

**“Sustainable Development in Water and Sanitation”
A Case Study of the Water and Sanitation System at
the
Lynedoch EcoVillage Development**

by

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Declaration

I, the undersigned, hereby declare that the work contained in this assignment is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: _____

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ABSTRACT

Water and Sanitation is one of the key factors in the socio-economic development of a nation and people. Billions of people worldwide do not have access to clean water or basic sanitation leading to many health problems and developmental issues. This article discusses the challenges facing the world, South Africa and in particular the Western Cape and Cape Town in the provision of water and sanitation. For most people the desire is to have access to their own private potable water supply and their own private flush toilet connected via costly bulk water services to sewage treatment plants far away.

The question posed is whether this model is sustainable into the future, given the water demands in many parts of the world affected by droughts and more violent weather cycles as a result of climate change and global warming. These factors will affect water supplies in South Africa and in particular the Western Cape and Cape Town. To answer some of the questions raised the Lynedoch EcoVillage development is discussed in detail in terms of sustainable neighbourhood planning and implementation. Sustainable Development is discussed, also various options in terms of applying ecological sanitation. The on-site water and sanitation system of the Lynedoch EcoVillage is discussed as a case study. The results of influent and effluent tests conducted by the CSIR are analysed to see whether the system is conforming to the Department of Water Affairs and Forestry standards for the use of effluent water in irrigation and re-use of water in toilets.

Localised models of water and sanitation provision might thus be a way forward to satisfy the increasing demand for such services made on national and local authorities as urban areas increase in size and population.

Key Words: Sustainable Development; sustainable urban development; on-site wastewater treatment; eco-sanitation; recycling of water and nutrients.

OPSOMMING

Water en Sanitasie is een van die sleutelfaktore in die sosio-ekonomiese ontwikkeling van 'n nasie en sy mense. Biljoene mense wêreldwyd het nie toegang tot skoon water of basiese sanitasie nie en dit lei to vele gesondheidsprobleme en ontwikkelingskwessies. Hierdie artikel bespreek die uitdagings wat die wêreld, Suid-Afrika en in besonder die Wes-Kaap en Kaapstad in die gesig staar wat betref die voorsiening van water en sanitasie. Vir die meeste mense is die wens om toegang te hê tot hul eie private spoeltoilet wat via duur, grootmaat waterdienste aan rioolverwerkings-aanlegte ver weg verbind is.

Die vraag is of hierdie model in die toekoms volhoubaar is, gegewe die feit dat die vraag na water in baie dele van die wêreld geaffekteer word deur droogtes and woester weersiklusse as gevolg van klimaatsverandering en globale verwarming. Hierdie faktore sal watervoorsiening in Suid-Afrika en veral die Wes-Kaap en Kaapstad affekteer. Om sommige van hierdie vrae te beantwoord word die Lynedoch Ekodorpontwikkeling in besonderhede bespreek in terme van volhoubare buurtbeplanning en implementering. Volhoubare Ontwikkeling word bespreek sowel as verskeie opsies in terme van die toepassing van ekologiese sanitasie. Die plaaslike water – en sanitasiesisteen van die Lynedoch Ekodorp word bespreek as 'n gevallestudie. Die uitslae van die invloed – en uitvloei-toetse uitgevoer deur die WNNR word geanaliseer om te sien of die sisteen aan die vereistes voldoen van die Departement van Waterwese en Bosbou – standarde vir die gebruik van gesuiwerde rioolwater in besproeiing en in die hergebruik van water in toilette.

Plaaslike (gelokaliseerde) modelle van water – en sanitasievoorsiening mag dus n stap vorentoe wees in die toenemende vraag na sulke dienste van nasionale en plaaslike owerhede soos stedelike gebiede in grootte en bevolking toeneem.

Sleutelwoorde: Volhoubare Ontwikkeling; volhoubare stedelike ontwikkeling; plaaslike rioolverwerking; eko-sanitasie; herwinning van water en voedingstowwe.

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LIST OF ACRONYMS

| | |
|-----------|--|
| COD | Chemical Oxygen Demand |
| CSIR | Council for Scientific and Industrial Research |
| DWAF | Department of Water Affairs and Forestry |
| GDP | Gross Domestic Product |
| IDP | Integrated Development Plan |
| LDC | Lynedoch Development Company |
| LHOA | Lynedoch Home Owners' Association |
| NWRS | National Water Resource Strategy |
| SFSD | Strategic Framework for Sustainable Development |
| SACCO | Savings and Credit Cooperative |
| SI | Sustainability Institute |
| SOPMP | School of Public Management and Planning |
| UD | Urine Diversion |
| UN WWAP | United Nations World Water Assessment Programme |
| UNDP HDR | United Nations Development Programme - Human Development Report |
| UNEP | United Nations Environmental Programme |
| UNEP IPCC | United Nations Environmental Programme - Intergovernmental Panel on Climate Change |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WCED | World Commission on Environment and Development |
| WSSD | World Summit on Sustainable Development |

“SUSTAINABLE DEVELOPMENT in WATER and SANITATION”
A Case Study of the Water and Sanitation System at the
Lynedoch EcoVillage Development

“VOLHOUBARE ONTWIKKELING in WATER en SANITASIE”
‘n Gevallestudie van die Water- en Sanitasiesisteem van die
Lynedoch Ekodorpsontwikkeling

“Water is the earth’s eye, looking into which the beholder measures the depth of his own nature”

Henry David Thoreau

“The sewer is the conscience of the city”

Victor Hugo, *Les Miserables*

1. INTRODUCTION

The headlines of a front-page article of the Cape Argus dated 10 November 2006 read “R4,5 bn to defuse sewage time bomb”. The article went on to state that the City of Cape Town would need to spend at least R4,5 billion over the next 10 years to save its waste-water management system – so residents are likely to pay more for water. Similar articles to this have appeared in the printed media of Cape Town throughout 2006. The national sewage crisis was a “ticking time-bomb” (Cape Times, 21 June 2006) where 30 percent of the sewage works nationally needed urgent upgrade while 66 percent needed short- to medium-term attention. Cape Town’s sewage treatment systems failed to meet the national health standards for sewage effluent 25 percent of the time when discharging sewage effluent into metropolitan rivers and the sea (Cape Times, 22 June 2006). Added to this is the problem of future supply of water in the greater Cape Town and Boland area (Midgley *et al*, 2005: 33-40). Cape Town is moving towards some re-use of treated effluent. Potsdam wastewater treatment works recycle treated effluent to the Tableview area, the Milnerton golf course and the farmlands in the Durbanville area¹. The

¹ Media release 22 June 2006. <http://www.capetown.gov.za>. Accessed on 29 September 2007.

Westfleur wastewater treatment works at Atlantis uses artificial groundwater recharge to recover drinking water.

The average citizen should be worried about health hazards and the provision of water and sanitation into the future. Generally the average person just hopes for the best. Most people in formal households turn on the tap in their homes and water flows. They have their own private toilets which flush and sewerage is carried away via bulk services and treated at a treatment plant usually at a fare distance away. About 65% of the people in South Africa have access to adequate sanitation and about 90% access to drinking water (SFSD, 2006:53). This does not mean that they have their own private flush toilet and private bathroom with running water. The question has to be asked whether this model of the provision of water and sanitation is sustainable into the future. The provision of clean water and sanitation is crucial for any form of sustainable development in the provision of housing and for the socio-economic upliftment of people. This article will review the strategies to achieve this, advocating a local neighbourhood approach. The system implemented at the Lynedoch EcoVillage, Stellenbosch, to support this argument, will be evaluated.

