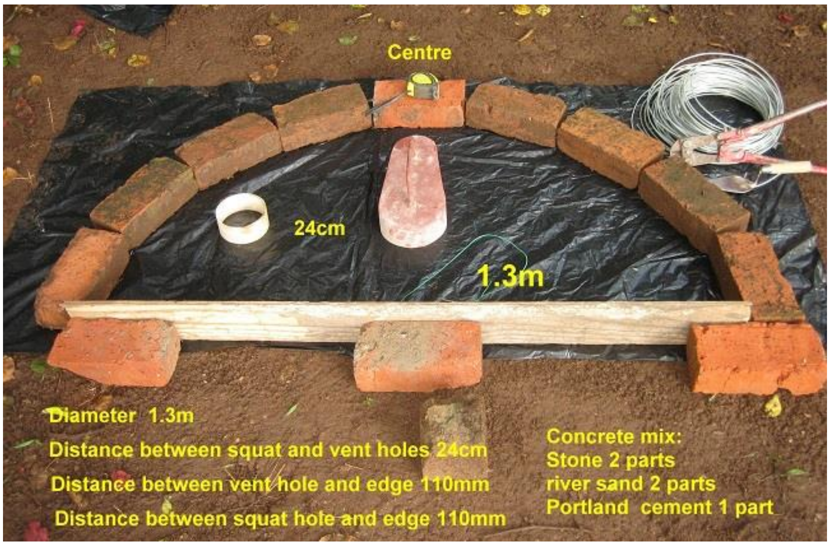
An extension to the slab is made in brick and mortar as shown

The structure is spiral with a 110mm PVC vent pipe and a roof made of corrugated tin sheet mounted on a treated wooden frame.

The Blair VIP with removable slab (2012/2013)

One great disadvantage of all pit toilets, whether they are ventilated or not is that the pit fills up. The rate of filling depends on many factors which includes the number of users and what other items, including garbage are added to the pit – it serves as a useful underground dustbin. A standard Blair VIP when used by a family normally lasted for between 10 and 15 years. Some for longer, some shorter. So it was inevitable that all the Blair toilets built during the great expansion of toilet building in the rural areas would fill up. Most during that era have filled up.

In view of this inevitability work was started on the design and constriction of a Blair toilet that could be more easily emptied. This work was undertaken in Epworth, near Harare in 2012. If a pit is to be empted with a standard Blair toilet, the entire superstructure and slab must be removed to gain access to the pit. This is not an easy task. Consequently a variant of the design was built in which the toilet slab was made in two parts, each being shaped like a half moon. The superstrcture was built on one half, leaving the second half to be free for uplifting and removing and then gaining access to the pit beneath. Removing material from the pit is a very messy business and can be undertaken only by those who do this as part of their normal work. Such people were available in Epworth. Also consideration had to be given to what to do with the foul smelling material taken out of the pit. Various methods were tried and are described in the DVD and on the website. They include converting the material in large shallow pits by adding the material to the pit and refilling and mixing with the excavated soil. This resulted in a drop in volume of the material and also producing a product that was manageable and could be placed into sacks and then tranpsorting to woodlots or orchards found in schools and on larger plots. The DVD and website describes the work in detail and also methods of processing the material removed from the pit and how to use it in woodlots and orchards after processing.



The first prototype of this type of BVIP built at the Chisungu Primary School in Epworth.


Half of the concrete mix is added first, then the reinforcing wires followed by remaining mix to make a final depth of about 60mm. One slab is made with holes for the squat hole and pipe and the other slab is made with no holes in it. Since each slab is half-moon shaped and not circular a thicker steel rod is added within the concrete along the straight side of each stab to increase strength. The superstructure is built over the slab with holes in it and the solid slab with no holes can be removed from the pit.


Adding the two halves of the slab to the pit lining, which has been described in an earlier part of this chapter.

Preparing to build the spiral superstructure


Foundations are made, extending from the slab so that the normal spiral superstructure can be built.


The interior of the toilet. The vent pipe, which is now inside the structure, does not interfere with the use of the toilet. The floor is finally sloped in strong mortar to all wash water to drain into the squat hole. Since the superstructure does not sit on the exposed half of the slab, it can be removed to gain access to the pit.


The PVC vent pipe is placed inside the structure of this type of BVIP. The brickwork is built up to the required level and a corrugated iron roof is made with a hole in it for the pipe. Three of these units were built in Epworth during the study. And various methods were used to recycle the contents of the pit. In this case the pit was built from new, but in the other two cases, new slabs were built and mounted on existing full pits, where the pit contents had been removed.


The same principle used on a square spiral BVIP with removable slab.

Blair VIP using a floating foundation principle

An experiment as a means of lowering the costs - 2015

Blair VIP's mounted on wide ring beams and not lined pits

Whilst the work on the removable slab was being undertaken, I heard that the uBVIP was getting some problems in some areas, because even fired bricks were not available at many sites to line the pits. This principle was built upon the idea that if a brick lined pit covered with a suitable concrete slab could be built, using a single bag of Portland cement, and the following superstructure was optional depending on what the family could afford, this could assist in increasing the number of households in the rural areas with basic units which could be upgraded over time. But I heard that many pits were being lined either with rocks or with very poor quality bricks which could crumble. And pits which were being lined with hard won rocks would have a very small capacity. This was worrying.

Then I thought of the *Arborloo*, a toilet without a pit lining, but a shallow pit, only one metre deep, which would last a year and then the slab and superstructure could be moved to a new site and a tree planted on soil placed above the pit contents. This method has proved popular in several countries in Africa and elsewhere in the developing world. The concept was Zimbabwean in origin, I had worked on it myself and it had been tested in Zimbabwe with success. But the concept has never taken route in Zimbabwe.

However, and once again on a private basis, I decided to try the method out in the back yard and also in Epworth, where the ring beam was widened and a one metre diameter hole placed within the ring beam and dug down 2m deep. The experiment in Epworth was a gamble, as the soils are sandy. In 2015 I built a prototype in the garden and then copied this at a site in Epworth. To make the gamble larger, I chose to build a fully brick spiral superstructure on this expanded concrete ring beam to see how long it would last and what effect the rains would have on the construction.

The theory was based on the fact that the load of a structure on any part of a foundation is lighter, if the foundation is larger. I thought that if the load on the ring beam could be reduced for every square metre or part of a square meter then the structure might hold up for the length of life of the pit, and then like the *Arborloo*, the structure could be dismantled and the slab removed and a new ring beam made and the same components and slab placed on the new ring beam nearby. Once again a tree could be planted on the used pit, or it could be left to compost on its own and then be dug out again later. The theory might work well on soils which were more durable and less prone to collapse. Unlined pit collapse can occur both at the bottom of the pit, if the contents are wet and at the top, especially outside the beam if is not surrounded by soil built up around it.

Trials in the back yard

An experimental unit was built in the backyard designed in 2015 to take a fully brick spiral superstructure**.**

The brick mould to cast the wide ring beam. The bricks inside will leave a hole 1m in diameter and the width of the beam at its narrowest is 30cm. The mould is filled with a 5:1 mix of clean river sand and Portland cement, covered and left to cure. Once hardened it is kept wet.

Once cured the pit is dug down to the required depth. 2m being the maximum in the later trial in Epworth. The excavated soil is laid around the wide ring beam to reduce erosion around the concrete. A 1.1m diameter slab is then cast with squat and vent holes laid in it. A full description can be found on the DVD or on the website.

The slab, once cured is placed on top of the wide ring beam foundation, made level and cemented in place. The right photo shows the configuration of bricks for a spiral structure laid on the ring beam.

Trial in Epworth

This work was repeated in Epworth and a full brick structure built on it and a 2m deep hole was dug down for the pit. The unit was then used as a toilet.

The experimental unit built in Epworth with a fully brick structure on sandy soil

This unit survived for 2 rainy seasons, without showing signs of any subsidence. However when the tenants of the property changed, the unit was vandalised, the roof and bricks removed. Thus it is not known for how long the ring beam would have supported the brick structure on this sandy substrate. The support provided by the soil under the ring beam will depend a great deal on the type of soil. Red soil will be more supportive than sandy soil. There are reports that brick BVIP's built over firm soils have remained standing for the full length of the pits life without fully lined pits and on ring beams, But the writers has not seen these. Certainly if the soil is hard and less vulnerable to erosion, then the method may well be cheaper to build than the standard structure with a brick lined pit. As a result another model was built in my backyard, to further test the concept.

Further trials in 2018 in garden experiments

In this case a large ring beam as a supporting platform was cast and used to support a self-closing doored superstructure with bricks built on edge to make it lighter. The unit could be seen as a type of hybrid between a BVIP and an *Arborloo*, although the superstructure in this case was made of bricks. In fact simple brick structures can be dismantled and rebuilt within a day, a trial which has been demonstrated in Epworth. However many types of superstructure are possible with this technique.

The unit could be described as variant of the *Arborloo* or a variant of the BVIP and could be called a ventilated *Arborloo.* The unit uses a wide "ring beam," acting like a floating platform, to support the slab and superstructure, like the *Arborloo*, but the slab can be fitted with a vent pipe. The pit is unlined and smaller, but has the advantage in that the whole structure is cheaper to build and also that the surface area of excreta in contact to the soil is much larger and the conversion of the pit contents into which tree roots can grow is much faster. Many of the components of this design can be recycled like the slab, the structure, the roof, the vent pipe and perhaps most importantly the pit contents, since they can convert quite quickly into a medium into which tree roots will grow. The pit can be 2m deep and thus last longer than the *Arborloo* pit.

The main theme is that these concepts when combined can solve two problems – an abundance of exposed pathogenic and harmful human excreta in the environment and a lack of trees. Solving these problems assistants not only in public health and the health of the individual but also in the health of the environment. It uses a process which is entirely natural. Nature performs this conversion as a matter of standard practice and that process can be mimicked by *Homo sapiens*. The toilet and the tree can make a remarkable and valuable partnership, which is described elsewhere in this book. This was never possible with the conventional Blair VIP because the pit was lined with bricks. Soil, leaves and other compostable materials rarely came into contact with the pit contents. Any conversion of pit contents in the conventional BVIP is slow. In this concept the advantages of the VIP are maintained but with the additional benefit of being able to grow trees on filled pits, as part of the process.

Considering the potential of this experimental concept, it was decided to build a new unit which used the same principles – a broad concrete ring beam with an inner diameter of 1m and an outer diameter of outer diameter of 1.6m. Once the concrete was cured, a 2m deep pit could be dig down inside ring beam, 1m in diameter. A ring of bricks was then built up around the central hole on which to place the concrete slab, which was placed on top above the level of the ring beam itself. In this case, a brick structure was then built on top of the ring beam around the slab. The structure was not spiral but horseshoe shaped with a self-closing door. The bricks were built on edge to save on the use of bricks and the weight of the bricks. In fact any structure which offers privacy and semi darkness is suitable. Doors must be self-closing and a roof must be fitted. Pedestals must have a closing lid.

The slab, in the completed toilet can be fitted without a pipe fitted at first, and remain unvented, but can no longer be called a Blair VIP toilet – more like an *Arborloo.* Or the slab can be fitted with low cost vent pipe (a 2.5m – 3m length of thin walled 110mm PVC pipe) fitted with a non-corrosive fly screen like aluminium. If the toilet is fitted with a roof and the interior is semi dark, by either building a spiral door-less structure, or fitting a door with self-closing hinges and the vent is fitted with a fly screen, the toilet becomes a Blair VIP. If a pipe is not fitted, the vent hole in the slab can be covered with a plug.

The structure is optional. It can be made of bricks, a portable steel frame, a steel frame door with sprags fitted, or in grass and poles or reeds. There are many options including those made of termite resistant or treated wood. As in the *Arborloo*, the pit is not lined with bricks, but the structure and slab are stabilised because they sit on top of a broad ring beam made of concrete, and the weight of the slab and structure is distributed. The pit is smaller than a normal BVIP, but the pit is deeper (2m) and thus has more volume than the *Arborloo*. Once again, as in the *Arborloo* some soil, ash and leaves are added to the pit from time to time, but not as regularly as in the *Arborloo*. No rubbish is added to the pit as this can fill the pit fast. When the pit is nearly full, which may take a few years, but is yet not yet fully known, a new ring beam is made and the old slab and structure are moved or rebuilt onto the new concrete ring beam. If the ring beam is made in strong concrete, it may also be moved to a new site. But it is heavy – with an external diameter of about 1.6mm and an internal hole of 1m in diameter.

It is easier to build a new ring beam. Once again, soil is added to the pit contents, at least 15cm deep, and a young tree is planted, preferably during the start of the rainy season. Mulberry is a good starting tree. Alternately the pit contents can be left to decompose naturally and can be dug out eventually. Then a structure can be built on top of it.

In the case described in this book and more fully described on the DVD and manual, bricks have been used to build the structure, but the structure is horse shoe shaped (not spiral) and has a self-closing door with car tyre rubber hinges. The bricks are built on edge. This reduced the weight of the brick structure considerably and the load bearing down on the ring beam. When the structure is built in a spiral shape with bricks laid normally, as many as 420 bricks are used in the structure. When built in the shape of a horseshoe attached to a rigid steel frame, as in this case, the number of bricks used is reduced to about 170. But this is not the only way to build the structure – wooden frames can be built but are less durable. The concept here is simple and cheap and also, like the *Arborloo* can provide something useful when a tree is planted into topsoil placed above the pit contents.

When fitted with a vent pipe without a screen the interior becomes odourless, but will not control flies. When the vent is fitted with a non-corrosive fly screen, the unit also controls fly output, if a roof is fitted and the interior is semi dark inside. The best non corrosive fly screen is made of aluminium. The pit volume in this case is smaller than a normal Blair VIP latrine, and will fill up more quickly. When the slab and structure are moved to a new ring beam and pit nearby, the used pit can be topped up with soil and a tree can be planted as described earlier in this book. But there is also the option of using two ring beams alternately as in the *Fossa alterna* concept. Whether soil, wood ash and leaves are added to the pit or not, the pit contents will eventually turn into a material which can be excavated. In fact since the pit is unlined, a lot of soil comes into direct contact with the excreted material and will have an influence on hastening the conversion. But this conversion process is accelerated if soil, leaves and wood ash are added. In this example the ring beam has been made with a wall depth of 75mm, a diameter of 1.6m and an internal diameter hole for the pit of one metre. The slab diameter is 1.1m. But the ring beam can be made with a larger internal hole of 1.1m using a 1.2m diameter slab.

In the example describes here the main ring beam was made with a mix of 5 parts river sand and one part Portland cement. 28 litres of cement were used and 140 litres of river sand were used. This was made up in batches. Bricks were used as moulds as shown in the photos below. A smaller ring beam of bricks was built around hole formed for the pit to raise the slab a little higher above ground level. This used a very small amount of sand and cement. The 1.1m diameter slab was also made with Portland cement with 10 litres of cement and 50 litres of river sand (5:1). Wire reinforcing was added. The vent pipe hole diameter was 110mm. Thus the ring beam and slab consumed about 38 litres of cement. A 50 kg bag of cement contains at least 40 litres of cement. The brick superstructure was bonded with mortar using a 20:1 mix of pit sand and cement, thus using up most of the remaining cement in the single bag of Portland cement. Good economy indeed. The full description is described in the accompanying DVD.

Photos taken during the construction

Two circles of bricks are laid on level and slightly raised soil. The inner diameter of the outer circle of bricks is 1.6m and the outer diameter of the inner circle of bricks is 1m. Note some weak cement and sand has been made up and inserted into the wedge shaped openings between the bricks of the inner circle. String and nails have been used to mark the inner and outer circle.

The pit is dug down. Not deep in this case as it is a demonstration only, but ideally to 2m. Excavated soil is placed around the outer ring beam to raise the soil level around the beam. The soil is compacted down. Construction of the brick superstructure can now begin.

In this case a steel door frame and door has been welded together using 3mm X 30mm steel strips fitted with steel sprags which fit into the mortar of the brickwork. The outer frame has 6 steel sprags welded to it. These are bonded into the mortar used to build the brick superstructure. The advantage of this method is that once the frame has been made it can be re-used time and time again on a series of toilets, which fill up and are then moved to another site. If the bricks are of good quality they can also be re-used as well as the slab and roof.


The bricks are built on edge using a mortar mix of 20 parts pit sand and one part Portland cement. This may appear weak to the trained builder, but experience over many years has shown that it works very well. It also makes the bricks easy to separate and reuse when the pit has filled and new structure is built. The bricks and mortar must be built in such a way that the sprag enters the cement mortar between brick courses. This structure used 140 bricks and the remains of the cement in the single bag.


A suitable roof is fitted over the superstructure so that it overlaps the brickwork all round. The vent pipe is inserted through a hole cut in the roof material so it fits vertically into the hole in the concrete slab. If a pipe is not used at first, a concrete plug or hole-cover with a wire handle can be made to cover the vent hole. The demonstration was built by the writer and his gardener, not professional builders, so the structure is not perfect. But its shape and attachment to a steel frame ensures its stability. Many types of superstructures could be built on the same ring beam. To conform to the Blair VIP principle, they should be fitted with a roof and offer semi darkness inside to effect fly control.


Various pedestals can be hand made for sitting, but the slab must be made with a suitable round hole cast in it for the pedestal. For older people, sitting is preferred.