2. THE GLOBAL SCENE

Only 2,53% of the world's water is not salty and some 2/3 of this is locked up in the ice-caps and glaciers (UN WWAP, 2003: 8-9)². This available freshwater is renewable but much of it is inaccessible as it is in remote areas and in other areas the rainfall arrives sporadically and often in the form of monsoons and floods – as has been experienced these last few years. Humans have access to only 8% of the world's available renewable freshwater. During the next 20 years, with world population set to reach about 8,5 billion by 2025, more than 3 billion people will be living in water stressed countries (UNDP HDR, 2006, Chapter 4:136). This future population growth is expected to be in urban centers of developing countries. Demands on the world's water supply will increase by 40%. 70% of the world's water is used on agriculture but by 2020 this will have to increase by 17% to feed the world. Facts concerning world water usage can be displayed as follows –

² Refer also to UN WWAP, 2006: Chapter 4.

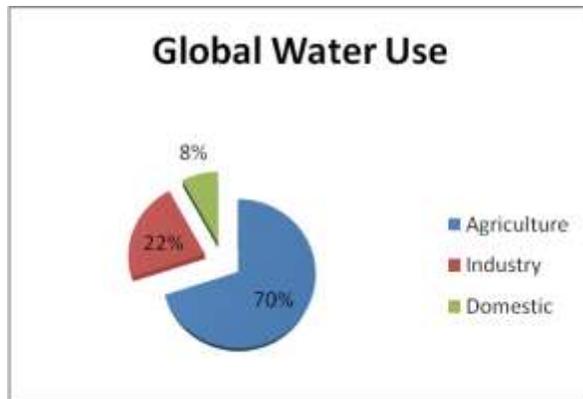


Figure 1.1: Global Water Use
(UN WWAP, 2003:19)

This paper concentrates on water savings and the recycling of treated effluent in the domestic use of water and the using treated effluent for irrigation. Agriculture and industry use the lion's share of available fresh water. Attention needs to be focused also, on water savings and the methods of water use in agriculture and industry.

Safe water and proper diet of people are key to good health but facts are startling – one in five people across the globe have no adequate access to safe drinking water and one in two lack safe sanitation(UNDP HDR, 2006, Chapter 1:33). On current world population of approximately 6,4 billion, this equates to approximately 1,3 billion people without access to safe drinking water and 3,2 billion people without access to sanitation. 1.8 million Children die each year due to lack of clean drinking water and proper sanitation (UNDP HDR Overview, 2006:3). These issues occur almost exclusively in developing countries. Human development is threatened by this global water crisis. Poor people will always suffer without adequate access to clean water and sanitation and will thus not be part of a virtuous circle of human development and economic growth. Countries with these challenges cannot follow a sustainable development path. Great political will is necessary throughout the world to overcome this challenge. The United Nations Environmental Programme report (UNEP,1999) identified water shortage and global warming as the two most worrying problems of the new millennium.

Improvements in water and sanitation provision have been made. At the beginning of the 20th century many of the big cities of the now developed world had similar problems to those

discussed above. With the development of municipalities and their concerted efforts generally, these problems were overcome.

In all regions the provision of sanitation lags behind that of water provision. Cost is one of the aspects affecting the supply of sanitation (HDR, 2006, Chapter 3). It is also illustrative of the rich-poor divide in the world, as most of the social problems of the world affect the poor directly. It is interesting to note that Sub-Saharan Africa has the biggest backlog in terms of the provision of water and sanitation. As well as this, urbanization in this region is taking place at the fastest rate in the world (Stern, 2005: 28). The Millennium Development Goals (WSSD, 2002) stated that the backlog in water and sanitation provision would be halved by 2015. Given the progress made between 1990 and 2004, these goals will not be achieved. On current trends sub-Saharan Africa would halve its water targets by 2040 and its sanitation targets by 2076. Even if these goals were achieved by 2015, there would still be a backlog of 1,9 billion people without access to adequate sanitation (HDR, 2006, Chapter 3:112). The report calls for 20 litres of clean water for each person and that government's should spend at least 1% of GDP on water and sanitation. To achieve the Millennium Development Goals would require about \$10 billion a year – a sum that represents 5 days worth of global military spending and less than half of what the rich countries spend each year on mineral water. These statistics show that the provision of water and sanitation, as a primary need, is affordable. Political will is necessary if improvement in the provision water and sanitation is to take place, especially in the rapidly urbanizing developing countries.

The illustration below shows the improvements that have been made globally between 1990 and 2004.

Figure 1.1 Shrinking slowly: the global water and sanitation deficit

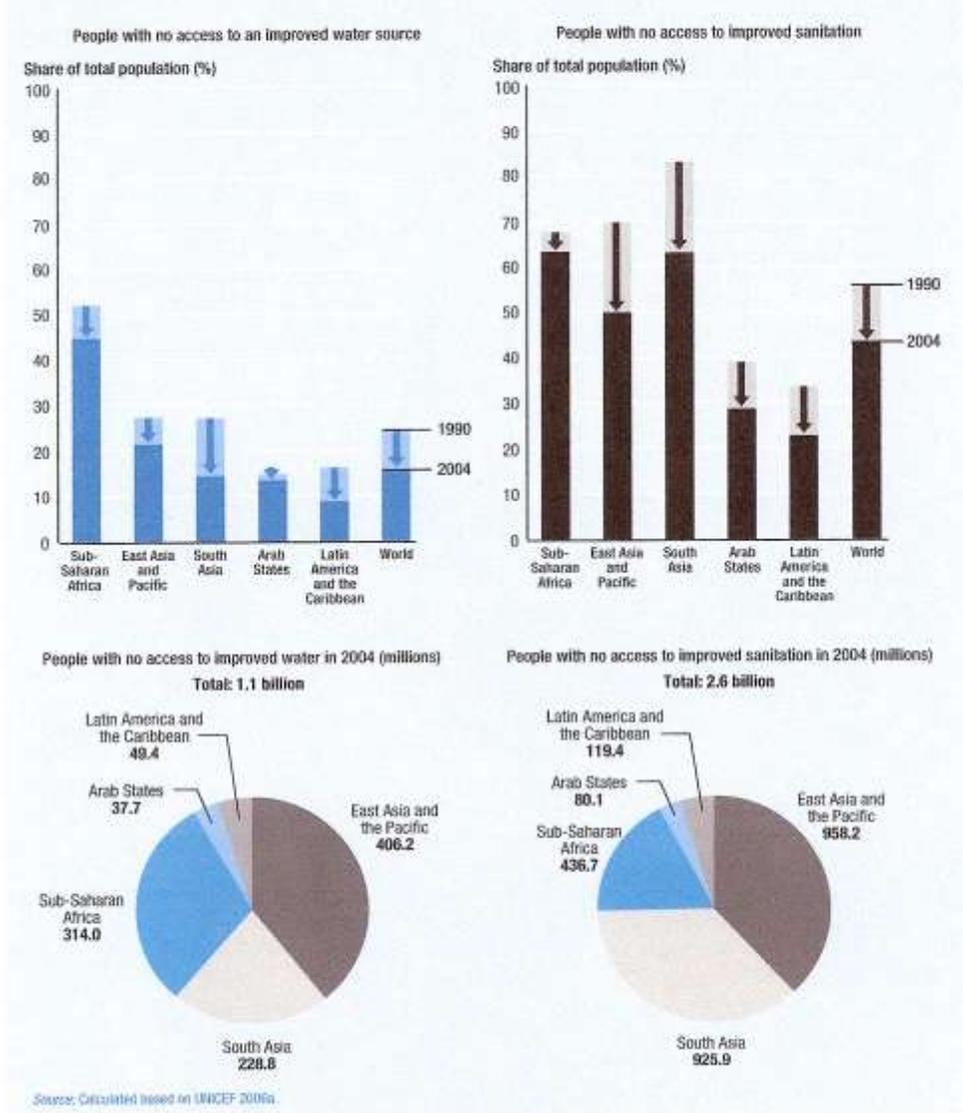


Figure 1.2: The Global Water and Sanitation Deficit
(HDR, 2006, Chapter 1:33)

The effects of climate change and global warming are also important factors in the future provision of water and sanitation. From the above discussion water security and protection against water-related risks, is vital for human development and sustainable development. The media has shown us during the past few years, graphic footage of floods in Mozambique, New Orleans and just recently north east Kenya and the Horn of Africa. Climate change does pose a

threat of water security to many developing countries and millions of the poorest people. The Stern Review (Stern, 2006), states that if no action is taken against Carbon emissions there is more than 75% chance of temperatures rising between 2 and 3 degrees Celsius during the next 50 years. Thus there will be more examples of extreme weather patterns worldwide – droughts will cause water shortages, decrease in food production and thus many economic refugees while floods damage infrastructure, especially sanitation, leading to health crises. Rising seas will also destroy fresh water aquifers. The report *Africa – Up in Smoke 2* (2006) states that Africa is already warmer by 0,5°C than it was 100 years ago and is set to get warmer with dry areas getting drier and wet areas wetter. At the recent UN sponsored conference on Global Warming in Nairobi (UNFCCC, 2006), it was stated that Africa was more vulnerable to global warming than previously expected and that 70 million people could be at risk from coastal flooding by 2080 if nothing was done about reducing Carbon emissions worldwide. By 2025, 480 million people could be living in water stressed or water scarce areas. Most of Sub-Saharan Africa depends of rainfall for its agriculture and food production, thus food production and human development will be affected (HDR, 2006, Chapter 4)³.

3. SOUTH AFRICA and THE WESTERN CAPE

The National Water act of 1998 (DWAF, 1998) required that a National Water Resource Strategy (NWRS) be drawn up. This has been formulated (DWAF, 2004). Water is to be regarded as a national resource and this implies therefore integrated water resource management in terms of water, land use and other resources to optimize social and economic development in a sustainable way. This follows the proposals of the WSSD (2002) that people have to be at the centre of sustainable development and the use of water resources. In Chapter 2 of the NWRS it is stated that there are enough water resources in South Africa to meet the growing economic development provided these resources are managed in a sustainable way. The mid-2007 figure for South Africa's population is estimated at 47,9 million⁴. The demand for water will increase in the urban areas as the urbanization rate in South Africa increases during the years ahead and as population size increases.

³ Refer also to UNEP IPCC, 2007. **Climate Change 2007**. Reports by Working Groups I, II and III.

⁴ Information obtained from Statistics SA. <http://www.statssa.gov.za>. Accessed on 26 September 2007.

The DWAF report “Development of a Sanitation Policy and Practice in South Africa” (2002) states that the South African Government is committed to ensuring that the entire population has access to adequate sanitation and intends to improve on the Millennium Development Goals by completely removing the backlog in the provision of sanitation by 2010. These are laudable goals.

In the early 1990s there were approximately 21 million people without even the basics of sanitation which was defined as a ventilated pit-latrine or the equivalent (DWAF, 2001). At the beginning of 2001 there was a backlog in the provision of adequate sanitation to about 18 million people or 3 million households, the majority of these in rural areas, peri-urban areas or informal settlements. 2,4 million people were provided with sanitation during 2002. Eradication of the bucket system is set to be totally achieved by 2007. Between 1994 and 2006 access to adequate sanitation had increased from 41% to 69% of the population and the backlog had been reduced from 52% to 31 % (DWAF, 2006). A range of toilet technology types are currently used in South Africa, including: buckets, chemical toilets, simple pit toilets, ventilated improved pit toilets, dehydrating and composting toilets, aqua-privies, flush toilets with septic tanks, flush toilets with small bore solids free-sewers, and, flush toilets with full waterborne and central treatment works (DWAF, 2002:9).

Choice of models however should take into account:

- affordability to the household
- operation and maintenance requirements
- sustainability
- improvements to health
- compliance with environmental protection regulations
- ability of community based contractors to implement

By 2002 over 7 million people had been provided with access to basic water supply but only half of this number had been affected by provision of sanitation. This is similar to the world trend of providing adequate water supply before sanitation. However, good health requires clean, potable water and adequate and hygienic sanitation. The aim is to provide a basic sanitation service and water supply within 200m of every household. Community participation is stressed as being vital in the upkeep of facilities into the future.

The profile for Cape Town would contain the following salient facts⁵:

- Total population: 3,27 million (projected) for 2007.
- Total of 904 000 households estimated for 2007; approximately 104 216 informal dwellings (2006) are serviced by the city.
- 7% of households have no access to safe drinking water (2005).
- 10% of households have no access to adequate sanitation (2005).

In terms of water use (Swilling, 2005: 13):

- Households used 37% of all water supplied to Cape Town in 1998, 21% of this was used to irrigate gardens and fill swimming pools.
- In 2000 approximately 60% of all domestic water was used by the high income bracket and 20% of the people in Cape Town had no piped water.
- 61% of all water used in homes (potable water) was used to flush toilets and transport sewerage.
- Only 5% of the 550 000 tonnes of sewerage produced each year is recycled.

Infrastructure targets have been set at 100% water supply to all households by 2014 and water-borne sewerage for 96% of all houses by 2014 (City of Cape Town IDP, 2006). This also presumes that there will be adequate water supply to meet these targets. With the completion of the Berg River dam it is predicted that there will be adequate water supply for the region until 2013 when demand will outstrip supply (City of Cape Town IDP, 2006). In recent years water restrictions have had to be introduced as a result of limited rainfall. The City has recently proposed a ten year scheme to save water, one measure being to increase the volume of recycled treated effluent water for irrigation purposes⁶.

The Cape Times (1 December 2006) reported on a workshop held in Cape Town on climate change. Climate change will take place over the next 50 years. The Western Cape was generally arid with less than 500mm of rain a year. Climate predictions are for a hotter and drier Western

⁵ Information obtained from City of Cape Town website. <http://www.capetown.gov.za/censusinfo/CityStatistics/>. Accessed on 26 September 2007.

⁶ Media release 11 June 2007. <http://www.capetown.gov.za>. Accessed 28 September 2007.

Cape over the next 25 years (People, Planet, Prosperity, 2006: 32). There would be an increase in temperature of 1°C by 2030 in the coastal regions and 2°C increase in the interior. The report also contains the findings of Arthur Chapman, a hydrologist at the CSIR. He shows that 95% percent of the rivers that feed into the water management region of the province are in an ecologically critical condition. Between 38% and 53% of Cape Town's water is "lost" every year somewhere between the supply dams and taps. The eastern side of the province is expected to become slightly wetter with an increase in intensity of rainfall in the mountain areas. The south western areas are expected to become drier (Midgley *et al*, 2005: 28-32)⁷. Eco-efficiencies are thus called for. The government was driving for a 6% to 8% growth in the economy which would mean an increase in water demand. The future options to meet this demand were to tap into the ground water of the Table Mountain aquifer and the desalination of seawater. Water tariffs will increase to meet the cost of servicing the demand.

4. SUSTAINABLE DEVELOPMENT

The words 'sustainability, sustainable development and growth', draw forth various understandings and responses. The World Commission on Environment and Development (Brundtland Commission) introduced the idea of sustainable development in a report for the UN in 1987. Sustainable development was defined as "..... development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987:Chapter 2). It can be argued that this definition is open to ambiguity in terms of meaning and interpretation. The question can be asked as to who determines what the present needs are and what future needs will be?