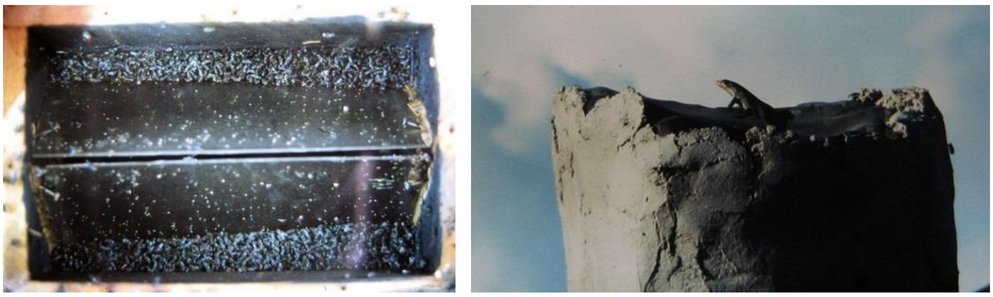
Using natural principles in Blair VIP designs

The Blair VIP latrine is characterised by using a vent pipe which imitates the termite mound turret, drawing air through an underground chamber. The turrets, skilfully built by termites, rise above the underground mounds, and are designed to catch the breeze, thus drawing air up the vent which is replaced by fresh air which enters the mound at some other lower point. Similarly, the vent of the VIP toilet draws out air from the pit – the air inlet being the squat hole or pedestal leaving the toilet house relatively free of odour. Curiously the insect world went further. Spiders weave their webs in VIP vents, in order to catch flies, as a source of food. This habit also reduces the efficiency of venting, and VIP vents need to be flushed down with water periodically to regain the full venting potential. Lizards are also known to sit on the tops of VIP vents to catch a meal. Flies are attracted to the pit odour which rises out of the vent.

The ant turret – the ultimate ventilator. The ant turret principle is copied in the Blair VIP toilet both old, middle aged and new designs.

Fly control

Fly control in the VIP toilet also depends on instinctive fly behaviour. Flies move towards odour on the way into a toilet and towards light on the way out of a toilet. It is well known that flies are attracted to odour emanating from food as well as from excreta, thus making the passage of pathogenic bacteria from one to the other possible. Flies also move towards light when leaving a darkened environment of the Blair VIP. When a vent is fitted over a toilet pit, and the interior of the toilet house is darkened, flies will be attracted to light falling down the pipe. By fitting a corrosion resistant screen at the head of the vent, where odour from the pit is released, flies are prevented from moving into the pit via the vent from above, and are trapped if they rise out of the pit from below. Thus fly control is achieved by using the flies own instincts – a thoroughly natural principle. The fly screen is the barrier.



Early experiments revealed the huge numbers of flies that could be released from unventilated pit toilets. A lizard awaits a meal at the top of the screened vent – knowing that the flies will be attracted there.

Other design concepts of the Blair VIP

Zimbabwe's Blair VIP commonly uses a door-less spiral superstructure, which provides strength as well as guaranteed semi darkness within – an important feature for effective fly control. The spiral, another of Natures achievements, seen in pre-historic fossil ammonites as well as modern snail shells, provides great strength and stability. The spiral brick form is copied directly from the Natural World.


The spiral design is a great achievement of Nature. Its shape provides great strength.

Cones, conical towers and domes

In modern BVIPs, the pit is conical shaped, which provides great strength and reduces the cost of the toilet slab, which is smaller than former designs. Pits are now made wider and shallower, increasing the distance between excreta and ground water tables and also increasing the area over which biological degradation of the faeces matter takes place. The vent provides a free circulation of air to facilitate oxygen feed to the numberless micro biota which accomplish waste break down and degradation through an aerobic biological process within the pit. Modern Blair VIP toilets are built upon corbelled brick pit linings, which have great strength, even when bonded with weak cement mortar.



The egg owes its great strength to its shape. Ancient domed roofs use the same principle and the conican tower of Great Zimbabwe owes its strength to the conical shape of the structure.



Modern Blair VIPs are built with a conical (corbelled) brick pit lining which gives the pit lining great strength.

My involvement in rural water supplies

When Dr Dyson Blair encouraged me in 1973 to look at technical methods of reducing the passage of disease carrying organisms by technical means, he meant a combination of sanitation, water supplies and hygiene. In this book we have looked at the various developments in sanitation covering a long period from 1973 to the present in 2020. However the development of new techniques for rural water supplies was also being studied during the same era and is still being studied now in 2020 in my retirement! It is fitting to describe these in this book, since, whilst not an engineer, I seem to have a natural affinity with technical gadgets which has enabled me to develop or improve upon several approaches, some of them novel, to the world of water supply. I shall describe some of these briefly in order of their discovery and development.

The Blair Pump

Looking back, my first development was a simple hand pump which became known as the Blair Pump, named again after my mentor Dr Dyson Blair. The first ever working model was thought out and built in Keep 5, Madziwa in 1976. I was on duty looking after this "keep" as part of my paramilitary duties as a "Vadette" working for "Internal Affairs under the jurisdiction of the local District Commissioner. This period between 1976 and 2000 was a very tense and threatening period in our lives and it corresponded with the last part of the war of Independence for Zimbabwe. I looked after several keeps during this period including the notorious Mukumbura on the border with Zambia. I also worked in other keeps including Chiweshe and Dodito. I also became a medic during this period and attended to many severe cases mainly the result of land mine explosions and also trained our men in emergency war first aid, often using rather real looking but artificially made wounds. During this era many Blair Latrines were also built inside the keeps, as well as on commercial farms.

Now back to the Blair Pump. Like Tommy Murgatroyd who was the first man to develop the Bush Pump, known as the Murgatroyd pump in 1933, I had a curiosity from making things taken from scrap heaps. This is true for the Blair pump. Although the "keeps" were equipped with boreholes, storage tanks and taps and thus required power, the ground water in many keeps was shallow. Using parts I found on the heaps, together with a few parts the staff of the District Commissioner brought me, a new type of hand pump was built, which is shown in the pictures below. It appeared to be a novel design and later searches through libraries and written works on the subject revealed no similar principle. It compressed water between a piston valve and a foot valve and water came up the hollow steel handle to the surface through a tee junction. I further developed the idea in the garden using PVC pipes and a PVC piston. It was a very strong pump with a 90mm class 16 rising main and could deliver water from up to 6m. These pumps were hand built and my team at Blair built them and installed one at Henderson and also in several other places including Epworth. It seemed to work well for shallow wells. The water came out by force and could be fitted to a hose pipe for watering gardens. Later I developed smaller and cheaper pumps using the same principle. It was intended as a home-made, do it yourself concept. And details of its construction have been well distributed.

In the early 1980's it was mass produced by the PVC manufacturer Prodorite and was used country wide by the Ministry of Health, for use on shallow wells on a family basis, although many were used by several families in combination and where the water table suited (down to 12m). 200 Blair Pumps were also used in a large program in Epworth to reduce the risks of water born disease after an outbreak of cholera. In a community setting and often heavily used, they lasted for up to 5 years continuous use.

The Blair Pump was also used in Zambia and the concept has been copied widely in several countries throughout the developing world. I still use a high delivery Blair pump almost every day to provide water for drinking and for our kitchen. Details of the Blair Pump can be found on the DVD and on our website.

Photos of the Blair Pump

Early heavy duty hand-made model

The commecial model at Epworth and the high delivery model at my home. Details of these pumps and how they work can be found on the DVD and on the website.

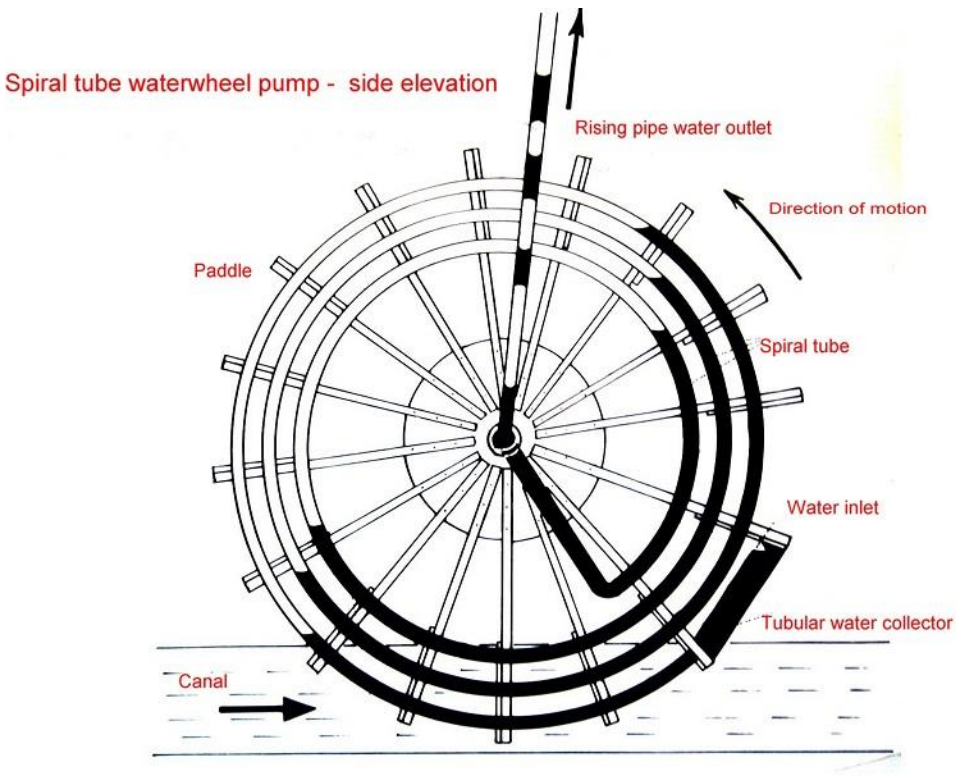
The Spiral Tube Waterwheel Pump

Along with the Blair toilet, home-made windmills, swing pumps, water filters and other contraptions we built at the Henderson Research Station during the period between 1973 and 1980. One was called a Spiral Tube Water Wheel Pump. Like the Blair Pump, I found no similar type of system in the literature. Both were thought out inside my head!! Accounts of both discoveries were published in the Science News, a journal of the Rhodesia and then the Zimbabwe Scientific Association.

The pump consists of a spiral tube fitted to a water wheel, which rotates in a canal, stream or river. The spiral tube, or 2 spiral tubes fitted to the wheel rotate as a results of moving water on the paddles and the spiral tube picks up gulps of water followed by gulps of air. These are transferred to the axle of the pump and rise up a vertical pipe to a storage tank above the level of the canal or river. There are no valves. Initially a 1m diameter wheel was built and tested at Henderson, and then a large 4m diameter wheel was built on the Mazowe canal at the Mazowe citrus estate. It worked for years and was able to pump 3697 litres of water up to a tank 8m above the canal per hour. Details of this equipment can be found on the DVD or the website.


The one metre water wheel pump at Henderson 1979


The 4m wheel upright and spiral tube fitted in 1979. About 35 meters of 50mm polyethylene pipe were coiled on each side of the pump. The pipes were threaded through holes made in the paddles. The two water collectors were made of 150mm PVC pipe, each about one metre long. The ends of the innermost coils were connected to the axle through polyethylene elbows.



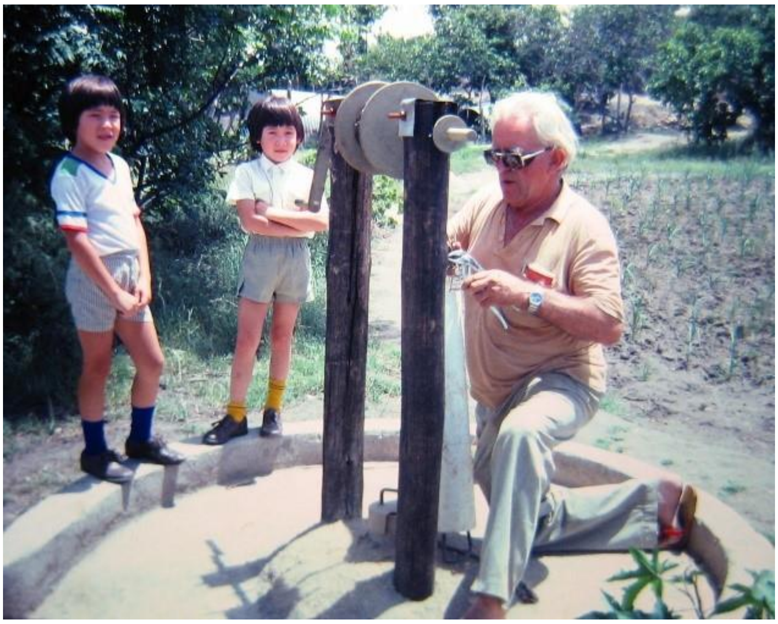
How it works


The writer and his pump in 1979. On the right a photo taken from the 8m tower looking down on the pump. The principle was first discovered by a Mr A Wirtz and his invention of 1746, but appears to have been lost to science. This work drew attention back to this novel concept.

The Bucket pump

We worked in Epworth, a suburb of Harare, a great deal and in many ways had similar characteristics of some rural areas. People used simple latrines and family wells as a means of providing sanitation and water. It was valuable as a research site, like Henderson before it, as it was relatively close to town. Later the area would prove invaluable in the studies relating to the upgrading of family wells and also to the development of the B type Bush Pump. In the early 1980's we had worked together with Prodorite in the development of a mass produced Blair pump. And we had also made our own hand drilling equipment to make tube wells. We were helped along after this endeavour in our own workshop with the workshops of Prodorite who had better welding equipment than our laboratory. They had made a better earth auger and we drilled a few tube wells in Epworth. Since a normal bucket could not go down a tube well, we also developed a bucket in the shape of a tube called a bucket pump. It has a valve at the bottom and could be lowered down a tube well on a rope and raised again. The bucket was made of PVC and they were raised and lowered without a windlass at first, but later with a windlass. A while later Mr Von Elling of V&W Engineering, saw the rather crude hand drilling rig at Prodorite and made links with Ephraim Chimbunde, as I was away at the time in Holland. Mr von, as we called him, made a much more sophisticated hand drilling rig called the Vonder Rig and this was used a great deal in many parts the country and eventually elsewhere in Africa. Mr von also made a commercial version of the Bucket Pump.

In the 1980's there was a single outbreak of cholera in Epworth and I was given money by the MoH to provide new water points and latrines in the area. This consisted of tank versions of the Blair toilet (see DVD and website) and also about 220 new water points, all hand drilled with the Vonder Rig and equipped with 200 commercial Blair pumps and 20 Bush Pumps of the "A" type (a short version of Cecil Andersons pump). My team worked very hard at this. And possibly as a result there were no more outbreaks of cholera after these new installations were fitted. The community were given advice on improved hygiene. The commercially made Blair pump used 50mm PVC pipe as rising main and a PVC pushrod.

Early hand made bucket pump made of PVC in Epworth work on a tubewell drilled with our own drilling rig. On the right my two young children Paul and Suan admire the Priest Brother Charles, at a mission in Chilimanzi building an early hand built Bucket Pump with a windlass and wooden supports.

The interesting thing about the Bucket Pump principle, is that the water drawn up with the tubular bucket through the tube well, which is lined with PVC pipe, has a higher quality than water drawn up from a wider diameter well. This is because of the high turnover of water in the tubewell compared to the wider diameter well. Later work involved re-making simpler home made drilling rigs for use in looser soils and testing them out in Epworth.

Making and testing a home-made bucket pump in the garden

Testing home-made drilling rig in Epworth

The hole being drilled in Epworth with home-made drilling rig, although the actual auger was made by V&W Engineering.

The final facility. The bucket itself was made by the school girl in the photo.

Improved family wells

As the demand for improved water supplies for the rural areas became clearer after 1980, the number of hand pump supplies increased. Of course that was already known before 1980, but the rural areas were dangerous at the time as a result of the war of independence. We had developed the Blair and Buckets pumps, whilst already realising the supreme importance of family based water supplies. The Environmental Health Department had been promoting the use of shallow wells for decades after World War II and we were privileged to have known members of that department who recalled this development, especially the late Nason Mtakwa. The Ministry was very strong at this time and well lead. It employed excellent doctors and a dedicated public health department (the Department of Environmental Health). Small subsidies in the form of cement had been given to communities to build simple communal wells, especially in areas where the water table was high. These simple wells had been copied by families living in the areas where the water table permitted. Whilst hardly any mention was made in the Water Master Plan written by the Norwegians at the time, it became very clear to us that huge numbers of family wells were being used in many parts of the country. The estimate at the time being in the region of 100 000. It was quite probably that more water was drawn from this source compared to hand pumps. Those of us at the Blair Lab (the research wing of the MoH) took this very seriously and had much information on the family activities through our colleagues in the EHD. We decided to take on the challenge of making family wells acceptable as a government backed source of domestic water. Since so many wells were not well protected and may have led to contaminated water supplies, we decided to perform studies on water quality related to well design, mostly but not entirely in Epworth. These studies have been well documented and can be seen on the accompanying DVD or website. In 1991 the GOZ legitimised the concept of the upgraded well into the official rural water program. Our own team at the Blair Research who had performed the field work, worked tirelessly to teach Environmental Health Technicians the method of upgrading family wells as well as building Blair toilets and even fitting Blair and Bucket pumps. All this took place during the 1980's and continued into the 1990's. Staff of the Blair Research Lab worked hard in those years to teach the country about improved water supplies and sanitation.