Mebratu (1998) and Dresner (2002) would put forward various understandings of sustainable development but each would emphasise that it cannot be limited to mere economic growth. Preservation of natural capital and ecological sustainability are stressed. Sustainable development will always have a political, social and economic context but basically sustainable development can only be achieved where resources are not used faster than they are regenerated

⁷ Refer also to *People Planet Prosperity – A Strategic Framework for Sustainable Development in South Africa*. A draft document, 2006: 32.

and pollutants and waste are released at a slower rate than the eco-systems can assimilate them (Merkel, 1998). This would not suit the speed at which development, poverty eradication and economic development needs to take place. The world has to become smarter in its use of resources. Technologies for re-cycling and re-use have to be employed more widely, so that resources can be sustained. It is 20 years since the Brundtland Commission and many argue that a renewed approach to sustainable development is needed. In taking the debate forward Sneddon *et al* (2005) argue that sustainable development should be viewed in terms of three simultaneous approaches – ecological economics, political ecology and ‘development as freedom’. Ecological concerns have to be part of economic methodologies and theories, and they have to be incorporated into critical social theory so as to reduce inequity and at the same time they must be part of the development and expansion of individual human rights.

The Lynedoch EcoVillage strives to follow this approach in terms of Ecological, Social and Economic sustainability, as will be discussed.

The rest of this paper will focus on ecological sanitation, using the approach advocated by Sneddon *et al* as a point of departure.

5. ECOLOGICAL SANITATION (ECO-SANITATION)

Depletion of natural resources and reduction in the planet’s biodiversity threatens the fabric of life, on which our well-being and the planet’s well-being depends (Capra, 2003: 181-187). Human activities are damaging the planet’s ability to supply all life with the ‘ecosystem services’ it does naturally, such as processing waste, regenerating the atmosphere, regulating climate, water purification. The global warming scenario attests to this. We, human beings, are members of the global community of living beings and our behaviour should reflect this basic respect for the dignity of all life. Incorporating alternative water and sanitation systems (eco-sanitation) into the design and operation of housing developments, can help in the reversal of the depletion of resources, specifically water and nutrients, and thus in preserving biodiversity.

In South Africa the water entering a household is purified to such an extent that it is safe to be used as drinking water. However only a portion of the water used in a household is used as drinking water and for cooking purposes. Most of the drinking water that enters a household is used to transport waste (e.g. as quoted above, 61% in the case of Cape Town). Dirt, detergents, food remains, urine and excreta are all dissolved or suspended in water and carried away via sewers to wastewater treatment plants. The aim of wastewater treatment systems needs to be expanded from sanitation and environmental issues to embrace also water quality control with the ultimate aim of recycling the treated wastewater i.e. both water and nutrients. The ideal would be to achieve all of these aims, what Wilsenach calls a ‘sustainable system’ (2006: 3-4). This approach was stressed by Michael Rouse, President of the World Water Association, in March 2003, when discussing the challenges set by the 2002 World Summit on Sustainable Development (WSSD) to provide water and sanitation for 1,2 billion people worldwide (Swilling, 2004: 13). He said this would not be achieved using traditional engineering approaches.

If we started sanitation again from scratch in Britain, we would not do it the way we do now. Instead of flushing and piping all the waste away, we would collect the solids once a week like household rubbish, take it to a central depot and compost it. Eventually it would be used as fertilizer, itself a bonus in the developing world, which would be able to cut down on expensive chemical fertilizer.⁸

The above statement does raise questions in terms of health issues and the logistics of collection on such a large scale as would be required by a city the size of London.

The Toilet System would include **collection**, **treatment** and where necessary the **transport** of the waste between the two. There are a limited number of options to do this and these are summarized below, with advantages and disadvantages (Harper and Halestrap, 1999: 12 – 30). Only flushing toilet options are discussed.

⁸ Quote in “Keeping sewage on home soil”, *Mail and Guardian*, 20-27 March, 2003.

With a WC⁹ or Flushing Toilet

Usually these systems can treat both black and grey water.

5.1 With Sewer connection

Standard WC or Urinal → sewer → sewage works

This would apply in most middle-class and upper-class homes and buildings. The only variation that can be achieved is in the particular type of toilet flush or urinal used e.g.

- Less than 7,5 litres or 6 litres flush (usually in building regulations)
- Dual-flush
- State-of-art low-flush: 2-4 litres
- Urine-separating
- Foam
- Controlled flush and waterless urinals

These variants can help the reduction of water use.

5.2. With no Sewer connection

5.2.1 On-site collection but no treatment

WC → collection tank → sewage works

Often used for temporary toilets. The WC flushes with anti-septic liquid. The collection tank has to be emptied by a tanker, usually an expensive operation. There are smells and the system is expensive and inefficient.

5.2.2 On-site treatment of liquid effluent/and solids

a. WC or urinal → septic tank → leachfield (soakaway)

A very common system. Liquids soak away into the ground water system and solids have to be removed via tanker collection. This is an expensive operation. There is leakage into the wider ecosystems.

b. WC → septic tank → various alternatives to the treatment of liquid effluents

⁹ WC is the British term for Water Closet or water flushing toilet in a bathroom or room/closet.

Techniques for the treatment of the liquid effluent include filter beds, aeration plants, reedbeds and treatment ponds. The Lynedoch EcoVillage uses a combination of these alternatives.

c. WC plus rapid physical separation of solids for on-site treatment

After the WC the solids and liquids are separated (filtration or surface-tension effects) before solids have a chance to break up and disperse in the liquids. Solids can be treated by the composting process and the liquids by any of the above means. Water is only used to transport material some distance from the pedestal and there is no septic tank. Heights and flow-levels are important and the system can be expensive.

Urine is a liquid and thus in theory should need no flushing. Most toilet visits are for urinations and it would make sense to have more urinals so as to save on water use. Urinals are mostly found in public male toilets. Individual flush urinals are probably the best type and with the small flush needed can save on water use. No flush urinals are available and would be preferred over low-flush urinals. Urine-separating flush toilets effectively incorporate a urinal for women but would also work for men sitting.

The low-flush WC does save some water and whether treatment of sewage is via sewers to some far-off treatment works or some on-site treatment system as described above, seems to satisfy public middle-class western social norms. Dry toilet systems are large and do not fit easily into bathrooms, lifestyles and budgets. There are operating costs and the time needed to do this. Thus the WC system would probably be a more rational choice and the dry-toilet system would be more appropriate in unusual circumstances e.g. no sewer connections, limited water supply, remote areas (Harper and Halestrap, 1999: 89).

The concept of source separation of waste and separate treatment has to be considered (Wilsenach, 2006: 18-22). Practically all pathogens in wastewater originate from faeces. This toilet water (**black water**) contains as well, some N (Nitrogen), P (Phosphorus), K (Potassium)

and most of the COD (Chemical Oxygen Demand). Separate treatment systems can be used and nutrients can be recycled. An anaerobic digester can convert organic material into biogas. **Yellow water (urine)** contains most of the N, P and K but only contributes about 1% to the total wastewater volume. Nutrients in urine can be used as a fertilizer. This will require source separation of urine at the toilet and separate collection. **Grey water (kitchen and bath water)** can be treated separately in artificially constructed wetlands and the treated water can be used to flush toilets. Grey water varies in composition. Bath water contains almost no nutrients or COD, while water from dish washers and washing machines has a high COD count and some nutrients. Grey water does contain pathogens. The main difference between grey water and toilet water is the mass and concentration of solids and nutrients.

Ecological sanitation sets out to close the loop by using ecologically friendly toilet systems that seek to save water and reduce pollution. Such systems are also designed to process excreta to make the effluent water safe enough for use in agriculture and to be recycled into toilet systems. Morgan (2005) addresses the different approaches in the Southern African context. There has been more of a concentration on the toilet device itself which aims at urine diversion (UD) where urine is separated from faeces at source. Urine can be tapped separately. It contains most of the nutrients, especially nitrogen, and can be used diluted or undiluted with water to enhance the growth of plants. It can thus increase yield in agriculture. At least 20000 UD toilets have been installed in eThekweni and a further 13000 units are being installed in the Eastern, Western and Northern Cape, in the North West and Gauteng. Added to this, the UD toilet can be linked to a composting pit toilet system. What is clear is that ecological sanitation has to be integrated with water resource management.

Whatever system is used, eco-sanitation implies a change of attitude and practice. The system needs human intervention and care, much like taking care of filters and backwashing the water in a swimming bath. A flush toilet would probably be the desire of most people.

6. LYNEDOCH ECOVILLAGE

The Lynedoch EcoVillage is situated near Stellenbosch, close to the Lynedoch Railway station, on the property of what used to be the old Drie Gewels Hotel. It is close to the main entrance into the Spier Wine Estate. Founded in 1999, it is managed by a non-profit company – the Lynedoch Development Company (LDC). The goals of the Lynedoch EcoVillage were set out by the Board of the LDC in 2000 (Swilling and Annecke, 2006):

- a mixed community organized around a child-centered learning precinct
- a working example of a liveable ecologically designed urban system
- a financially and economically viable community that will not require external funding to sustain itself.

Funding for the development was enabled through an alliance with the Sustainability Institute (SI) (a non-profit Trust based at Lynedoch) and the School of Public Management and Planning (SOPMP) at the University of Stellenbosch. This NGO-University alliance was able to mobilize funding both locally and internationally for the development. Economic viability and sustainability would have to be established once the main development had taken place.



Figure 1.3: The Lynedoch Primary School and Sustainability Institute – Lynedoch EcoVillage

Key Features of the Lynedoch EcoVillage are (Swilling and Annecke, 2006):

- Pre-school for 40 children based on the Montessori system; Primary school for approximately 475 children (Grade 1 to Grade 9) - mainly from the surrounding farms; A large multi-purpose hall; Offices and classrooms for the Sustainability Institute (SI) The SI in conjunction with the University of Stellenbosch offers a Master's degree in Sustainable Development, Planning and Management (MPhil). 2007 was the fifth year of the course.
- Conversion of the old Drie Gewels Hotel and an existing house into 18 residences that provide accommodation for participants in the programmes of the SI.
- 42 residential sites catering for middle to low income families from all communities (Phase 1). In 2005/2006 12 houses were built, 10 of them being for people qualifying for the government housing subsidy. The remainder of the sites will be sold at a commercial rate. The urban design does not separate the subsidy erven from the commercially priced erven. It is envisaged that there will be 5 commercially priced houses built in 2007.
- Commercial space for offices or small manufacturers.
- The gardens and landscaped areas laid out in accordance with natural planting and indigenous principles and eventually planted with indigenous plants.
- Limited traffic environment and thus a secure space for children and pedestrians.
- On-site treatment of sewerage, for re-use for irrigation and in the houses.
- Energy saving, including renewable energy.

The Primary School, the Community Hall and the premises of the Sustainability Institute were built out of renovations to the old main building which was a huge shed used for entertainment, mainly by students of the University of Stellenbosch.

Governance in Lynedoch is achieved via the Lynedoch Home Owners Association (LHOA), a section 21 company, to which all home owners automatically become members. The LHOA is responsible for the maintenance of the services and infrastructure of the Lynedoch Development in accordance with the powers and functions delegated to it by the Municipality.

Characteristics of the Lynedoch EcoVillage are thus (Swilling and Annecke, 2006) –

6.1 Ecological Sustainability:

- *Water and Stormwater:* A dual water supply was installed with the intention to reduce consumption of municipal water by 40% by recycling water to toilets and irrigation; water saving taps and shower-heads and dual flush systems for toilets are used; stormwater runoff is minimised by restricting hard-surface landscaping or channels; rainwater harvesting is encouraged. It is calculated that low-income house-holds could save 90% of their monthly water bill and middle-income houses up to 70% of their bill. This would need to be substantiated.
- *Household Effluent:* Grey and black water is treated by two different systems on-site. This will be explained in the next section. No stormwater or treated black or grey water waste will leave the boundary except via groundwater flows and evaporation. On-site treatment reduces the capital costs for bulk service provision and the payment for such services via rates.
- *Energy:* Each structure is connected to electricity supply via the national grid. Energy efficiencies are achieved by use of solar-water heaters (no geysers); no electric stoves (all cooking done on LPG hobs); space heating and cooling by effective designs of buildings; low energy lighting by using compact fluorescent lights (CFLs).
- *Refuse:* Municipal refuse is managed by the LHOA. All members are required to separate waste (currently organic and solid). Further separation takes place at the on-site depot. Separated refuse is sold to recyclers. A composting depot has been established for organic waste for later use in gardens. The ultimate aim is for 95% of the waste to be sold to recyclers or for productive re-use.
- *Roads and Housing:* All internal roads are constructed of gravel to reduce runoff. There are no curbs or paving to reduce cost. Houses are designed according to guidelines attached to the constitution of the LHOA.
- *Building Materials:* 11 of the 12 houses built so far have been built out of adobe blocks (sun-dried clay and straw). Hardwoods needed for window-frames and doors were obtained from Forest Stewardship Council approved plantations in West Africa. This was to obviate the use of Meranti wood (imported from unsustainable forests in Brazil and Indonesia).

6.2 Social Sustainability:

- *Governance:* The LDC acts as developer and has established a Special Management Zone Trust into which 1% of all land sales is deposited for future investment in the natural environment. The LHOA governs daily living in the EcoVillage. All members of the LDC and all home owners are members of the LHOA. An Operations Manager is employed by the LHOA and bulk service providers such as Eskom, Stellenbosch Municipality and various contractors are paid for via service charges and levies paid by members of the Association. The Code of Conduct of the LHOA governs the way the community should live on a daily basis.
- *Social Mix:* This is to be achieved via the sale of commercially priced plots and subsidized plots.
- *Focus on Children:* In achieving and sustaining social integration children are central in the social dynamic of everyday life and also in the development of the EcoVillage. The Lynedoch Primary School is at the center of the development. Various initiatives around early learning training, ecological early learning, psychological services, IT and aftercare have been established.

6.3 Economic Sustainability for Urban Development:

The situation of rich neighbourhoods and poor areas in cities in South Africa continues to be a problem. The poor usually have to commute into rich areas to find work. The Lynedoch Development has sought to make the EcoVillage a sustainable neighbourhood and addresses this problem in various ways.

- ‘asset-based’ purchase of properties. The subsidised plots enable these owners to have a substantial asset as security for bank loans.
- Conditions of re-sale make it compulsory for the owner to offer the property first to the LHOA.
- The LDC has established a Savings and Credit Cooperative (SACCO), essentially a non-profit community bank that offers non-secured loans to poor people and others based on their savings record. 5% of the monthly repayment of the housing loan must go into savings in the SACCO. They redeem these savings plus interest when they have paid off their loan.

- The EcoVillage is connected to a land-reform project led by farmers from previously disadvantaged backgrounds. Direct supply of organically grown vegetables and fruit bypasses the high cost of purchasing from supermarkets and thus poor families can afford proper nutrition.

7. WATER and SANITATION SYSTEM – LYNEDOCH ECOVILLAGE

The water and sanitation system at the Lynedoch EcoVillage was designed in response to the following -

- the scarcity of future water supply in the Western Cape;
- the cost of potable water will increase over the next 20 years as new high cost dams are built and aquifers are sought or desalination is introduced to meet increasing demand for water;
- the cost of off-site sanitation will increase due to the cost of the provision and maintenance of bulk services and sewage plants. Increased infrastructure will be needed to cope with increasing demand;
- the necessity to achieve eco-efficiencies, re-cycling of water and nutrients present in the wastewater.