The evolution of family wells in Zimbabwe

Many traditional family wells in Zimbabwe were fitted with windlasses

Initially improved family wells were fitted with an improved headworks (rurrounding apron and water run-off. The windlass supports were supported by poles. Later the poles were replaced by brick columns fitted with rubber bearings for the windlass.

Hygiene at the well head was emphasised. Later the straight brick columns were replaced by buttressed brick columns.

These family wells were popular. Naturally, they evolved in traditional practice. They were very close to the homestead kitchen and could water a productive family garden. The idea spread to Mozambique (right photo). The Upgraded Family Well program in Zimbabwe was generously supported by donors and large numbers of families benefitted. But donor support for family based support, backed by government policy saw the end of such financial support


Martin Rall, who worked for GTZ in Mozambique was involved in a program of improving family wells in Manica Province. These improved wells did not use a windlass but used a strong apron around the well head and a water run-off. This idea was also being used in the simplest improved family wells in Zimbabwe.

Upgrading family wells in stages

The idea of upgrading family wells in stages, a more affordable approach for poor families was also tested in Epworth.

Once again the importance of the headworks (apron and water run-off) was emphasised, with the possibility of upgrading with a windlass. Lining the well with well fired bricks was seen as a worthwhile measure in any family well. In times of poor rainfall, the well can be deepened.


The same upgradeable upgraded family well was also studied in our garden. Detailed accounts of all of these workers were written up and are available on the accompanying DVD.

Developments of the Bush Pump

The original Bush Pump, known as the Murgatroyd pump was conceived and designed in 1933 by Tommy Murgatroyd, a water supply officer working in Plumtree, Western Matabeleland. It used the same basic principles which are still used today. It was always fitted to boreholes. After the borehole had been sunk, the pump frame, made from steel borehole casing was set in a huge block of concrete at a certain distance from the borehole and fitted with a block of hardwood, mainly teak with holes drilled in it. The block was connected to the pump rod with a series of shackles and a long handle made of 2 inch steel pipe fitted to the wooden block. The wooden block acted a long lasting bearing, and with the handle, also a lever. The pump developed an excellent reputation for its strength and durability. Down-the-hole components were probably not so dissimilar to those used today, but I have found no record of what was used then in 1933. They probably consisted of a 2 inch galvanised steel pipe with 16mm mild steel pump rods and a brass cylinder (probably 3 inch) and a brass piston fitted with two leather seals and a foot valve. Similar arrangements had already been designed in America by The F. E. Myers & Bros. Co (USA) and may well have been copied in South Africa and then copied again in Rhodesia. The fact that they were reliable and long lasting is summed up well in a book called *Valley of the Ironwoods* (1972) by Alan Wright, who worked as a District Commissioner in Nuanetsi, in the hot south eastern part of Rhodesia, many decades ago. Extracts from this book are copied below.

…..Each year numerous six inch boreholes were sunk in dry areas from depth varying from 120 to 350 feet….. the maintenance of pumping equipment on the hundreds of producing boreholes was a constant headache but I never visited a site without sending up a small prayer of thanks to a man called Tommy Murgatroyd whom I had known when I was a boy who had perfected a simple and sturdy type of hand pump when he was employed as a Water Supplies Officer in the Plumtree District. …. This rugged but extremely simple bit of machinery is virtually unbreakable. …Our Nuanetsi boreholes seldom exceeded 300 feet as this was the maximum depth at which a Murgatroyd bush pump would comfortably operate.

I imagine that Alan Wright would drive through the bush, and would hear the old pump clanking away before he saw it.

Exactly how many Murgatroyd pumps were made is not known, but it must have been a few thousand. What is known as that the pump used no welding and was designed and built during an era when steel was bolted together. As the pump aged it was necessary to visit the pump (which could not be removed from its concrete base, and do jobs on the site. A number of revisions were made to the design over the years and these included welding parts together using portable welding machines. Some of these pumps certainly were working 1989 and I filmed and took pictures of these ancient and remarkable relics which were still pumping water over 50 years later. It was an inspiration.

In the 1960s, an engineer called Cecil Anderson revised the Murgatroyd pump so it could be detached from the borehole. Large U shaped bolts were used to attach the pump frame to the borehole casing, a method which is still used today. It also used a strong steel pump stand made of steel borehole casing, like the Murgatroyd pump. The series of shackles used in the Murgatroyd pumps were replaced by two link arms and a sliding tube mechanism which was also attached to the rods. This was Cecil Anderson's pump, which became known simply as the Bush Pump and the pump that Zimbabwe inherited at Independence in 1980.

There may have been several thousand fitted (I recall 5000 or 6000) throughout the country in the rural areas and they were built and installed by the Department of Water and maintained by the African Development Fund (ADF) based as district level. The pumps could be detached from the borehole and taken to the district workshop for repair. But this could take time. I recall during my duties as a Vadette during the late 1970's in the Zambezi Valley witnessing the replacement of 2 seals on a Bush Pump. The Bush pump has 2 inch (50mm NB) steel piped (rising main) and a 3 inch (75mm) cylinder. The piston has 2 leather seals. In order to replace the seals it is necessary to take out all the rods and the pipes to gain access to the piston and its seals. Nothing has changed since those times. On this occasion in the valley, the repair team arrived on the Monday and set up camp. On the Tuesday a start was made to lift all the pipes and rods and this continued on the Wednesday. Having gained access to the piston and its seals, two new seals were added. But they were not new, but less worn out than the ones taken out. On the Thursday the remaining rods and rising mains were fitted back and the pump started to pump water gain. On the Friday the team broke camp and returned to their base. This memory has never left me. This method of replacing seals is still the method used today, but is performed far more efficiently. It would have helped if the seals were of high quality and new. Down time for the Bush Pump is often related amongst other things to the quality of the two leather seals which operate far below ground.


The Murgatroyd Pump, left and the Bush Pump (Anderson type) right.

I became involved with the Bush pump itself in the mid 1980's. At Independence in 1980, many if not most donors rushed in with huge sums of money. The Norwegians were the first to arrive and set themselves up in change of the new DDF water division. And almost every donor wanted to bring in and establish its own hand pump. Needless to say they all failed, as there was no maintenance system set up for them and the Government didn't want them. The Government of that day to the present insisted on having its own hand pump – the Bush Pump. That insistence remains to the present day.

The advent and development of the B type Bush Pump

During the 1980's several other variants of Anderson's Bush Pump were designed and built and installed by the manufacturers and the NGO's. There may have been up to 8 different models including one called the A type which was a condensed version of the Anderson model. At this time I was a member of the technical sub- committee of the National Action Committee and the members discussed the seriousness of the hand pump situation and asked me, as a government official to restyle the Bush Pump and set a new national standard which is what I did. All the preliminary thinking and the first ever new Bush Pump, which I called the B type, was put together in my garden. I wanted to reduce the number of wearing parts linking the rods to the wooden block with a single U bracket. The pump had to remain small but strong as it would fit into my Golf car. I used a new concept using floating washers through which the rods passed. The two washers, enclosed in a "floating washer housing" were able to move about and achieve a full stroke of about 220mm within the internal diameter of a standard 50mm GI pipe. The so called pivot pins and their attachment to the pump frame were also improved. I put the various parts together using old parts from other pumps. I had no welding equipment at home so took the parts to the Eastlea workshops of the Department of Water and asked them to weld them together. It was this pump made in 1987 which was first used in trials performed in Epworth.

Left: The first B type Bush Pump being tested in Epworth, 1987. Right: A later B type Bush Pump being tested in the field by DDF.

With a donation from UNICEF (David Williams), ten more were built by Lane Engineering for trials in the rural areas with full and willing co-operation of the DDF and the Department of Water. Further B type Bush Pumps were made by V&W

Engineering for trial. The pumps were tested under very heavy duty settings in Epworth where my team constantly monitored them and also were tested when the pump was placed in very deep boreholes. Heavy duty model were made for this purpose by V&W. The heavy duty trials in Epworth revealed a weakness in the pump frame which was strengthened and the wear on the pivot pin and its attachment to the pump frame was also studied. These issues were also attended to and led to the current design. By 1989 the pump had gone through its trials well and the NAC examined my report and working pumps and agreed to make it the new National Standard hand pump. It also had support from Erich Bauman and Karl Erpf of SKAT, Switzerland, a major world centre for hand pump development and it became a public domain pump with international specifications. It remains the national hand pump of Zimbabwe to this day.

But the problem of ease of exchanging the seals fitted to the piston also remains to this day and concerns me. Further work was carried out in collaborative working between myself (government) and Mr Erwin von Elling of V&W Engineering to design and test pumps which had open top cylinders, where the piston could be drawn out through the rising main. At first a 2 inch models were made and later a 2.5 inch open top cylinder (63.5mm). Mr von Elling designed hook and eye rods for the job. These were tried around the country. But the users did not like the reduced output of the 2 inch cylinder and the cost and weight of the larger steel pipes was prohibitive for the 2.5 inch model. We also had a problem with locally made nitrile rubber seals and even imported ones from India and the UK. Trials were also undertaken with PVC and high density polyethylene pipes. But none could match the stamina of the original arrangement, a large 3 inch cylinder and a 2 inch rising main. One improvement was the standardisation of the heavy duty foot valve - a masterpiece of engineering.

It is this pump which is still in use today in 2020. “Down time” (the period when the pump is not operating) has increased with slightly over half of existing Bush Pumps out of action. This is the result of a combination of technical and financial problems. The DDF whose responsibility it is to maintain the fleet of pumps, numbering about 55 000 has inadequate funding, manpower and resources to perform the task of maintenance adequately. Fitting new pumps helps, but maintenance is the key word. Also, manufacturing pumps to the required specification, fitting them properly and then maintain them properly is what is required. Large numbers of Bush Pumps were built poorly in the past, not following the exact specifications. This has been resolved by much stricter control over the manufacture of pumps. Also pumps may be fitted poorly. New training is required to do the job properly. And maintenance should be seen as the top priority. It is not solved by just fitting new pumps.

It is the problem of the Bush Pump which still bothers me in my retirement. When pumps are well made and fitted properly and have good seals, the pump can continue to operate for years with little attention. This of course also depends on the quality of the water pumped, the number of users and also the quality of the borehole. Hand pumps, including the Bush Pump do not like operating on boreholes which are not vertical. On a curved borehole, and many are, the rods and pipes come into contact with each other. This creates friction and wear and the pump is not happy with this. If two identical pumps are placed, one on a curved borehole and one on a near vertical borehole, the two pumps will respond differently. This can be felt by the pumper, but also by the pump itself. The pump on the curved hole will be heavier to pump and the down-the-hole components, particularly the pipes and rods were wear out more quickly. Also something that appears to have been forgotten is that all machines require maintenance, like the glorious history of steam engines reveals in the UK. My thoughts and work on this are revealed in one of the next chapters.

I have chosen to look at the ongoing problem in two parts. First methods of improving the design and fitting of standard down the hole components which, when fitted properly will reduce the down time. The second method is to use open top cylinders again with knowledge which has been gained over the years from pumps like the Afridev which uses very thick walled (4.7mm) 63mm PVC as a rising main and 50mm pistons. These operate down to 40m depth. This thickness of 63mm PVC pipe is not available in Zimbabwe. Several manuals have been written on this subject for worked performed in my back yard. A chapter in this book is devoted to some of the latest back yard developments.

But a word about the first method is fitting here. The pump head is robust and takes a lot of punishment like its predecessors, but the main head bolts, called pivot pins do need to be kept tight. The wooden block remains functional for a very long time. The pump head was designed so that even if many of the bolts were missing the pump could still be made to work. The main problem was the down the hole components. How long could they last without attention - the leather seals being the fastest wearing part. Clearly quality leather seals should always be used. I have written a paper on this first approach – that is to make small revisions to the standard down-the-hole components that are currently used. This has been placed on the DVD and website. The point is that the Bush Pump is expected to pump down to a maximum of 100m. Experience with the Afridev shows that even with very thick walled PVC pipe, the maximum pumping depth is 40m.

So steel piping must still have a place as a rising main, especially at greater depths. Corrosion is a problem for steel pipes and rods, but the acidity and corrosive effect of the water varies from one site to another. Overall, aggressive ground water has not been a major problem in Zimbabwe. My manual includes the use of a piston with three seals, not two, a method also use by F. E. Myers and Co in the USA years ago. It also includes revising the methods of jointing the 16mm galvanised iron pump pipes and rods to reduce corrosion of the threads which are most vulnerable. This involves being careful on protecting the threads of both pipes and rods with special sealants. Clearly the pump must be fabricated and installed correctly if a long working life is to be expected before lifting the parts for renewal. The fact that a well-made Bush Pump can perform for several years with little attention, is a testament to how correct Alan Wright was, although he may never have seen the B type.

The Bush Pump is not a VLOM (Village Level Operation and Maintenance) pump, like the Afridev. What if the fix is easy, but is performed by less experienced people, prompting other maintenance visits. Perhaps there is room for both concepts – longer lasting and not so easy to fix and less durable, but easier to fix, that is if quality parts are available locally. The real answer is very durable and easy to fix. Not an easy one to find!

Two of the proposed methods of reducing "down time" on the current down-the-hole standards of the Bush Pump. A piston with 3 seals requires only one adjustment to the current design. Also a method of joining the standard 16mm mild steel rods which does not expose the vital threads. This method of joining rods has been on trial for several years in the back yard and when used in combination with Marine Silicon sealant has revealed no rusting. Clearly these and a few other suggestions, like exposing the minimum of pipe thread to likely water corrosion, checking the pump before installation and improving the installation process, could greatly reduce down time, when the pump does not deliver water.

Open top cylinder models

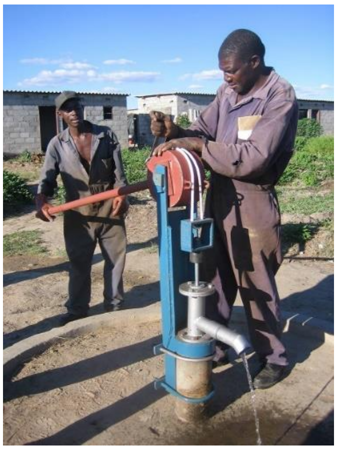
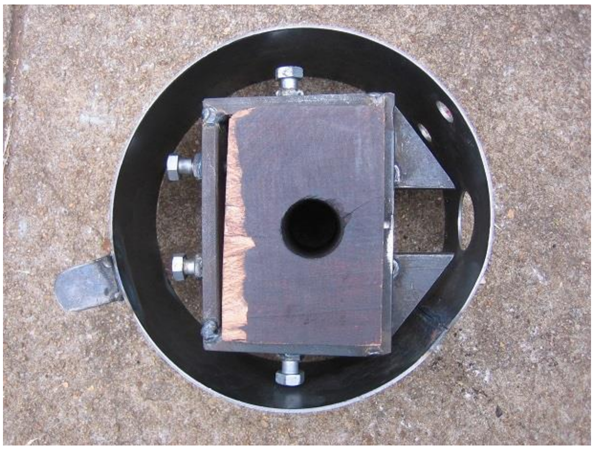
This approach has also been mentioned and a great deal of back yard work has been performed on this subject. The line of investigation has concentrated on the use of 65mm PVC pipe together with both 53mm and 54mm internal diameter stainless steel cylinders, and more recently with 12mm stainless steel pump rods. Work has also been carried out on 75mm PVC pipe together with 63.5mm open top brass cylinders. The water output of a 53 and 54mm mm piston is less than the 63.5mm piston which is also less than the 75mm piston, but the seals of open top cylinder models are much easier to replace. Various methods have been studied on connecting the PVC pipes. The very reliable heavy duty foot valve has been retained in these trials, as it is long lasting and makes a very good seal when properly made and installed. In the writers experience removable foot valves fitted into a cone can become cemented in place with silt and may be difficult to extract. But it is very possible that this problem has been resolved on the world stage. Work has also been carried out on bottom support for the PVC rising main, so it does not need to hang under its own weight from the pump head.

The "old man" at work on this garden Bush Pump

The “C type” Bush Pump

I was also asked to design a lower cost Bush Pump by UNICEF in 2007. At that time the economy was going off course, just as it has been ever since in Zimbabwe and the cost of the Bush Pump was becoming high by international standards. I accepted the challenge and designed what became known as the “C” type Bush Pump.

The new design was based on the fact that the most expensive part of the Bush pump were the 50mm NB GI (nominal bore – galvanised iron) steel pipes used in the rising main. In the standard Bush Pump the uppermost rising main pump must be a 50mm NB GI pipe to accept the movement of the rod during the stroke. Pipes below this could be 40mm, but this fact never seems to have been taken seriously into consideration. The Afridev rods also move about, but the rods of the India Mk pumps move up and down vertically due to the design of the pump head. This means that smaller steel pipes can be used with the India Mk pumps and actually are 32mm – lighter and cheaper. But the India Mk pumps also use 12mm rods which move up and down well inside a 32mm pipe. Our own work with 12mm GI rods on the Bush Pump revealed that their life was limited. A description of the “C” type is included on the DVD presented with this book. This pump was also designed in the back yard from parts and 50 were tested around the country. They worked quite well, but were not much cheaper than the “B” type (a reason I have never understood) and my colleagues at SKAT (Switzerland) urged me to retain the well tested “B” type. The “B” type was retained. Interestingly I had designed this new head and had a prototype in my garden, even whilst preliminary meetings were still being held at the UNICEF office. Meetings are important to very bureaucratic organisations. Long meetings sitting around tables can be tedious.