The water and sanitation systems have been installed in parallel, with the potential for a cross-linkage. A schematic representation of the water and sanitation system in the Lynedoch EcoVillage is as follows:

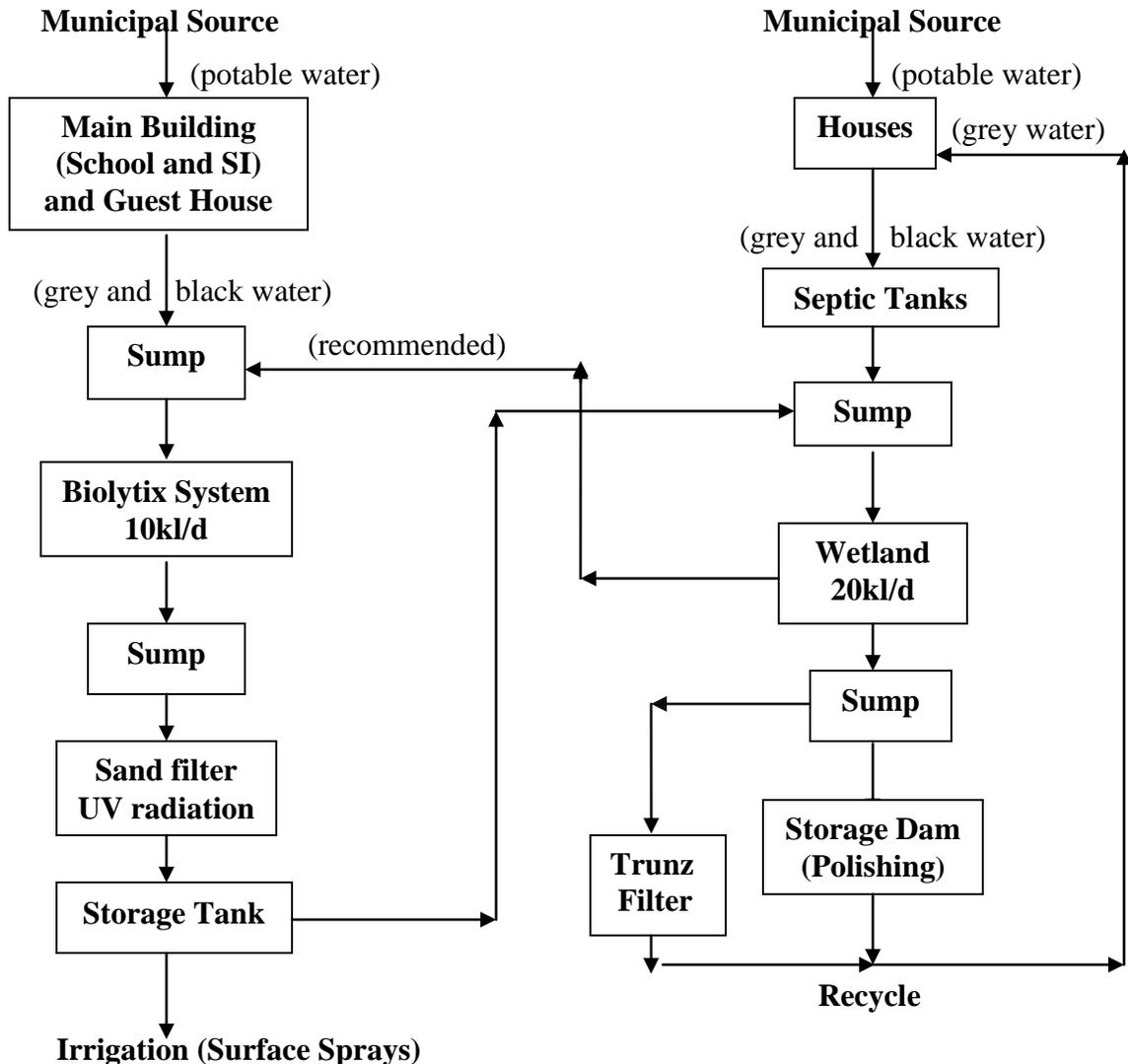


Figure 1.4: Schematic Representation of the Water and Sanitation System – Lynedoch EcoVillage

The Lynedoch development is connected to the municipal water supply and there is a dual piping system so that recycled water can be fed into the houses for the flushing of toilets and for irrigation purposes. The treatment of effluent at the Lynedoch EcoVillage consists of a combination of processes as shown above.

Effluent consists of grey and black water. The effluent from the main building (school and SI) and the guest house is treated via the **Biolytix system** and then a **sand filter and UV radiation**. Outflow is used for irrigation via surface sprays. Primary treatment of effluent from the houses is

through **septic tanks**. The layout is for every two households to be connected to one septic tank. The septic tanks are thus purposely overloaded. Their function is to capture solids and for outflows to the treatment works via small bore pipes. The outflow from the septic tanks is conveyed to a **halophyte filter (vertically constructed wetland)** where secondary treatment takes place. The outflow is to be pumped into an existing dam for polishing from where it can be recycled into the houses. It must be noted from the above discussion of the Lynedoch EcoVillage development that an eco-sanitation system is used and not UD toilets or composting pit toilets systems. Water saving devices in the form of low flow taps and shower heads and a dual flushing system on the toilets are used.

7.1 Biolytix system:

The general principles of the Biolytix system are the following (Bart Senekal Inc, 2003).

The Biolytix system is an organic soil ecosystem. The system comprises a tank which is inoculated with earthworms and charged with peat and plastic tubing to provide structure to the organic bed. It provides both physical filtration and microbial degradation of any organic matter present in the incoming effluent. A further advantage of the system is that all nutrients are retained due to the aerobic nature of the system making it ideal for re-use. At the Lynedoch development the outflow is collected in a sump and then filtered via a sand filter to remove further particulate matter, and pathogens are then removed by ultra-violet (UV) radiation.



Figure 1.5: Biolytix Tanks - Lynedoch EcoVillage

The Biolytix system has been employed in other developments, namely ¹⁰ –

Spier Village Hotel;

Bushmanskloof Private Nature Reserve – Main Facility;

De Hoop Nature reserve – Main Complex;

Cedarberg Algeria Camp Site.

Goukamma Nature Reserve – Groenvlei Complex.

The workings of the Biolytix tank are briefly as follows (Biolytix Australia, 2006: How Biolytix Works). The top layer is made up of coarse mesh bags with plastic media in them. This houses the wet soil ecosystem. It accommodates worms, beetles and billions of microscopic organisms. These soil creatures are vital “macerator” organisms, breaking up the organic material, converting the waste into humus and structuring it so that its drainage and air porosity are continually renewed and maintained indefinitely. The organic matter particles then wash through and accumulate on the surface of a finely structured humus and coco-peat layer. In this middle layer it is reprocessed repeatedly by the soil organisms in it, renewing the drainage and aeration properties. In the third layer the effluent drains through a geofabric or geotextile filter which filters out particles larger than 90 micron. This filter is biologically cleaned and does not need maintenance. The water component of the wastewater finally accumulates in the sump where some more of the very fine sediment is settled out. The processes involved are fully aerobic and odour free. The layers are illustrated below.

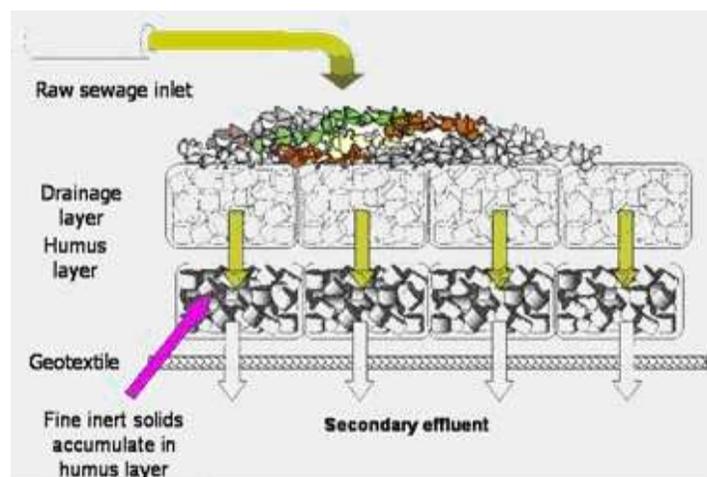


Figure 1.6: Layers in the Biolytix System (Biolytix Australia, 2006)

¹⁰ Information obtained from files at the Sustainability Institute, Lynedoch.