The “C” type Bush Pump used a steel drum with a wooden block placed inside and was initially surrounded by very strong concrete. The handle was welded to the steel frame surrounding the wooden block. A rope was fitted around the drum and handle and on a special shackle which connected the rope to the pump rod (left pic). The vulnerable part was the rope, but it was replaceable. Some “C” types worked for years. But it never became a standard. The B type retained many of the features of the Murgatroyd pump. The “C” type did not.

Further developments of the “B” type are discussed in another chapter of this book. The Bush Pump forms the backbone of the rural water supply in Zimbabwe.

Family wells in the rural areas

My interest in family owned wells probably began when we moved to a house in Marlborough in 1977. The water table was very high at the time – between 1 and 2 metres below the surface. I dug a well to provide water for gardening. Since that time the water table has fallen considerably and how lies at about 13m down. The chapter on water tables indicates the fluctuation in level over the last 4 years. Some work was performed in the garden on well lining and also on how to support the windlass, which is often fitted to family wells in the rural areas. The windlass is an ancient idea and had been introduced into Rhodesia (now Zimbabwe) through the mining industry. It had been used to excavate mine shafts. It was copied in the rural areas because it made lifting the bucket of the well easier. It also wrapped the rope attached to the bucket in a hygienic way above ground, thus avoiding contact with the ground which might have been dirty or contaminated.

My interest in shallow wells also resulted from working with the Environmental Health Department of the MoH. They encouraged families to dig their own wells and had done for decades before 1980. That was why family wells were so common. The MoH also gave cement to communities to build community shallow wells, but the families financed their own wells. This was perhaps the earliest self-help program in water supply in this country. Hand pumps (the Murgatroyd and Bush Pump) had also been installed by the Department of Water (who also made the pumps) and they were maintained at District level by the ADF (African Development Fund – now the DDF). However by 1980, this amounted to only a few thousand hand pumps and not enough to serve the rural population. Thus family owned wells were very common. We estimated that 100,000 family wells may have been operational by 1980. They probably moved more water than all the hand pumps put together. Family wells were also used in townships on the outskirts of Harare, like Epworth in very large numbers. They still are!

The National Water Master Plan, drawn up by the foreign consultants in the early 1980's barely mentioned family wells. The reason was that the water was considered unfit for drinking from such shallow aquifers, and wells (or boreholes) had to be sealed before the water was considered safe or drinkable. For many wells this may have been true, as the protection at the well head was poor. Many family wells were little more than holes in the ground, and could become contaminated by rainwater run-off or simply from exposure to animals and the people who attended the well.

Despite the edicts of the NWMP we at Blair decided to look into this problem with the fully backing of the Environmental Health Department of the MoH. Family wells are water wells built by families for their own use. Because they are usually constructed using simple technology at low cost, they are generally hand dug and shallow, and tend to be found where ground water tables are also shallow. This has been a traditional way of accessing water across Zimbabwe, and Africa, throughout history. In Zimbabwe in the 1980s, it was estimated that at least 1 million people drew their water from shallow, family or community-dug wells, with over 30% of the population in some areas using such wells daily. The problem was that many of these wells were either unprotected or poorly protected, with unhygienic or non-existing headworks and the well water often became contaminated – either because of the runoff of rainwater that was contaminated, or because the buckets and ropes used to draw water became contaminated from unhygienic conditions at the wellhead. Because many of the wells were open at the top, they also posed a hazard – especially for children. But despite family wells being so widely used, they were generally not recorded in official inventories of water sources, and not regarded seriously by government or other agencies involved in water supply at the time. The emphasis of official water supply programs was on installing community boreholes or deeper wells fitted with a hand pump - the Zimbabwe Bush Pump.

However as the map below shows, hand dug family wells are not appropriate or possible in areas where there are no shallow aquifers, or the rock is too hard to dig through. In some parts of the country, therefore, there is little scope for expanding family well facilities. Family wells are also not appropriate for larger community supplies, such as for schools or community centres. Hence the hand pump has always and will continue to play an important part of the rural water supply program, alongside other methods of raising water such as electric submersible pumps and water storage facilities, where electric power is available.

A simple map of Zimbabwe, produced in 1992 indicating areas where there may be suitable ground water conditions for shallow, hand dug family wells. Black areas = potentially suitable groundwater conditions for shallow wells; hatched areas = unlikely to be suitable groundwater conditions: white areas = state or commercial land. Image credit: Morgan (2015)

Research into the value and further development of family wells in Zimbabwe

Zimbabwe's "National Upgraded Well Program" ran from late 1980s throughout the 1990s, aimed at improving the tens of thousands of privately owned 'family wells' across the country. Reports have been written describing this programme, the problems that it addressed, and how it worked to improve Zimbabwe's water supply situation.

Official attitudes to family wells started to change in the mid to late 1980's when we researchers at the Ministry of Health's Blair Research Institute (now known as the National Institute for Health Research) recognised both the extent and popularity of family well use across Zimbabwe. Family wells were often preferred to communal hand pumps, in part because they were more convenient and promoted self-sufficiency – and the fact that many family wells had been privately improved in a way that addressed some of the problems with them. For example, some families constructed lined wells, or added well covers, or a surrounding wall to protect the well from contamination, or windlasses that kept buckets and ropes off the ground when not in use. The Environmental Health Department of the Ministry of Health and Child Care (MoHCC), had also been promoting shallow well use for decades.

Traditional wells independently upgraded by a family

We, at the Blair Research Laboratory carried out research showing that improving the construction of family wells could indeed reduce the risk of well water contamination. They showed that the bacterial load in well water could be reduced if the following changes were made compared to many traditional hand dug wells. These improvements included lining the well with fired bricks, installing a robust concrete well cover and sanitary apron around the well, and a water run-off channel which led waste water away from the well head. Also a raised collar fitted with a tin lid on top of the well cover. The use of a windlass to raise the bucket also helped to maintain hygiene of the water lifting equipment (bucket and rope). The improvements were confirmed by bacteriological testing of well water from unimproved and improved (upgraded) wells, as shown below.

Faecal E. coli for water samples*

Source of water	mean *E. coli*/100ml sample	number of samples
Traditional well with bucket	266.42	233
Upgraded well	65.94	234

• Source: Zimbabwe's Upgraded Well Programme. Background Paper. 1992. P. R. Morgan

Further evidence of water quality improvement for *Faecal Streptococci* as well as *E. coli* were studied between January and March 1988 during a heavy rainy period.

Faecal *E. coli* and *Faecal Streptococci* for water samples

	Traditional well with bucket	Upgraded well
Mean faecal E. coli/100ml sample	342.48 (n= 85)	84.01 (n= 86)
Faecal Streptococci /100ml sample	579.48 (n=88)	103.01 (n=88)

These figures also show that increases in water quality could be achieved without the use of a hand pump in shallow wells. Further bacteriological tests were performed to re-confirm these results. Such improvements in water quality could not match the lower *E. coli* levels found in water delivered by completely sealed hand pumps fitted to wells and boreholes. But the important issue here remains that family wells are much simpler and easier to maintain and are also used by relatively few people who generally remain within the same social group for years and become accustomed or adapt to their own water supply and its quality.

Armed with this evidence for improvements in bacteriological quality and also physical safety of the well, the Blair Research staff then started a series of pilot projects. A series of pilot studies were undertaken by Blair Staff during the period 1988 to 1992 when about 5300 upgraded family wells were built with the full backing and support of the Environmental Health Department of the MoHCC. The first were built in the Makoni District, funded by Swedish Sida. At the same time training teams from Blair, were deployed throughout the country to pass on knowledge of the technique to health teams and local builders and leave a series of demonstrations, country wide.

The National Upgraded Well Programme in the 1990s

The concept was studied and debated by MoHCC officials during 1988 and 1989 from all parts of the country, and was officially endorsed by the MoHCC in 1990. This followed encouraging feedback from the users from all parts of the country and also from MoH officials who had come into contact with pilot programs. In 1991 the technique was officially endorsed by the National Action Committee of Government and introduced on a small scale at first into their National Integrated Programme. Later, this concept was expanded across Zimbabwe. Throughout the 1990s, donors, including Water Aid, subsidised family well upgrading programmes.

Families had to fund the digging and lining of the well shaft themselves, and also pay a builder, but they were supported by a generous material subsidy from the government (using donor support) to cover the costs of cement, a tin lid and a windlass (commercially made at the time). District Environmental Health Officers and their staff supervised upgrading according to the procedures recommended by the program. In order to expand the program further, those Blair Research staff involved in the program moved to a newly established NGO supported by Water Aid (UK). This later became known as the Mvuramanzi Trust.

The Blair Institute and Mvuramanzi Trust alone upgraded over 38,000 family wells in the early 1990s, and the efforts of other agencies may have brought the total to nearly 50,000. Additional benefits of the programme were also seen. The increased number of operational wells led to an expansion in vegetable gardening, irrigated with well water, which further supported local economic development. Some commentators also reflected on the relative advantages of organising water supply at both the family and the community level. On one hand, family based water supplies reduce pressure on community pumps, reducing the likelihood of breakdowns. On the other hand, families with their own well were thought to be less likely to contribute to the upkeep and maintenance of a community pump.

Pictures of Upgraded Family Wells built during the program

The rise and fall of the program

One of the reasons for the success of this program was that it built upon a traditional practice that had been already been established for generations. It facilitated families to do something for themselves with something they could build and manage for themselves. The well upgrading methods are based on relatively simple, locally tried and tested techniques, which promoted their uptake. Private ownership was also an important factor and the convenience of having a private water supply close to home, was seen as important. The long term involvement of the Ministry of Health was also a factor in the success of the project. The Ministry of Health had the manpower to provide supervisory and training staff at many levels, including those that operated in the village. Other ministries would not have been able to do this so effectively.

Also the combined efforts and input and collaboration of the Government of Zimbabwe, the NGO's and generosity of the donors helped to achieve a common goal – that is to improve the quality and access of potable water to the large numbers of people living in the rural areas of the country. The acceptance of the level of service had already been assessed by the MoH during the experimental stage of the program. It had also been accepted at by the Government, as an important part of the national program,

During this era, the private sector played a part in the program by manufacturing the windlass (formal sector) and the tin lid (informal sector). However the windlass component was already known in traditional practice and countless thousands, of various designs, had already been made and put into service in the rural areas. Large numbers of builders were also trained.

On the other hand from the year 2000 a decline in the number of wells upgraded was noted. During this era Zimbabwe's entered a much troubled political period which resulted in economic decline. These factors resulted in a huge reduction in donor support which affected many developmental programs including the water supply program, leading to a slowdown in the construction of new family wells. But those many units in existence proved to those that saw them operating in declined economic conditions that family owned units had great merit. The decline of Zimbabwe's infra-structure and much reduced donor support also saw many community hand pump supplies failing. Currently about 50% of hand pumps are functional.

Also, the concept of providing quite large subsidies to families has proved unpopular to donors in recent years and also is not encouraged by the GOZ. After Zimbabwe's Independence in 1980, the donors were willing to provide generous material subsidies for improving family based toilets and wells. This is no longer the case. As a result the designs of both the local family Blair VIP toilet and the Upgraded Family Well unit have been restyled so they could be built in a series of step by step stages at lower cost and where families could perform construction work with minimal support, or no support from outside. The Government now promotes the revised method of supporting family Blair VIP construction, known as the uBVIP. It has continued to use the multi-compartment Blair VIPs in schools. Currently there is no plan to follow this same step by step upgradeable system for family wells. But it still has much potential.

Technical constraints -quality of construction and constant maintenance

As with all construction, the same ingredients can be used to make structures of varying quality. Even family wells require care and maintenance to survive. Corrosion around the well head needs to be checked a built up with new soil, as any water point is well used and erosion takes place around the well head, even when a water run-off is used. The same applies to a hand pump supply. Poorly made and installed pumps and a lack of routine maintenance can lead to a shorter working life span than pumps which are made, installed and maintained properly.

Further experimental phase 2012

In a later and much smaller research program which was based in Epworth, close to Harare, the suburb where some of the first family wells had been upgraded in the 1980s, local artisans were trained and encouraged to train others to upgrade their own wells. The program was still subsidised, but to a much lesser extent than the programs of the 1990s: families who wanted to upgrade their well received a bag of cement and two properly treated gum poles with which to support a locally made windlass. An adaptation of the original program was that upgrades could be made incrementally and with fewer resources. For example, it was not seen as compulsory to begin with a windlass and the supporting poles, as these could be added later, and the design of the windlass and its supports was optional. A strong concrete well cover serving as an apron with raised external rim and raised internal rim supporting a lid together with a water run-off channel were seen as essential components. Each well in the research program provided water to between 8 and 64 people. Surprisingly water quality was not changed by the absence or presence of a windlass, but further tests are needed to confirm this. Such a simple and upgradeable system was seen to be affordable at the family level. Further upgrades were viewed as option and seen as also being the responsibility of the family alone. Guidance to well siting was also seen as important. This alternative step by step method has not yet been tested beyond the experimental stage in Zimbabwe.

Family well upgraded in the later experimental programme. At first without and then with a windlass.

Possible approaches for the future.

During the last decade or more, Zimbabwe has faced immense financial and political turmoil and the reduced levels of donor support, has had a negative impact on the growth and development of both water and sanitation projects, as well as many other developmental projects in the country.

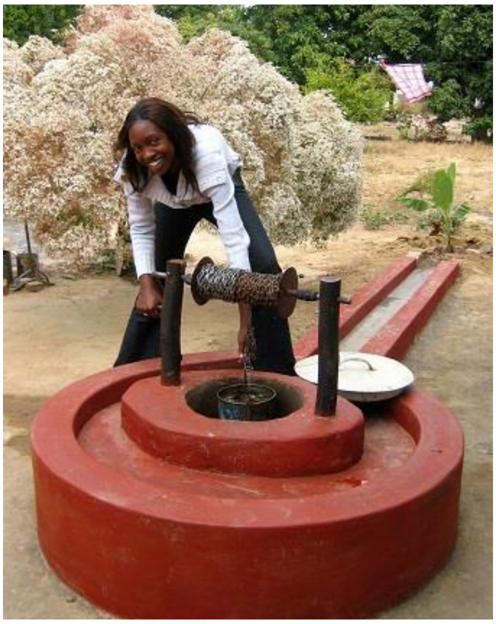
Whilst family based self-supply projects have great merit, and have probably been responsible for maintaining the flow water for domestic use in many parts of the country, not only in the rural areas, but also in the towns and cities, both donors and government prefer to support community projects rather than family based projects. For family based water supplies and sanitation projects, the way forward seems to be towards promoting the concept of self-supply or self-help using a technical approach which is affordable to the family itself – with features which are cost effective for the owner, but structurally robust, are easily maintained and can be upgraded over time. In the rural context, low cost, simplicity, maintainability and upgradeability are important.

To conclude it is becoming clearer that self-owned supplies of water may become the only means of survival for many in the country. The exact number of improved privately own wells of varying quality is not known, but may be well in excess of 200,000, serving as many as between one and two million people, a figures which needs to substantiated by effective monitoring. It is clear the concept self-supply is very much alive in Zimbabwe, even in the cities, where huge numbers of privately owned boreholes have been drilled simply because municipal supplies have failed or deliver water of unacceptable quality. The concepts of self-supply and self-sufficiency will indeed become stronger as the years pass by. As always only time will tell.

Photographs of family wells built in Zimbabwe



Upgraded family well without and with windlass

Family well training program in Epworth being supervised by Annie Kanyemba

The Zimbabwe Bush Pump-back yard research

Latest developments of open top cylinder models using PVC as rising main and various open cylinder and pump rod designs. 2018 – 2020.

A brief overview of my work performed on the Zimbabwe Bush Pump has been described in this book and also on a large number of manuals and other publications which can be found on the DVD or website. The overall aim being to reduce the frequency and complexity of maintaining this strong national hand pump. At the time of writing (August 2020) the national down-the-hole components remain standardised – using 50mm GI rising main, 16mm mild steel pump rods, a 75mm diameter closed top brass cylinder with a brass piston carrying two leather seals and finally a very robust and reliable foot valve.

I have written an account of why relatively minor changes in the design and installation of the down-the-hole components of the existing model may reduce down time, by increasing the life of the various components (seals, pump rod threads and rising main pipe threads etc). High quality leather seals are essential to a long working life between essential maintenance procedures. Bolt tightening remains important above ground level.

Most of the rest of the work has centred on open top cylinder and rising main designs where the piston can be withdrawn through the rising main. This work has been carried out with 53mm and 54mm open top cylinders matched to 63mm PVC rising main and 63.5mm open top cylinders matched to 75mm rising main. Both 16mm mild steel and 12mm stainless steel rods have been tried. Preliminary trials have also taken place on using the principle of the PVC rising main supported by a bottom anchor. In this case the PVC is supported from the bottom and not slung from the pump head. However this method is complex and the most recent work on open top cylinders used in conjunction with PVC rising mains concerns the use of a 53mm open top cylinder, in conjunction with 63mm PVC rising mains, where PVC socket unions are used to connect pipes. The rising main is slung from the pump head. The 53mm open top version has been chosen because it should be able to pull the piston through a thicker walled (4.7mm) PVC pipe with a water output which is slightly greater than a 50mm piston. These recent developments have been written up and are now placed on the website of RWSN.

This experimental back yard pump is mounted on a well – very shallow by Bush Pump standards, but enough to learn a great deal. During 2018 and 2019, I made improvements to the design of the piston and also used 12mm stainless steel as pump rods. Previously I had used the standard 16mm mild steel pump rods. 12mm stainless steel rods are not made and are not available, to my knowledge in Zimbabwe at the present time, but are available together with the thicker walled (4.7mm wall thickness 63mm PVC pipe in Zambia (used on the Afridev). But as a retired tinkerer, I must use what is available on the local market. PVC socket unions, which are available on the local market have been used together with other methods of connecting the PVC pipes together.

Experimental Bush Pump with a 53mm open top cylinder, 63mm PVC rising main connected with PVC socket unions and 12mm stainless steel pump rods

The standard pump head itself remains unchanged apart from the modification of the dip plug hole in the rising main support plate. This hole is opened up and smoothed down to allow access to ropes which are fitted to the lower part of the cylinder and assist in lowering and raising the rising main pipes. Also the heavy duty 65mm heavy duty steel socket welded to the bottom flange plate of the water discharge assembly is used in this version to support the 63mm class 16 PVC rising main. This is one of the two options described in the standard specifications for the Bush Pump. Currently all standard Bush Pumps use a heavy duty 50mm socket welded to the bottom flange plate of the water discharge assembly to carry the 50mm NB GI rising main pipes. The 65mm GI socket was used to connect to 65mm steel pipes in former work. This has been used to connect the 63mm PVC rising main to the pump head as described below. The connections between 63mm PVC rising main pipes has been made with strong PVC socket unions. During lowering and lifting of the 63mm PVC rising main and rods, a pipe and rod guide and holder has been used to secure the pipes and rods during the connecting procedure. A rope is also attached at the foot valve level of the rising main and comes to the surface and is attached to the head of the rising main. This rope is used to assist the pulling out of the rising main together with people at the head also pulling out the rising main.



The standard dip plug hole in the rising main support plate has been opened up to allow access to support ropes attached to the cylinder which greatly assist the lowering and raising of the PVC pipes. As the pipes are lowered or raised they are held secure with a rising main pipe support tool whilst the pipes are joined. The pipe support tool supports the pipe connectors as shown.


The water discharge unit with a 65mm heavy duty steel socket welded to the rising main support plate. The connection to PVC is made through a 65mm thread to 75mm PVC pipe adaptor. A 63mm PVC connector cement jointed to the 63mm pipe is bonded within the 75mm socket. In this adaptation standard 63mm PVC connectors or PVC socket unions are then used to connect the rising main pipes together.

The 63mm PVC rising main and its joints.

The rising main is made up of lengths of 63mm class 12 PVC pipe in experiments, but class 16 pipe should be used in future experiments. PVC pipe is sold in standard 6m lengths in Zimbabwe. If 6m lengths are too long to carry, the length can be cut in half reconnected with PVC sockets or socket unions. They can be shortened or lengthened using PVC pipe connectors and PVC solvent cement. It is essential to chamfer the ends of the cut pipe to ensure the piston and its seals passes through the joint smoothly. 63mm class 16 pipe (wall thickness approx. 3.2mm) is commonly available in Zimbabwe, but the thicker and stronger 63mm PVC pipe with a wall thickness of 4.7mm (used on the Afridev hand pump) is not available in Zimbabwe and special orders must be made to secure this pipe and also the 12mm stainless steel rods.

The 63mm PVC pipe joints using PVC sockets or PVC socket unions and PVC solvent cement

These are standard off-the-shelf items which are used to connect PVC pipes using PVC solvent cement. The wall thickness of the socket is greater than the wall thickness of the pipe. The strength of the unit depends on the cementing process to be performed properly. It is essential to chamfer the ends of the pipes being joined to allow easy passage of the piston through the joint. At first solvent cementing seems to be an easy process, but it is not. PVC solvent cement when properly applied and allow to cure properly forms a weld which bonds the pipe with the socket. The connection is very strong. Solvent cement is very volatile, and loses its quality very quickly when exposed to the atmosphere. In hot weather the evaporation is rapid. So the process of joining must be done properly and at speed. Old solvent cement is useless – new cement should be used and if stored the bottle should be capped tightly and kept in a cool place if one is available. It is best stored in a tube. For this reason PVC socket unions are also being tested as a means of joining PVC pipes. This type of work is also being carried out internationally.

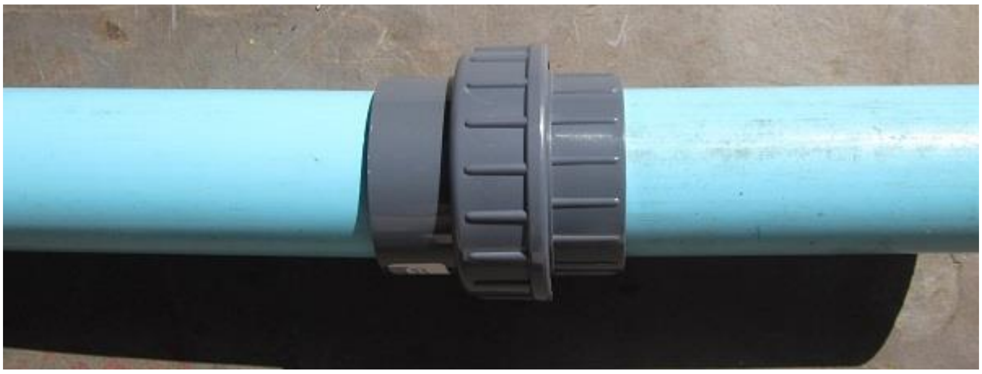
Solvent cement should be applied to outer pipe and inner socket surfaces thoroughly and joining with a twisting motion. Excess solvent cement must be removed with a cloth immediately. The joint must be allowed to cure properly. The advised time is 24 hours, but this may not be practical. Tests are still being conducted on the ideal time to allow the joints to cure and this may depend on many factors.


The simple 63mm PVC pipe socket joining pipes using PVC solvent cement. To dismantle the pipes must be cut and re-cemented on lowering. Thicker walled pipes can be pulled out on one go, a method being used in Malawi. This requires very strong PVC and connectors.

The 63mm PVC pipe joints using PVC to thread adaptors and brass barrel nipple

A method using 65mm pipe to thread adaptors. Stainless steel or brass barrel nipples should be used. This method can work for smaller 50mm or 2 inch open top cylinders.

The 63mm PVC pipe joints using 63mm PVC socket unions



The 63mm PVC socket union is an ideal method of joining pipes, but tests still need to be carried out on what weight and pressure the socket union can cope with. Trials using this method are still underway.

The cylinder

In this case a stainless steel tube is used to line the inner side of a length of 63mm class 12 PVC pipe. The stainless steel tube was ordered from the UK with an OD of 57mm and an ID of 53mm. The length being 400mm in this case. 500mm lengths are also possible and two are in stock and give more latitude in piston positioning. The company (Intamet Ltd) that produces the pipe can polish the inside of the tube to varying degrees of polish (240 grit or 320 grit), with the latter being more preferable. The higher the polish the longer the seal life. The length of stainless steel tube is bonded into a 500mm length of 63mm class 12 PVC pipe using a material called “Pratley’s white.” At the lower end of the PVC pipe (below the stainless steel section) additional tubes of cut PVC pipe are bonded within the outer pipe, as a means of limiting the movement of the piston downwards. Later a 500mm length of polished stainless steel tube was bonded into a 600mm length of 63mm class 16 pipe and is used as a demonstration at this point. Once cured the upper end of the stainless steel tube was filed down to form a chamfer, for easy access of the piston. Finally a standard PVC socket was solvent cemented to the upper end of the cylinder unit. A standard PVC to pipe fitting with 2 inch female thread was solvent cemented to the lower end of the cylinder tube. Where steel sockets are used the upper end of the cylinder would be fitted with a pipe to thread adaptor.

The stainless steel tube and the 63mm class 12 or 16 PVC pipe into which the tube is bonded. Details of the procedure of preparing the cylinder in its casing can be found on the DVD.

Fittings at lower and upper end of cylinder pipe

PVC inserts are bonded beneath the stainless steel cylinder pipe, as a means of holding the piston above the bottom of the cylinder tube. A standard 63mm to 2 inch PVC pipe adaptor is solvent cemented to the bottom of the cylinder. The brass foot valve is threaded into this fitting. The centre photo shows the upper end of the cylinder inside the PVC pipe. A standard PVC 63mm connector is then solvent cemented to the top of the cylinder pipe.

The Piston

The 50mm piston used in this trial is a locally made unit using two expanded 50mm nitrile rubber seals and a 16mm thread for the pump rod. Nitrile rubber seals must be of the highest quality, as all hand pump seals should be. These nitrile rubber seals are the same as used on the Afridev hand pump and were kindly sent to me by Karl Erpf of SKAT many years ago. They are now standard equipment used with the Afridev hand pump. The India Mk brass piston poppets use a rubber seat attached to the poppet valve, a well tried method which may reduce was slippage in the piston. Zimbabwean piston poppet valves have, so far, not used a rubber seat. Heavier poppets also close more quickly and may reduce slippage which is an advantage when smaller diameter pistons are used.

In this trial, a small brass piston arrangement has been used with the upper cage designed to screw into a 16mm pump rod, and the lower piston tube designed to accept a PVC tube around which expanded 50mm nitrile rubber seals have been fitted. Smaller 50mm nitrile rubber seals may wear out more quickly than the larger 75mm leather seals used on the current standard Bush Pump, and the water delivery rate is about half. But with the open top cylinder they are more easily removed and replaced. A full range of photos and specification is available on the DVD accompanying this book

The complete piston attach to lower 12mm rod. The component holding the two seals in place on the brass piston unit can be removed and replaced if worn. It is possible to design piston units which have several seals.

The foot valve

This is the high quality heavy duty brass unit fitted to all Bush Pumps. If properly made it is very durable and has a long life. The poppet valve is fitted with fins which make the valve rotate in use. The poppet sits on a rubber ring which forms a good seal if properly mounted and tested. The rubber wears down slowly, but has a life of several years. In a modification of the foot valve stainless steel screens are fitted both above and below the poppet valve. This is an attempt to avoid the possibility of foreign objects which may cause leaks becoming trapped in the vital foot valve. It is essential to ensure the poppet valve is mounted perfectly over the rubber ring to avoid leaks. In addition a phosphor bronze poppet return spring has been fitted between the upper housing of the foot valve and the poppet. This spring system was first developed and used by the Myers Company, Ohio, USA, in the 19th Century to reduce the so called "slippage" (loss) of water as the poppet valve returned to its lowest position. This spring improves the efficiency of the valve, helping to reduce leakage and thus increasing water output. Any method of increasing the output of a 50mm or 53mm ID cylinder (when compared to a 75mm cylinder) is seen as an advantage. This type of foot valve has been used on an earlier version of the open top cylinder model described here. It has performed well with no leaks noted. A full range and photos and description is available on the DVD attached to this book.

Use of Marine Silicone Sealant

This material is available in tubes for about US$3.50 per tube. This is enough material for sealing many threaded joints. After the male and female threads have been cleaned and dried, the sealant is applied by finger to the both the male and female threads thinly, so as to just fill the grooves of the thread. No excess should be used. Then the two components are threaded together using a wrench spanner to make a tight joint. This material never sets solid, so the joint, whilst well sealed can be unscrewed when required and also protects the threads. This sealant can also be used on the rod and pipe threads.

Marine Silicon Sealant

The 12mm stainless steel pump rods and rod connectors

Both 12mm stainless steel and 16mm mild steel rods have been used in my backyard trials. In this case 12mm stainless steel rods were chosen. Reports reveal the 12mm stainless steel rod version with threaded connectors have been successful on the Afridev. In this case four of the 5 pump rods were stainless steel with the short uppermost rod being retained at 16mm mild steel to fit into the existing U bracket of the pump head. A steel adaptor from 12mm to 16mm was used to join the 12mm and 16mm rods. A short 12mm rod was attached to the piston. U brackets and also floating washers have been made to suit a fully 12mm stainless steel rod.

12mm stainless steel rod connector and the rods prepared for lowering down the rising main.

Preparation of cylinder, foot valve and piston

Left: The short 12mm rod attached to the piston. Centre: the PVC wear reducer bonded to the 12mm socket. Right: The photo shows the foot valve with the male thread screwed into the pipe to thread adaptor solvent cemented to the bottom of the cylinder pipe. All threaded parts are sealed with marine silicon sealant. The foot valve with the male thread is standard in Zimbabwe and this joint is shown above. The operational distance (stroke) of the piston is marked on the cylinder (220mm). This gives some allowance for minor changes in rod or pipe length. This demonstration cylinder unit is 500mm long. Standard 75mm cylinders on the Bush Pump are 600mm long. The lengths of rod and pipe are adjusted so that the piston comes to lie about 50mm from the bottom of the working length of the cylinder.

Chamfering the pipes and couplings and solvent cementing

In order to allow free lifting and lowering of the piston within the rising main and its couplings the inner walls of the pipes must be chamfered, so that the piston seal meets no squared ends on its way up or down the rising main pipe. The squared outer edge of the pipe must also be filed down slightly. All these surfaces should be lightly sand papered and cleaned down. More detail on solvent cementing is available on the DVD.

Attaching support ropes

The entire rising main and cylinder assembly is slung from the pump head, but a safety rope attached to the base of the assembly assists in lowering and raising the pipes.

Supporting ropes are attached around the lower end of the PVC connector attaching the cylinder to the rising main pipe and also to a link on the steel socket welded below the rising main support plate.

Installing the pipes and rods

The pump head will have already been fitted and bolted to a 150mm diameter steel tube mounted in concrete on the well slab (or borehole). The first length of 63mm PVC rising main will include the cylinder, and foot valve with supporting ropes attached around the cylinder. The rope is useful as it can be used to both lower and lift the PVC pipes to assist the pump mechanic who handles the pipe directly. The rope slides through the opening in the rising main support plate where the sharper edges have been smoothed off. This hole also serves as a dip plug hole where the water level in the well or borehole can be checked.

The twin ropes of durable material are bound securely to the cylinder and are long enough to reach the pump head and at least half a meter beyond. The lowest pipe with cylinder, foot valve and rope attached is lowered down through the opening in the base plate of the pump head. The rising main support plate holds up the rising main pipe through the PVC socket bonded to the top. The rope is also secured to the pump head. The next rising main pipe is then brought to the pump head and made ready for attaching to the PVC socket held up by the support plate. In this trial installation the writer and his gardener performed the job. Note the pipe holding tool mounted to the top of the pump head. This holds the upper pipe in position which the solvent cement bond between the pipes, cures. In this installation a barrel nipple joins the foot valve and cylinder pipe.

Using PVC socket unions to join the pipes – an experiment


Using the PVC socket union to connect PVC pipes. The two halves of the socket union have been screwed tightly together before the rising main is lowered further. The pipe holder secures the pipe. The rope assists in both lowering and raising the PVC pipe. If the pipe is raised when fully or partly filled with water, water is extracted first with a bailer. This reduces the weight of the rising main considerably.


Spanners of various types can be used to tighten the socket union joint. Each section of pipe is lowered using the same method of connection. It is wise to tie the supporting rope to the rising main as it is lowered. This may help if a mistake is made and the rising main needs to be lifted and not lost.

Fitting the PVC rising main to the pump head


The 65mm steel barrel nipple attached to the rising main is threaded into the 65mm steel socket of the pump head. The threads are secured with marine silicon sealant and the steel parts coated with red oxide. The supporting rope is also attached to the pump head and barrel nipple. The water discharge unit is now tightened to the pump head.

Lowering the piston and 12mm stainless steel rods down through the rising main.

The lowest rod (including the short rod attached to the piston) is lowered down the rising main. As a safety precaution a special tool which screws into the 12mm stainless steel rod socket is attached to the top of the rod. The rod is lowered and is held up by the round rod holding tool which has a slot into which the rods fits and holds it up securely.

The sockets on the upper and lower rods are tightened with spanners. After all the rods have been lowered and the components of the floating washer assembly fitted the bolts securing the Floating washer assembly are tightened and the wooden block with handle fitted. A full description of this model of the Bush Pump can be found on the accompanying DVD.

Tools

Left: Tools and equipment for rod lowering and extraction. Right: Selection of tools used for 53mm open top cylinder Bush Pump management.

Overall summary

It can be seen that a great deal of back yard work has been carried out by the writer on various aspects of the Bush Pump, and in recent years, those parts which lie underground. The overall aim is to make the pump easier to maintain and to cut down on "down time." The Bush Pump head is a strong durable unit and as this work has shown can be adapted to a range of down-the-hole components. As with all the backyard experiments carried out by the writer, the value of these adaptations of the revised down-the-hole components of the Bush Pump can only be judged by monitoring working units in the field which are heavily used through a range of depths. It is hoped that such testing will reveal merit in the field and eventually an increase in the ease of maintenance of this hand pump. It is important in the national interest and also for those people who rely on the Bush Pump for their daily water that the pumps provide a good and reliable service and where the pumps are more easily maintained.