7.2 Septic Tanks:

The septic tanks (Bart Senekal Inc, 2003) partially treat the wastewater (effluent) from the houses by allowing the solids to separate from the liquid and then partially decompose. Settleable solids and partially decomposed sludge settle to the bottom of the tank, accumulate and decompose over time. A scum of lightweight material, including fats and greases, rises to the top. The sludge and scum are retained by a system of baffles and the partially clarified liquid is discharged into a pipe and transported to the helophyte filter (see below). The accumulated sludge has to be removed (usually every 18-24 months). Municipalities are generally not in favour of doing this and private contractors have to be employed to do this. In the Lynedoch development these arrangements will be handled by the LHOA. It is noted that if anything goes wrong in the operation of a septic tank then according to the constitution of the LHOA the particular householders concerned are responsible for fixing the problem.

7.3 Halophyte filter (Vertically Constructed Wetland):

A halophyte filter or constructed wetland is distinguished by the following principles (Bart Senekal Inc, 2003):

- A water column
- Substrates with different rates of hydraulic conductivity
- Swamp water plants
- Communities of aerobic and anaerobic microbes.

The purification effect is based upon microbiological, physical-chemical and plant-physiological processes, which take place in the system substrate and plants. For the Lynedoch village a vertical filter system has been constructed, the advantage being that for the inflow volumes expected a smaller surface area is required. This results in less evaporation in summer and thus better conditions for filter vegetation. The wastewater is fed close under the surface of the bed intermittently through pipes. The water gradually drains through the bed to the base, where it is collected in drainage to be led out of the filter. The filter drains completely free and this allows refilling the pores with air, which is needed due to oxygen related processes; especially

nitrification. The wetland does not produce any sludge. The filtered water drains into a settling dam for further polishing.

The diagram below represents a vertical Halophyte system. The reed types are selected according to their ability to absorb nitrogen. *Arum* lilies and *bloodriet* reeds are high nitrogen feeders. A layer of iron filings absorbs the phosphorus as phosphate forming Fe_3PO_4 (IronIII Phosphate). This salt is highly insoluble and not available as plant fertilizer. One of the key nutrients (Phosphate) is removed in this system. This water would therefore not be suitable for irrigation but suitable to be recycled through toilet systems as no algal growth will take place. The three layers around the root zone in the drawing below have iron chips spread at the bottom of each layer. The iron chips would have to be replenished once they have become deactivated through the formation of Fe_3PO_4 .

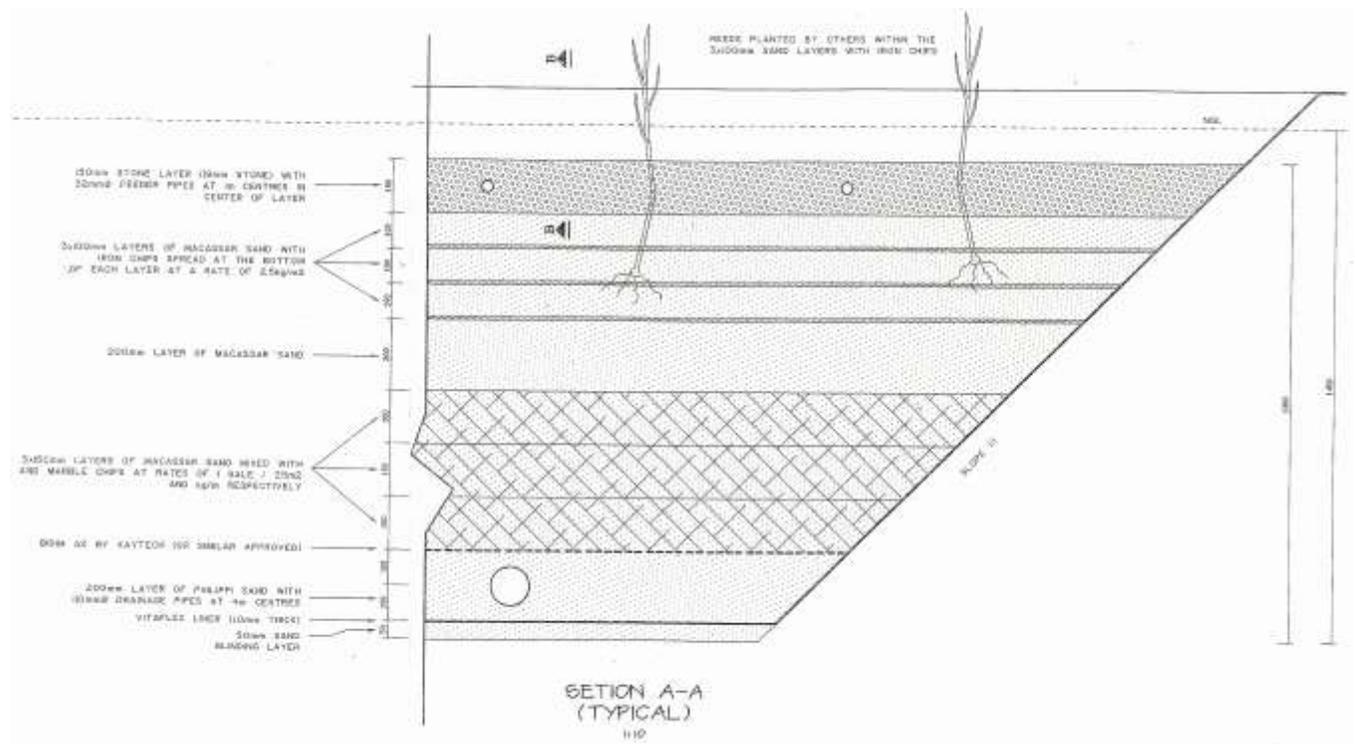


Figure 1.7: Layers in the Vertically Constructed Wetland – Lynedoch EcoVillage
(Bart Senekal Inc, 2004. Drawing No 1110/9C. Stellenbosch)



Figure 1.8: Surface area of the Vertically Constructed Wetland – Lynedoch EcoVillage

The final phase of polishing in the dam has not been implemented. Instead a membrane filter (manufactured by Trunz, Switzerland)¹¹, powered by a windmill and solar panels, has been installed to treat the output from the wetland. This was installed in February 2007 and is being tested at the EcoVillage. The system can purify 20 000 litres of water per day to a purity necessary for drinking purposes. The output from the membrane filter is fed into the houses for toilet flushing.

The costs of such a system might discount its application generally in future developments (section 10.1).



Figure 1.9: The Trunz Filter system, showing the windmill and solar panels - Lynedoch EcoVillage.

¹¹ Information obtained from Sustainability Institute (SI). <http://www.sustainabilityinsitute.net>. Accessed 2 April 2007.

8. CRITERIA USED IN THE DESIGN OF THE LYNEDOCH ECOVILLAGE WATER and SANITATION SYSTEM

The strategic intent in the design of the Lynedoch EcoVillage water and sanitation system was as follows¹² -

1. **to treat sewage on site**
2. **recycle effluent for re-use for flushing**
3. **recycle for irrigation and food production**
4. **prevent leakage into the wider eco-systems.**

In terms of these 4 stated criteria the following can be noted –

- pit latrines and septic tanks fail in terms of the criteria 2, 3 and 4.
- the Biolytix system performs in terms of criteria 1 and 3 but cannot be used for criterion 2. The great advantage of the system is that nutrients can be recycled but in winter, with the winter rainfall, too much rain means irrigation is not needed and so the high nutrient load that comes out of the Biolytix system would feed straight into the eco-system.
- the Halophyte filter (Vertical Wetland) satisfies criteria 1, 2 and 4 but in terms of criterion 3 the nutrient load is too low (in theory) and thus the effluent would not be useful for irrigation.