Those of us who have been involved with the Bush Pump, realise that it's a model which is only used in Zimbabwe, and thus has little interest for those who operate outside this country. We have never thought of this pump as a competitor to any other hand pump, but as Zimbabweans, we are proud that a hand pump which has its origins within this country and so far back in time, still operates, albeit in modified form, serving millions of folk, both in the towns and cities as well as in the rural areas, for which it was designed.

What we have tried to demonstrate is that the pump is adaptable and can be used in many settings. Looking back over the years, we have been involved with a great deal of research work linked to this pump. Almost in every case trying to improve its ease of maintenance. But on every occasion, we seem to come back to the original, that is the robust version which has a generous output of water and rugged components from top to bottom, and yet takes an effort to replace the fasting wearing part – the leather seals.

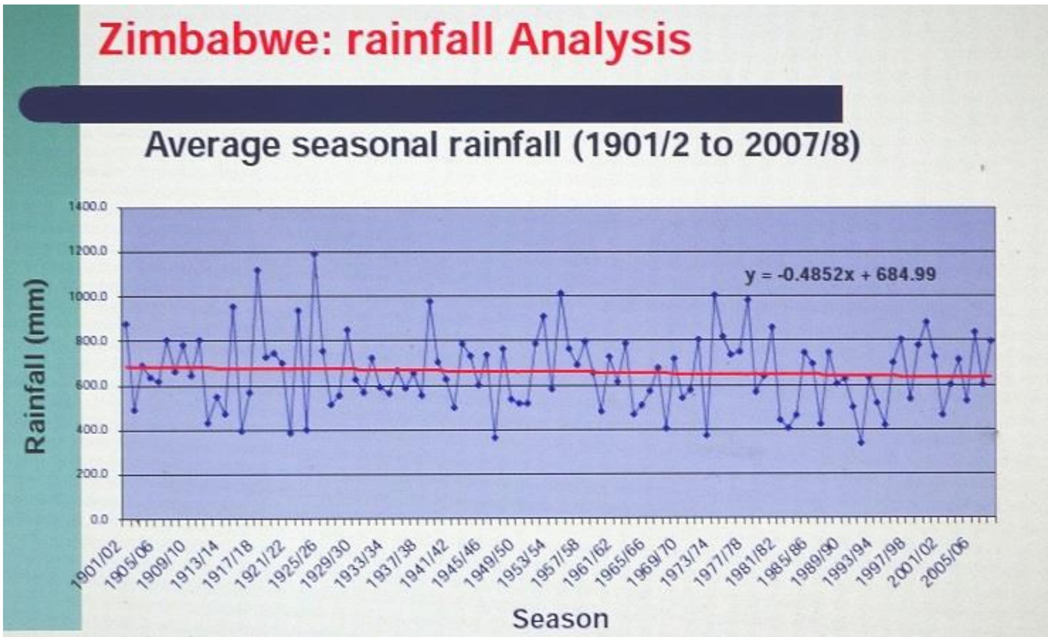
And yet our experience has shown that when the pump is well manufactured with high quality seals and is properly installed on a properly made borehole, it can function for years with little attention. These features in themselves have great merit.

When using smaller seals, the life of the seals is reduced, and within the VLOM concept, a change of seals and even bearings (in the case of the Afridev) may require a change of parts on a yearly basis. Whilst the change of seals is much easier, it still requires special skills by those who do the job and also a supply of spares. As we have found out with the Bush Pump, if an error is made in the re-assembly of parts after a maintenance procedure the pump will break down again for one reason or another. So the emphasis remains on quality workmanship at every level. One aspect of the B type Bush Pump, which has been overlooked is that it can be completely removed from the borehole and many parts reconditioned in a workshop. Many older pump heads can be restored to work as new. The wooden bearing has a very long working life with two sets of working holes.

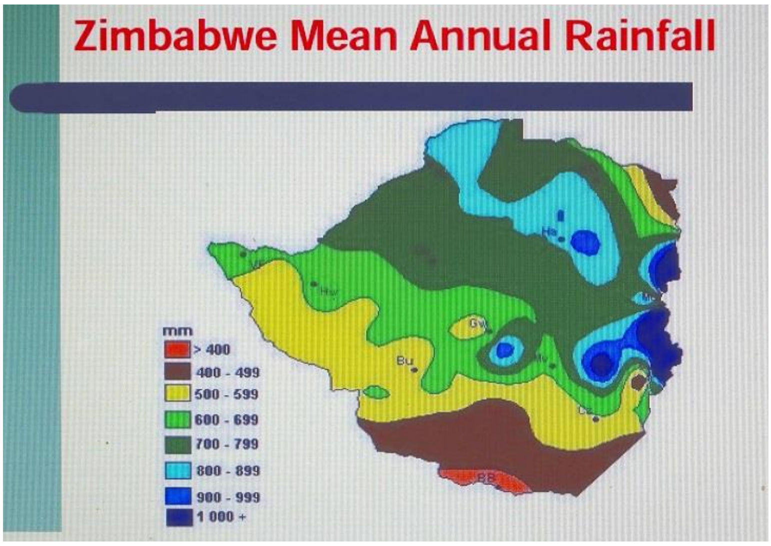
The many descriptions of the pump and the various research studies that have been performed on it can be found on the DVD attached to this book, together with descriptions of many other aspects of Rural Water Supply, Sanitation and Hygiene.

A study of rainfall and ground-water levels in a suburb of Harare, Zimbabwe.

Several studies have recorded the state of rainfall and climate since the beginning of the century in Zimbabwe (formerly Rhodesia). The following charts summarise this very briefly. There can be little doubt that in Zimbabwe the conditions of drought (below average rainfall), have occurred several times in the past (1912-16, 1927-37, 1943-52, 1959-73, 1982–2000, and beyond. The charts also clearly show periods of above average rainfall in the 1920s, between the mid-1950s to the mid-1960s, and the mid-1970s to the early 1980s. These periods of both above and below average rainfall are likely to continue into the future. After the period shown in the graph below the rainfall has continued to be variable with increasing variability within the rainfall season itself being recorded.



Annual rainfall in Rhodesia and Zimbabwe 1901 to 2006. Country wide averages. Data from Zimbabwe Meteorological Office



Variation in seasonal rainfall in different parts of the country. Data from Zimbabwe Meteorological Office. Note the area around Harare shows a mean annual rainfall lying between 800 and 899mm

This chapter reports on rainfall patterns linked to ground water within the Harare area, which has an average, although variable rainfall between 800mm and 900mm. The 2015/16 total rainfall for our recording station in Harare is below that of 2014/15 which is below that of 2013/14. The 2015/16 season not only reveals reduced amounts of rain, but also a repeated change in the distribution of rain throughout the rainy season, which affects the growth of the main stable crop, maize. Furthermore, reduced rainfall in the region has resulted in drastic reductions in the level of the Kariba Dam – one of our main sources of Zimbabwe's electric power. However, during the 2016/2017 season we received a rainfall well above average. The 2018/2019 season was well below average in Harare, despite the enormous floods and damage caused by cyclone Idai. The bottom line on all this is that fluctuations in weather patterns are quite normal for Zimbabwe and will continue. And they appear to be unpredictable. These fluctuations are also quite normal for the planet as a whole. As far as ground water is concerned, we know it is linked to a combination of rainfall and local geological conditions.

Linking ground water and rainfall

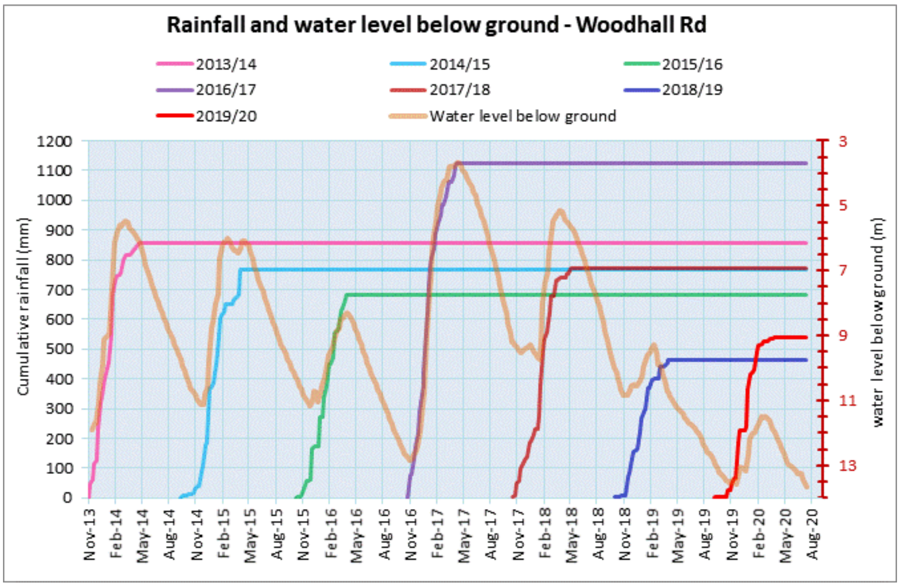
Studies of ground water levels related to rainfall in Zimbabwe seem to be scarce. Within the last 40-year period, ground water tables appear to have reached a peak in the mid to late 1970s. Since that time, water tables have generally fallen even though there have been years of heavy rain. There may be several reasons for this, including ground water extraction by efficient pumping methods. Changes in ground water tables related to rainfall in a shallower aquifer have been recorded in the writer's back yard, a suburb of Harare called Marlborough, and also in his former research area, a peri-urban settlement called Epworth, close to Harare. Rainfall recordings taken in Harare only reflect the position in this specific region. Other parts of the country receive both higher and lower rainfalls each year. As seems quite normal, there is much variation from year to year in all regions of Zimbabwe.

Studies in a specific site in Marlborough, Harare (2013 - 2020)

Marlborough, where we live is a northerly suburb of Harare. It is fortunate to sit above a relatively shallow ground water aquifer, thus providing an excellent source of underground water compared to many suburbs of the city. However, as the years pass, the level of ground water is definitely receding. Our hand dug well, 12m deep, dried up for the first time in 2013 since 1977 when the water table was only a metre or two below ground level. Our tube well (borehole), hand drilled in the early 1980s to 16m, showed signs of stress for the first time in 2013 when the electric submersible pump switched off automatically when it started to pump air. In late 2013 the pump could only run for less than 20 minutes until it started to pump air. It was then that I decided to keep accurate records and make provision for harder times to come.

Normally the ground water table starts to rise in December, after a normal rainy reason which should begin mid-November. In that month the "overburden" – the soil layer above the water level becomes saturated and this has an effect on the water level in the ground below, which starts to rise.

Monitoring water levels is valuable as one can assess the state of one's own water supply throughout the year and assess one's own and the neighbourhood's vulnerability. Since the end of 2013, I have recorded both rainfall and water table in our garden, as a means of understanding more clearly the relationship between the two. The simple method of recording water depth in the tube-well in which an electrical submersible pump is installed is described in another report (*A simple method of measuring water depth in wells and boreholes. Aquamor. 2015).* There is a remarkable correlation between the rainfall and the rise of the water table. The graph below shows the latest position of the water table on August 1st 2020. The graph also reveals the effect of mid rainy season dry spells on water level and most importantly the comparison between consecutive rainy seasons. The poor rainy season of 2015/16 was in stark contrast to the heavy rainy season of 2016/17 with the rainy season of 2017/18 being closer to normal and the 2018/2019 season and 2019/2020 season being below normal.



Relationship between rainfall and water table in the Marlborough station, Harare 2013-2020. The latest reading shown here was on 1st August 2020. The close relation between rain and water table is very clear.

The graph reveals how closely the water table relies on rainfall at this station, and how one might predict the ground water level at the end of the dry season by using the rate of fall of the water level once the rain stopped. By doing this one can take appropriate steps (e.g. water storage) to prepare for the critical months of October, November, and December. As the graph reveals, the rate of fall of water in the tubewell seemed to be similar in 2015 compared to 2014. The heavy rains of the 2016/17 period revealed a steep and unbroken rise of water table, reaching a new high level for the period which was followed by a slighly faster (steeper) rate of decline. This single heavier rainy season of 2016/17 restored the water table significantly and assisted the following year in raising the water table to a respectable level, even although the rainfall of 2017/18 was slightly below average. The water table measuments of 2016 reveal the first sign of a water level drop on 24th April, an observation repeated almost to the day on 21st April, 2018. The heavy rainfall of the 2016/17 season also restored the water level in many dams. The poor rainfall on 2019/20 lowered the level of many dams. The graph above reveals the lowest water level recorded at this site since 1977. After this reading, pumping was no longer possible and stored water became the only source of our water before the rainy season.

Three other observations are worthy of note. The first is the length of the dry spell within the overall rain season. Years ago, there was no such dry spell and rain (according to local reports) followed a regular pattern throughout the maize growing season from mid November to the end of April (see *Wayward Winds* by Jack Hattle, 1972 – Bundu Series).

Rainfall by month. 1972 (Harare) in mm from *Waywood Winds*

Jan	Feb	Mar	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
190	180	100	40	10	10	0	0	10	30	90	190

In more recent years this prolonged rainy period of rain from November to April has changed with a drier period within the overall rainy period. This has a serious affect on the growth of the staple crop, maize. This was particularly noticeable during the 2015/16 and 2017/18 rainy seasons. Early planting in mid November often fails unless there is a chance of artificial watering during that period.

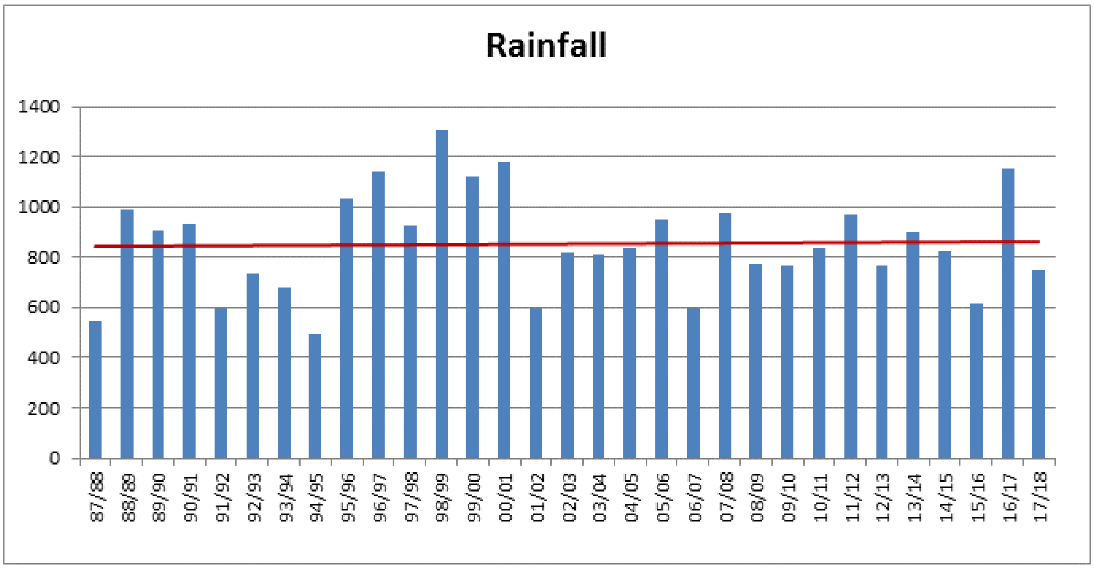
The second observation was the curious early rise of the water table during the 2017/18 season before sufficient rain had fallen to saturate the overburden. It is thought that after the rains started in 2017 the use of boreholes for watering slowed down dramatically, reducing the withdrawal of water from the aquifer thus making the water table rise before the influence of water draining down from the overburden took place. Our tubewell site is now surrounded by many self funded boreholes, which use a meaningful amount of water during the dry season for domestic use, and garden and lawn watering.

The third observation and possible influence on the water table is the abundance of large trees in the area, which include gum, pine, and cypress trees, and a huge rubber tree and Kenya coffee tree. These were small in earlier times but have grown significantly. These can extract large amounts of water from the overburden and possibly deeper ground water.

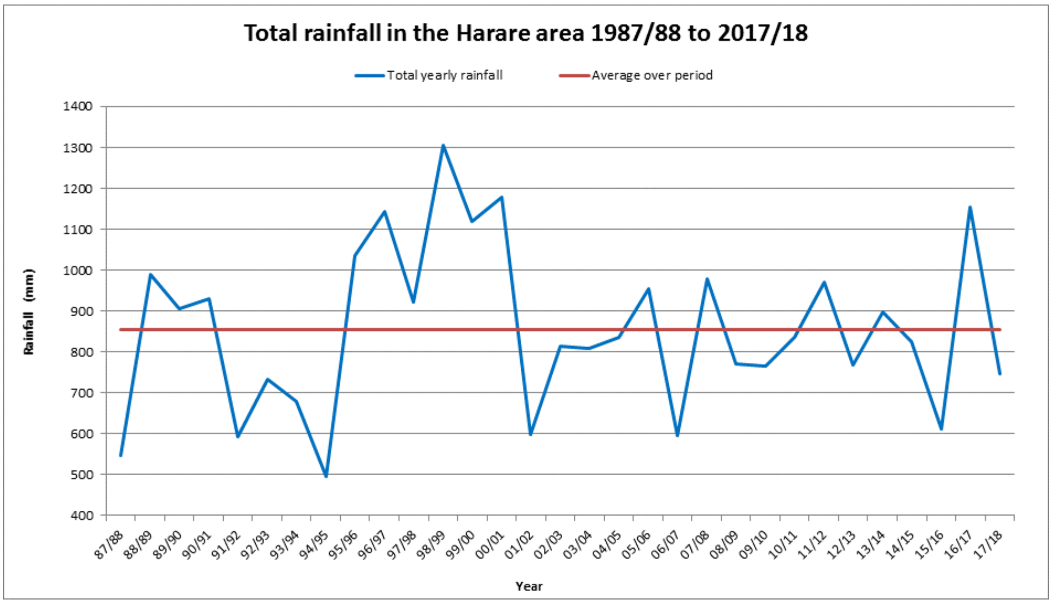
Further observations

Whilst postulations suggest that Zimbabwe will become a drier country as the years and decades pass by, it is interesting to note that in the lower Gweru district of Zimbabwe, several very deep family owned wells were dug many years ago - up to 30m deep. Currently the water table in these wells is only a few meters from the surface (Peter Morgan. A report to Sida, 1995). Such wells could not have been dug under more recent conditions, simply because when using traditional methods (bucket and rope) it is only possible to excavate a few metres below the resting water table when a wel1 is dug. It is very likely that these wells were dug towards the end of the 1960-72 "drought" period which was characterised by persistent below average rainfall, when the water table might have been very low indeed. These deep wells provide evidence that water tables have been very low in the past. This also suggests that reduced water tables are not just a feature of the most recent era, but also occurred in the past. Digging down deep during periods of low rainfall and particularly during the months of November and December may have significant benefits.

The variable nature of the rainfall has been well recorded on a daily basis by Lynn Coetzee and her family in the Harare area. Like the Marlborough figures, these record rainfall for sites in the Harare area, and are not country-wide. The figures recorded below are derived from very accurate data recorded since the 1987/88 rainy season. They reveal very clearly that a good rainfall year can be followed by a poor rainfall year and vice versa. The borehole in the Coetzee garden is 50m deep and was prolific in years past. Since the municipal water supply became sporadic, the borehole capacity reduced significantly and became seasonal. This was partly due to the number of additional boreholes drilled during this period for private use and a huge influx of businesses into the upstream area. The period 2015/16 saw the borehole producing very little for almost the entire season. These figures also reflect the great variation in water depth even within Harare itself, no doubt reflecting local geological and other conditions.



Figures for total rainfall 1987/88 to 2017/18 in the Harare area kindly provided by Lynn Coetzee who is much thanked for her generous contribution.



An alternative way of revealing Lyn Coetzee's figures for rainfall. Many thanks to my son, Paul Morgan, for producing these graphs.

Interpreting these graphs

These graphs reveal a great variation in rainfall (and most probably how it affects ground water levels) which are not only charcateristic of the present but also of the past. The Earth on which we live passes through many natural cyclical pathways, which have been quite normal throughout the ages. The graph above shows quite clearly that a season of high rainfall can be followed by a season of low rainfall and vice versa. It is noteworthy however that the graph above reveals 14 years of above average rainfall and 17 years of below average rainfall. Does this mean there is little difference over time, or is there is a trend towards an increase in lower rainfall seasons. Perhaps it is too early to predict, but most specialists believe we are entering a period of below but still variable rainy seasons. Also the writer has noticed over the years a relatively drier spell which occurs during the overall rainy rainy period. This is revealed in steps in the accuulation of rain during the initial rise of the season. The 2019/2020 season reveals the lowest level in our own tube-well since 1983 when it was first drilled. And it is predicted (but not yet certain) that the tube well (which is our only supply of water, apart from rainfall) may dry out later in 2019. However, by early December 2019 it was still possible to pump limited quantities of water from it. As a result, steps to increase our water storage capacity have been increased. After August 2020, we had to rely solely on stored water until the rains

Global weather patterns and influences on local rainfall

Predictions for a below average rainfall for the 2015/2016 season had been made for Zimbabwe, based on the relationship between El Niño, La Niña, and the climate of Southern Africa. The El Niño-Southern Oscillation (ENSO), is a cyclical pattern involving the relationship between the temperature of the Eastern Equatorial Pacific Ocean and global weather patterns. One of the relationships is said to occur between a warm-ocean phase linked to an El Niño effect and below average rainfall in Southern Africa, and a cool-ocean phase linked to a La Niña effect and above average rainfall. However, the climate throughout Southern Africa does vary greatly from region to region, and predictions based on the relationships described above do not always materialise. The El Niño and La Niña effects are not the only factors that influence the climate in Africa. There are other locally relevant influencers of climate, like the sea surface temperatures of the Indian Ocean, the southeastern Pacific Ocean, and the Tropical Atlantic Ocean, which are also known to influence the climate in adjacent land areas. The severe cyclone, which caused much damage and loss of life during March 2019, was influenced by raised sea temperatures and other factors in the Indian Ocean. In terms of climate and climate change, a huge number of influences are at work, not least the intensity of radiation from the sun and the orbits and rotations of the Earth, and of other heavenly bodies around the sun, as well as those many thoroughly natural and cyclical patterns taking place on the Earth itself. These include tectonic plate movement, volcanic activity both above and below sea level, and many other factors. Global warming and cooling are quite normal and natural events and there is much evidence to support this. Predicting what can happen remains a difficult part of scientific endeavor.

What can we do now – in Zimbabwe

That varying weather and rainfall patterns have caused and continue to cause the country and its people periods of difficulty, there is no doubt. Zimbabwe's well-being is much dependent on water as in any other country. The staple diet of the population, maize, depends on a good consistent rainfall season. But in recent years the pattern of rainfall during the growing season has changed, with dry periods occurring within the span of the wet season from November to April. This has influenced the growth of maize considerably. Also dams, which generate power are also vulnerable to a series of below level rain fall years. However Kariba rose during 2020, giving hope of more electricity.

Kariba, a main source of electric power in Zimbabwe

If these changes in rainfall pattern are to become more pronounced, if variable, as seems possible, adaptations must be made to cope with the changes, such as modifications in farming techniques, or changes to those foods which are more drought resistant, and alternative sources of power. Survival is closely linked with the ability to accurate predict future patterns and adapt to them even if improved conditions return periodically in the future. However, as we have seen world-wide, so called accurate predictions may not always work. Mother Nature is very elusive in her ways.

For a start, a carefully planned national hydro-geological survey is required to gain vital information on which future national water projects might be planned for Zimbabwe. This would include the state of ground water, linking past records, if they can be found, to present ones, and making wise if not guaranteed predictions for the future. As far as the ever-growing cities and towns of the country are concerned, efforts to renew existing piped supplies to regain former levels of service are obviously required. A huge task indeed. Current evidence shows that an era of self-supply for water has reached the citizens of the cities and towns and even the rural areas of this country. This is partly, but not wholly, a reflection of growing populations and a general migration from rural to town or city life. Maintenance and upgrading of such water supplies is essential.

The concept of family self-supply country-wide

For areas where ground water is still shallow (down to about 15m depth) the promotion of self-supply concepts using family or extended family-based water supplies using wells or tube wells makes sense. Of course wells must be deepened to follow falling water levels, but with some effort this can be achieved at the homestead level. A range of water lifting devices exist from the common bucket, windlass, and hand pump, to the electric submersible. The link between home owned supplies and homestead gardens also has great merit and is commonly practiced in Zimbabwe. The promotion of simple home-based rain water catchment systems can also play a part. In times of water shortage, the construction of simple yet effective methods of storing water, with emphasis on careful and economic use of the precious stored water, makes a great deal of sense. Capture and store the rain when it falls, or the ground water when it is available from whatever source, also makes sense. Conserve and store it and use it wisely when periods of water shortage occur.

Supply for Rural Communities

For rural communities, the use of our National Hand Pump Program must continue, but with far more emphasis placed on maintenance issues and training. New, more user-friendly versions of our National Zimbabwe Bush Pump are on trial. The use of family owed and family-maintained sources of water like wells also deserves a boost in support to improve the overall delivery of water in the rural areas. For centers where many people may congregate, like schools and clinics, the use of electric submersibles and controlled water storage facilities makes sense if power is available, either from the grid, generator, or solar sources. Priority for deeper boreholes should be directed to the drier areas of the country, where the use of family owned back yard facilities is not possible. Coupled with this is the construction of more storage tanks, reservoirs and dams (both large and small) which can hold and retain the precious water when it is available.

Conclusions

Whether *Homo sapiens* moves forward and adapts wisely to a life on Earth is yet to be established. We have a bad habit of conflict and over-exploitation of the natural resources, both living and inorganic Mother Earth provides. Whatever the future may bring for humankind, and for those of us living in Southern Africa, we live now and not in the future, and should rightly take steps which positively influence not only our own generation but also those that will live in the lifetime of our children and grandchildren and far beyond. Whatever happens on a large and influential scale in any country requires wise leadership and practical and dedicated government support. This is an essential requirement for any positive development - optimism, adaptation, and sustainability. Without wise governance, such a scenario is far more difficult to achieve on a national basis. It is very possible that rainfall patterns will improve as they have done in the past. It is also possible that the entire sub-region will become drier. We do not yet know, for we have not been there.

We must come to terms with the world in which we live. We must learn about its finite resources and not just the opportunities which Mother Earth puts in our path. The careful use of our finite resources should take priority – but the evidence suggests that the resources of the Earth are being over exploited more and more to cope with an ever-expanding population and the greed of certain sections of our species. Our very survival on this planet rests solely on coming to terms with Mother Earth, our only home in this never-ending universe.

My home and garden laboratory - a tour

Over many decades I have used my garden and home as a testing ground for many new Health Technologies related to water, hygiene and sanitation. I call it my "Garden and Home Laboratory." The garden is quite large and wild, and lends itself well to all sorts of developments, which if successful or at least promising, can then be transferred and further tested in nearby settlements. The one I have used for decades is the Epworth peri-urban settlement close to Harare.

Living in Harare and the rest of Zimbabwe is very challenging. Power cuts are not infrequent and we use a generator and inverters to keep us with light and electric power. Electricity is called ZESA in Zimbabwe. On the water front, we have not received municipal water for decades, but still are forced to pay for it. The meter reading is not ours- it is either fiction or somebody else's. Our water is drawn from the ground through a tube well 16m deep fitted with an electrical submersible pump, running off ZESA. The generator can be connected if necessary. We have quite a lot of storage capacity for water. We can also tap rainwater and store that. We have two hand pumps. An experimental Bush Pump on a well, but that is only 10m deep. I also use a modified Blair Pump, which raises water from a submerged water tank (cistern) which is filtered and used for drinking and also used for general kitchen use. Water for the flush toilets is pumped from the borehole/tube well into a tank. In order to save flush water for the two flush toilets, I have modified both to narrow the throat of the entrance to the U bend of the toilet. This is a feature of most modern flush toilets. It allows the toilet contents to be flushed with greater speed and thus uses less water. In our case I narrowed the throat, as I call it, with smoothed concrete. We also use a special home-made water heater for our shower unit which saves on ZESA. We top up the tank in the roof daily from the submersible and then switch on the heater for between 30 minutes and an hour to make enough hot water for my wife and I to take our daily shower. When there is no ZESA we can heat water up on the gas stove and mix this with cold water and add this water by bucket to a special shower unit which hangs in the shower cubicle. Alternatively we can heat water in the sun in a simple solar water heater and place this heated water into the shower unit. We also use solar panels to recharge inverter batteries and small solar powered lights. All these gadgets have been in use for many years and they work.

Most people who live in the modern world would think the use of these devices is quite ridiculous. But living in Harare is becoming more challenging and steps must be taken, or must be shown to be taken by demonstration to be practical and possible to save on both water and electricity.

The garden of 1.3 acres has enough room for me to carry out my experimental work and has been used in this way for over 4 decades. Certain sections of it are dedicated to experimental work. Some call this R&D (research and development), I call it tinkering. Many of the first technologies described in this book were created in house and home and garden. The first testing of the spiral tube water wheel pump were undertake there, and other models of the Blair Pump (which was conceived and first built in Madziwa in

1976). Early tests of the "Bucket Pump" now known as the "Bailer bucket" were also undertaken in the early years after 1980 (Independence in Zimbabwe). Many variants of Health Technology had were first developed in Marlborough. These include the "B" Type Bush Pump which became the national standard in 1989. The "C" type Bush Pump – a simpler version was also first built in the garden. I still retain the first prototype B and C type Bush Pumps in my home museum. Various hand washing devices have been developed and a home-made water filter (the candle part was purchased). The work on improved wells took place mostly in Epworth, but the concept of upgrading a series of "upgradable family wells" started in Marlborough. The concept of the "upgradeable Blair VIP was first researched in Marlborough, with its corbelled brick lined pit. Then the work was transferred to Epworth. The garden laboratory was also used to develop many aspects of Ecological Sanitation – not only toilet designs like the *Arborloo*, *Fossa alterna* and *Skyloo*, (a urine diverting toilet), but also many plant trials on vegetables and trees using toilet compost and diluted urine as nutrient sources. Several rain water harvesting methods have also been built and tested in the garden together with a range of water storage tanks. A simple hand drilling rig for drilling shallow tube-wells in softer formations has also been designed and constructed our garden and tested in Epworth. A section of the garden was set aside to train people how to examine the national "B" type Bush Pump. Trials in our garden have started using PVC rising main pipes (rather than steel) together with galvanised iron and stainless steel pump rods as part of the "B" type Bush Pump development programme. This work uses an "open top" cylinder concept which makes possible the exchange of piston seals without lifting pipes. This work continues to the present day. On the home front modifications have been made to our flush toilets in the house to make them more economical and efficient in terms of water use. Novel shower units have also been developed to use water economically and wisely, frequently heated by the sun. This technique makes possible the concept of aromatherapy, buy adding special oils to the heated water prior to the shower – with a resulting health benefit. This chapter briefly describes and illustrates some of the more obvious developments – I have forgotten some and no doubt more will come. My garden and home laboratory has played a major part in the developments I have made. This is still the case today when I am in my 77th year. I am putting together a series of photos with a brief caption beneath, to try to provide the type of developments which have taken place in our garden and home in Harare.

Part of the experimental part of the garden in April. 2019.

The annotated photographs of technologies used or demonstrated in house and home

In the home


Two flush toilets which have been modified so they use less water more efficiently. All these techniques are discussed in more detail in the accompanying DVD.



Left: simple solar water heater made from a used 5 litres plastic oil container and painted black on one side. It is placed at a slant to face the sun. The slant also produced a circulation of water within the container. Middle: The shower unit is simply made from a bucket and pipe fittings and can hold about 9 litres of heated water. The water can be heated by the sun, gas or electricity. It makes an excellent shower. Right: the essential candle filter to purify water. This version was made in India, but the candles have been changed several times. The latest candles were made in the UK. The candle filter is an excellent way of purifying water bacteriologically.

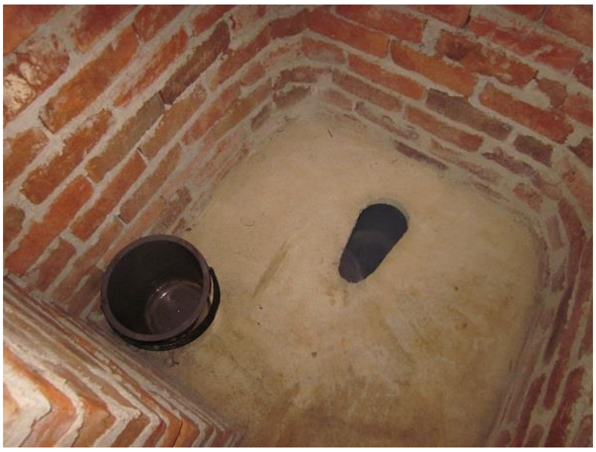


Solar powered lights and a solar panel together with a generator. Many households in the cities and even the rural areas are using these devices to generate their own power. Also in the cities people are drilling their own boreholes to get their own supply of water.

In the garden

The demonstration include a variety of toilets, wells, pumps, hand washers, gardens, rainwater harvesters etc.

Toilets

The spiral brick Blair VIP. Interior. Blair VIPs are also used as bathrooms – so they have a dual function. This version has an asbestos pipe and roof. PVC pipes can also be used and roofs made of corrugates tin sheet nailed to a treated wooden frame.



The Blair VIP (doored version) sitting on a ring beam with no pit lining.
There are many versions of what can best be described as a ventilated *Arborloo*, which is a hybrid between the Blair VIP and the *Arborloo.*



The "Skyloo" is an above the ground urine diverting toilet. It uses a specialised pedestal which separates faeces from urine. Urine passes to the front and faeces to the rear. The faeces collect in a plastic bowel together with soil and ash. After a period, the contents of the bowel are transferred into a twin pit composter together with leaves and more soil.

Skyloo: Faecal solids fall into the basin and soil and leaves are added. Urine passes down a pipe into a plastic container. The mix in the basin when nearly fill is transferred to a double composting pit (right). Further soil and leaves are added. The mix turns into a good compost. The composting pits are alternated.

VIP toilet using a door fitted with self-closing hinges. The interior is fitted with a smart pedestal. The unit is completely odourless. Toilet paper kept in container and hand washing facility outside. The structure is made from a steel frame with grass used for walling.

***Fossa alterna*: This toilet uses two pits alternately. Soil and leaves are added to the pit as well as faeces and urine. The toilet structure, which is portable, is moved from one pit to the other at yearly intervals. When one pit is filling the other is composting.**

Blair toilet configurations. The spiral structure provides a unit which is stable and semi (but not completely) dark inside. Semi darkness is required for fly control. On the left bricks built on edge. On the right and demonstration of a wide foundation on which the structure is built. An experiment to see if such a broad base will support a brick structure without a pit lining. A pit lining is far preferred.

Hand washers

Alloy can hand washers (larger and smaller size). A bucket acting as a reservoir of water is also required for the alloy can washers. For inside or outside a bucket with lid is fitted with a simple tap. Convenient as a back-up when water runs short at the hand washing basin.

Family well demonstrations

Family wells with and without a windlass. An improved “head-works” – a concrete “apron” and water run-off, a raised collar on top of the well slab and a lid help to improve safety and water quality. The addition of a windlass keeps the rope or chain off the ground. The family well is an excellent example of a self-supply principle which originates in traditional practice. Simple improvements make the unit safer and more hygienic. These examples have been replaced by later examples.

The latest demonstrations of the upgradeable upgraded family well (uUFW). Details on the DVD.

Hand Pump demonstrations – Blair and Bucket pumps



A raised head works is an important part of an improved water supply. The Blair pump is a simple direct action hand pump which can lift water up to 12m. It can be hand built from parts off the shelf. Bailer- bucket principle is even simpler and raises water mainly from tube-wells. School pupils have been taught how to make bailer buckets.


The high delivery Blair Pump is used almost daily in our home. It pumps water from a brick and mortar built tank (cistern) built mostly underground. It is normally filled with water from the borehole/tube well. The water is pumped into buckets and 5li containers. The buckets of water are stored for kitchen use and the water collected in 5 li containers are passed through a candle filter for drinking. This water is very safe for drinking and has a good taste. It has no chemicals in it.

Bush Pump trials and demonstration



Bush pump on trial. The “B” type was first designed in Marlborough in 1987 and placed on 2 years trial by the Government of Zimbabwe. It became the national standard in 1989. Current work involves testing the use of PVC pipe and stainless steel rods on a “53mm open top stainless steel cylinder” version of the pump. On the right a place in the garden for demonstrating how to examine the bush pump. The Bush Pump work is described in far more detail in another chapter of this book and on the DVD.

Rainwater harvesting

As the annual rainfall pattern is changing in Zimbabwe, as global climate change is taking place, the role of collecting rain during heavy bursts becomes more important. In 2019 the rainfall pattern (at time of writing) seems to be far less than normal. This is despite the fact that sometimes heavy storms occur and deliver much water. Our ground water table is falling, due to reduced levels of rainfall, together with an increasing amount of ground water being taken by others users of boreholes which surround us and also by the ever growing trees in the garden, which also take up the water. Thus the place of alternative sources of water, such as rain water becomes more important. This particular collector is stored rolled up, but within minutes can be slung between the 4 treated wooden supports and the resulting rainwater stored in the tank or in plastic water containers. An up to date account of the use of this rain catcher can be found on the accompanying DVD, where the collected rainwater was delivered to two tanks for onward passage to other tanks or to the kitchen supply.

Rain water harvesting is an important method of gaining water for families. Here a plastic sheet collector is shown together with a brick and plastered water tank to receive the water from the rain water collector. Rainwater can also be collected from roofs in large quantities but the quality is suspect. The plastic sheet is solar protected and delivers good quality water if the system is cared for. It is always best to pass water for drinking through a candle filter. Water can also be collected from this "rain catcher" in 20li or 25li plastic water containers.


The rain catcher in March 2019. A full account can be found on the accompanying DVD.

Water storage tanks

The storage of water during periods of below average rainfall becomes more and more important, whether it is for the homestead or for the nation in dams and reservoirs. This is particularly important as we seem to be entering a period of below average rainfall. Our 16m tube well became unusable due to falling water levels after August 1st 2020, for the first time in 36 years this. This reveals the diminishing ground water levels in our own aquifer and also the aquifers of Harare, other towns and cities and the nation as a whole. It is very possible the same trend is occurring in many parts of the African continent. Changes in climate are partly responsible and also the greater dependence on underground water for domestic supply in the towns and cities as municipal supplies are failing or inadequate and where the water quality may be suspect. Thus water storage becomes more important. Here are a few photos of the current water tanks in our garden.


Left: This interesting tank is built from concrete and bricks. Its novel features are the use of shade cloth to reinforce the domed concrete roof and the "bailer bucket" to take water from the tank. Right: a home-made brick tank and a commercially made plastic tank. These rugged plastic tanks are very popular.


A brick built storage tank with heavy duty plastic and shade cloth cover. A 5000li plastic tank



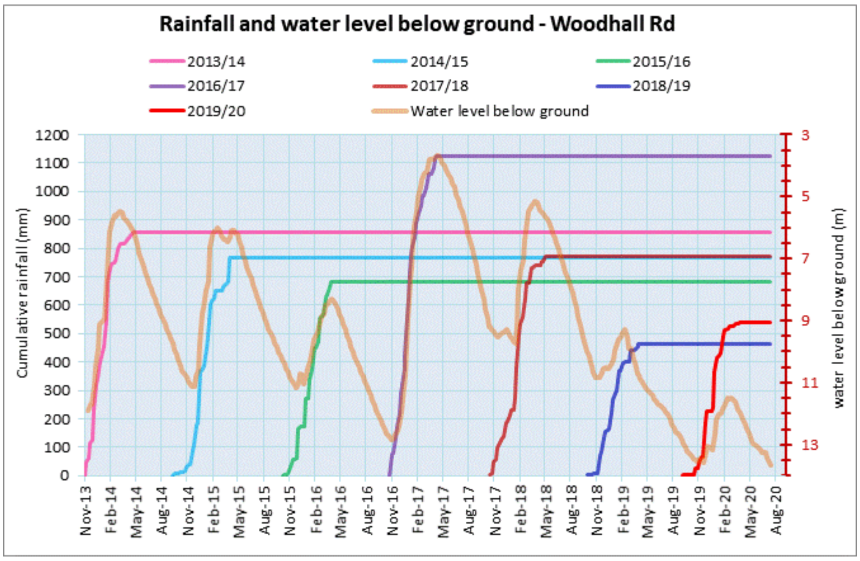
Left: A rainwater harvesting tank for the garden, normally covered by a high density shade cloth. This appears to stop the breeding of mosquitos. Leaves also fall on the shade cloth but the water is just used for gardening. Centre: tank linked to the rain water harvester. Right: tank linked to the kitchen supply.

Measuring rainfall and water table

For a few years now I have been measuring our rainfall and the related water table level in our tube well. This work clearly shows the relationship between rainfall and water table level. I use a home-made water table measurer, which consists of a simple electric meter (the old type with a needle) attached to a twin cable wire which a weight on the end (a long thin file) and the two exposed copper wires on the electric cable. At monthly or two weekly intervals I lower the wire down the tube well (there is an access hole) and when the water is reached – the needle deflects. I place a plastic tape around the wire and mark it and then measure the difference between the new and older mark. This is recorded on a chart. I send the results to my son, Paul in the UK and he sends me an updated graph. An electric submersible pump is fitted down the tube-well.

Measuring the water depth in the tube well with homemade equipment. When the two bared ends of the electric cable meet the water, the needle deflects. The cable is marked and the result recoded. This shows us the state of our vital ground reservoir of water.

Deflection of the needle



Graph of rainfall and water table 2013/14 to 2020

Home-made hand operated drilling rig

The best known and successful hand operated drilling rig in Zimbabwe is called the *VonderRig* designed by Erwin von Elling, This is a very robust unit capable of drilling through soil and even decomposing granite down to a depth of over 20m. I decided to design and make a simpler, lower cost unit in the back yard which could also drill shallow tube-wells, but in softer soils which had a water table up to about 12m deep.

It all starts with thinking it out, then building and testing prototypes. Then construction in the garden, in this case using off the shelf components (apart from the auger itself which forms part of the *VonderRig*. Street-side welders were used to do welding. Then testing in the field. Shallow hand drilled tube-wells are lined with PVC pipe. They can be fitted with different types of water lifting devices. For simplicity my favourite is the bailer-bucket, which is simply made and very reliable.

Ring beam gardens and growing vegetables and trees

Many experiments have been undertaken with "ring beam gardens" in the past. These photos show a few earlier experiments.

Earlier photos of ring beams with spinach, rape, covo, lettuce pumpkin and sweet potato.

One ring beam cropped. A large amount of green vegetable was cropped followed by pumpkin and sweet potato

Times to remember

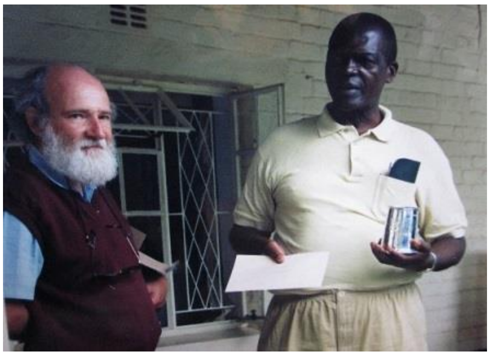
No memory of my work in this sector can be complete without the memory of many of my dear friends and colleagues who have played an important part in assisting me over the years. Below a few photos to commemorate those times

Left: With some of my team, Ephraim Chimbunde, Fambi Gono and Philimon Ndororo and Right: Mr von Elling who mass produced Bucket and Bush Pumps and our team members.



The "B" type Bush pump on trial in Epworth in 1987. The mass produced Bush Pump at a demo site. Standing next to several demonstration Blair VIPs.





Ministry of Health Staff around an Upgraded Family Well. Ephrain Chimbunde, my Field Officer and an excellent trainer with Philimon, one of our 3 builders. I presented Nason Mtakwa, Decade Officer for the MOH with an award of my own. Sadly all those people shown in the photos above, apart from Philimon have passed on and are memories of the past.

There are many people who have helped me enormously over the years. They are mentioned in full in the acknowledgement section of this book. The work which has been achieved would not have been possible without them. I am particularly grateful to my wife, Linda and my family who have supported me over all these years. Linda has had to put up with a mess in her home and garden for years – without complaint!

Brief summary and conclusions

This new small work attempts to reveal how much of my development work, at least the first stages, have taken place, backstage, as it were. In this case the back stage is the back yard or garden. Once the backstage work has been developed to the point where it can pass on to the "outside world" the back yard work may continue. In the back stage, away from public view, one can observe and ponder on the various developments in one's own time. Faults can be found and corrected quietly and without fuss or embarrassment. And faults are possible during the course of development work. As always the emphasis has been on simplicity of design and, this has been revealed in all my written works. So this book has also been prepared in a simple language which is understandable to others as well as the writer. I also find that a good photograph can take the place of many words and like all my other works the book is well illustrated. So numerous illustrations with short captions are important.

Little of the works are complete, but make steps forward in the state of the art. That is all one can do as a researcher and also more so as one ages. One feels there is so much left undone. As stated before, this book describes technologies and not methods of promoting or implementing them on a wide scale. That greater achievement can be performed by others more skilled than the reclusive writer of this book. This book and its predecessor printed in 2016, was compiled during the author's retirement. The book is really intended for those who work in Zimbabwe, but some of the concepts are transferable to other countries in Africa and perhaps elsewhere. Few countries will use the Bush Pump as their national hand pump. But this model is revered in Zimbabwe and has a long history which can set an example to others. In current trials, its down-the-hole components are being modernised to make the essential component of maintenance easier or the period of "down time" - when the pump does not provide water - shorter.

The concept of the upgraded family well is also an important component of the rural water supply programme. This is because it makes sense to the users. The question of ownership is solved – the family owns its own asset. This sense of ownership does not appear in community water supplies. It is an early attempt to reveal how important self-supply can be in the developing world. But that concept cannot work everywhere – and like the toilets, there is no one single solution. The good old Bush Pump continues to clank away – often far from where larger communities live – way in the remote bush. That is why I enjoy so much the statement made by District Commissioner Alan Wright in his book "The Valley of the Ironwoods" how he sent up a prayer offering thanks to Murgatroyd and his pump which continued to work far away in its dusty remoteness. I have myself sensed the feeling of being left in isolation deep in the bush, when the dust of the last vehicle faded in the distance and one was left almost alone in the quiet wilderness.

The concept of promoting self-supply by the construction of family wells and rain -water supplies is central to the years ahead in a world where the family unit or extended family unit must look after itself. The same applies to the realm of providing adequate sanitation – where, as in the application of suitable water technology, a range of options is available so the family can make a choice. There is no single technical solution that fits all. So a range of options is very desirable and even essential. If the family has access to information, or better still working demonstrations, then they can make a choice. It is curious that the concepts of the Blair VIP and the *Arborloo* (tree toilet) can be put together as a hybrid and one which is also upgradeable. This is described here for the first time.

Perhaps for the advanced urban areas the modern duel flush toilet system may show the way ahead, in which the user can make a choice as to how much water is used for the flush, which is now more efficient. I have tried to mimic this idea and the efficiency of water use in our own two flush toilets to increase the efficiency of our old fashioned flush. They have worked well for years and saved us precious amounts of water.

The important concept of upgradeability has been introduced here, again, for both water supplies and sanitation. A step by step process of improvement over time, as families can place their precious savings into facilities which improve their life style and health and wellbeing. In the rural environment, low cost and simplicity of design are important, not only for the pocket but for the mind. If such methods have merit, then they have a greater chance of entering traditional practice – the true measure of acceptability and practicability.

The greatest challenge lies in providing reliable and quality water supplies and associated sanitation in the urban environment. It is clear that people in Africa are moving away from the rural areas and locating in the urban and peri-urban areas and in sites with moderately easy access to "town" where they, if luck turns their way, can find work. This is far more challenging in several of its aspects to solving the rural problem of providing adequate water supplies and sanitation. Maintenance is the key. My own experience in peri-urban work, was based in Epworth, where the plot sizes are quite large and the water table not so deep. Here a combination of suitably sited shallow wells and several versions of the Blair VIP have been shown to be suitable.

But this does not apply to areas which are far more tightly packed and where there is no space. Space on a plot provided far more opportunity for the variety of water and sanitation options which have been described in this book. But where there is no space, the solutions are far more difficult to find. For the more sophisticated, duel flush toilets leads to self-managed septic tank or to a working sewer system may continue to be the option for years to come. Many of these owners are now providing their own water from self-managed boreholes. But for millions this is not the case. Attempts have been made in some high density settlements to provide hand pumps (the Bush Pump in Zimbabwe's case) to tap water from underground aquifers in such high density settlements where sewers, laid down in former times have failed, often due to a lack of adequate water. Waterborne toilets do not operate well without water. But unmanaged sewers can leak and then then burst and can pollute the underground water considerably. The planners of earlier times brought their water into such areas from outside if sewers had been laid. And the maintenance of sewers and municipal piped water supplies cost huge amounts of money and constant maintenance. This updating and maintenance is clearly not taking place in our towns and cities.

The dams which provide water for the cities may themselves be polluted (Lake Chivero is an example). It is true that well-chosen sites where quality ground water can be accessed and treated for some areas has potential. But the challenge of providing reliable water supplies and appropriate sanitation for the cities of Africa remains a huge challenge.

Studies to solve such problems are taking place in such areas as eThekwini, Durban, in South Africa, using urine diverting toilets. Much literature on this subject is available on web sites. But even these projects must be well managed so that the large quantities of urine formed and the dried faeces are removed and processed. And there is the every present burden of maintenance – in this case much of it in the hands of the owners. By and large most people of the world do not like the concept of coming into contact with their excreta. The squat and drop method and the sit and flush method are highly favoured, where their use is appropriate, since the user does not have any contact with the waste he or she finds so revolting. Even with urine diversion, which has no flush system, there is always the problem of what some people call "side wall fouling" which must be cleaned up with water and by hand and a brush.

The answer of course is to make the outer peri-urban areas more attractive as places to live where gardens can be larger and people of sense can make informed decisions on how they deal with their water and sanitation. If electricity is available, then submersible pumps on wells and even boreholes can be used. And relatively low cost generators are now also available. The cost of a submersible and a generator is less than the cost of a Bush Pump. But storage is required and a tap. This does not apply to the distant rural areas, where electricity may be far away, and even with solar power, there is a risk of theft. And even solar powered systems require attention and maintenance.

The question of the climate and weather is uppermost in the mind of those who care about our future. The great variation in climate and rainfall has been witnessed and recorded in Zimbabwe, and Rhodesia before it, for over a hundred years. That periods of below average rainfall can be followed by periods of normal or above average rainfall can be clearly seen on the records. But overall, the level of the ground water seems to be falling. This is partly the result of human use and partly due to changes in weather patterns. The over exploitation of ground water in the urban centres is clear to see, as municipal supplies fail to be consistent and reliable in their quality. The availability of water has a great impact on human lives and populations and the state of each nation.

We live in a changing world and not only climatically. The weather cycles are constantly changing and so is the world in which we live. We must adapt to change or suffer the consequences. *Homo sapiens* has adapted well over the thousands of years of his existence – but as the dominant species on Earth, he is pushing to the limit the resources which our precious Earth can provide. And let it be said again. We must come to terms with the world on which we live and survive. We must learn about its finite resources and not just the opportunities which the Earth puts in our path. The careful use and preservation of our fresh water supplies, the land and the sea – the most precious resources on our planet – must take a high priority. Our very survival on this planet rests solely on coming to terms with Planet Earth, our only home in this never ending universe.

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