Thus in designing the water and sanitation system at the Lynedoch EcoVillage, a combination of the various elements was used. The expected performance standards for the Biolytix system and Halophyte filter of effluent concentration after treatment are as follows -

Biolytix System (Bart Senekal Inc, 2003): **COD (Chemical Oxygen Demand) < 90 mg/l; TSS (Total Suspended Solids) < 65 mg/l.**

Halophyte Filter (Bart Senekal Inc, 2003): **COD (Chemical Oxygen Demand) < 50 mg/l; Nitrogen < 1.2 mg/l; Phosphate < 0.2 mg/l.**

¹² Discussion with Prof Mark Swilling of the Sustainability Institute, 29 November 2006.

9. ANALYSIS: INFLUENT AND EFFLUENT – LYNEDOCH ECOVILLAGE WATER and SANITATION SYSTEM

In analyzing the influent and effluent of the water and sanitation system reference is made to the standards required for irrigation and wastewater limits for use in recycling in the DWAF (2004) “Revision of General Authorisations in terms of Section 39 of the National Water Act, 1998 (Act No. 36 of 1998)”. The expected performance for the Biolytix system is taken from Biolytix Australia (2006) –“How Biolytix Works”- and compared with Spier Village Hotel (Moosa and Duminy, 2003). The expected performance for the Halophyte Filter is taken from Bart Senekal, Inc (2003). Samples of effluent and influent were taken in September and October 2006 and analysed at the Council for Scientific and Industrial Research (CSIR) laboratories in Stellenbosch.

9.1 Significance of the various tests.

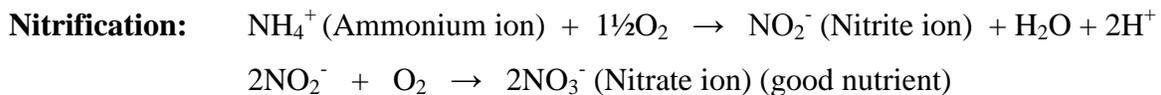
The principal nutrient elements for maintaining and reproducing life are Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N) and Phosphorus (P). By limiting the discharge of nutrients the growth of unwanted aquatic organisms and uptake of oxygen from receiving waters (of effluent) can be restricted. Eutrophication takes place when the receiving waters are enriched with Nitrogen and Phosphorus and, together with Carbon Dioxide, causes prolific growth of algae (algal blooms).

The significance of the various tests is summarized below (Wood and Pybus, 1992: 9-23; Lilley *et al*, 1997: iv-1.4; Wilsenach, 2006: 3-5)¹³.

- **Faecal coliforms:** These are an indicator of pathogens present.
- **E coli:** It is an indicator organism for the presence of Faecal coliforms. It indicates the amount of faecal contamination and microbial pathogens present.
- **COD:** This indicates the organic load (faecal matter, food rests, fatty acids, soaps etc). If effluent containing a high COD enters a river it can deplete the oxygen in the river as all the oxygen in the water will be taken up by this organic load in its decomposition.

¹³ Also, discussions with Dr Jac Wilsenach (CSIR) and Prof Mark Swilling (Sustainability Institute), 29 November 2006.

- **pH:** If low pH (<7) the water will be corrosive (acidic) while high pH (>7) (alkaline) could lead to metal precipitation. A neutral pH (pH = 7) is needed. The bicarbonate (HCO_3^-) buffers against alkalinity change and is used up in the Nitrification process.
- **Alkalinity (measured as mg/l CaCO_3):** With Nitrification, H^+ ions (acid) are produced and pH drops (decrease in alkalinity). If the alkalinity of a wastewater drops below 40 mg/l (as CaCO_3), the pH becomes unstable resulting in a sharp decrease in nitrification efficiency due to the retarded growth rate of the autotrophs (organisms responsible for the Nitrification process). Their growth rate is severely inhibited outside the pH range of 7 to 8.5. The alkalinity as measured in mg/l CaCO_3 is thus an indication of the buffering capacity – 2 mol acid is buffered by 1 mol CaCO_3 .
- **TSS:** Total Suspended Solids is an indicator of flows of bacteria and raw solids not being filtered out.
- **Nitrogen:** Nitrogen in wastewater is converted from the ammoniacal and organic forms to nitrate in an **aerobic** environment (a zone where oxygen is present). The nitrate can be reduced to nitrogen gas in an **anoxic** environment (a zone where nitrite and nitrate are present, but deficient in oxygen). This is the denitrification process. Under anoxic conditions the most readily biodegradable carbonaceous material is used as the food source.



Without Oxygen nitrification will not take place.

De-Nitrification: $\text{NO}_3^- + \text{COD} \rightarrow \text{N}_2$ (Nitrogen escapes to the atmosphere. There is loss of nutrients).

- **Phosphorus (P):** Phosphorus removal is achieved by a group of micro-organisms which have the facility to store and release phosphorus under appropriate conditions. Under **anaerobic** conditions (a zone which is deficient in nitrate and oxygen) these storers release the phosphorus as ortho-phosphate into the water. Phosphorus can be removed from the wastewater chemically using metals such as iron (as is the case with the Lynedoch vertical wetland). The aquatic plants planted on the surface of the wetland can also remove P from wastewater under low load conditions. The disadvantage of using metals is that they can cause a decrease in pH and alkalinity as well as an increase in the concentration of dissolved salts in the effluent.

- **Flouride (F):** A high Fluoride content is dangerously toxic in terms of domestic use.
- **Conductivity:** This is a measure of salinity or concentration of dissolved salts.

9.2 Biolytix System Influent/ Effluent (2006)

Table 1.1 Test Results: Biolytix System – Lynedoch EcoVillage

| Standards Required | Faecal coliforms | E coli | COD | pH | Alkalinity as CaCO ₃ | Suspended solids | Nitrate (N) | Ammonia (N) | Ortho-phosphate | Fluoride (F) | Conductivity | |
|-------------------------------------|------------------|---------|---------|---------|---------------------------------|------------------|-------------|-------------|-----------------|--------------|--------------|-----|
| | /100 ml | /100 ml | mg/l | | mg/l | mg/l | mg/l | Mg/l | mg/l | mg/l | mS/m | |
| Vol irrigated (DWAF) | | | | | | | | | | | | |
| ≤ 2000 cu m | ≤ 1000 | ≤ 1000 | ≤ 75 | 5,5-9,5 | | ≤ 25 | ≤ 15 | ≤ 3 | ≤ 10 | ≤ 1 | 70-150 | |
| ≤ 500 cu m | ≤100000 | ≤100000 | ≤400 | 6-9 | | ≤ 25 | ≤ 15 | ≤ 3 | ≤ 10 | ≤ 1 | ≤ 200 | |
| ≤ 50 cu m | ≤100000 | ≤100000 | ≤5000 | 6-9 | | ≤ 25 | ≤ 15 | ≤ 3 | ≤ 10 | ≤ 1 | ≤ 200 | |
| Wastewater limits (DWAF) | | | | | | | | | | | | |
| General | 1000 | 1000 | 75 | 5,5-9,5 | | 25 | 15 | 6 | 10 | 1 | 70-150 | |
| Special | 0 | 0 | 30 | 5,5-7,5 | | 10 | 1,5 | 2 | 1-2,5 | 1 | 50-100 | |
| Specs Biolytix system (BF 6) | | | av | | | av | | | | | | |
| Spier Influent | | | 8.7 | | | 5.4 | | | 0.9-9.8 | | | |
| Spier Effluent) | | | av | | | av | | | 0.7-9.6 | | | |
| 145 | | | 42 | | | | | | | | | |
| Test Results (CSIR) | | | | | | | | | | | | |
| Lynedoch sample | Date | | | | | | | | | | | |
| Influent Biolytix | 01-Nov | 4500000 | 3060000 | 514 | 7,5 | 496 | 70 | <0,1 | 134 | 13 | 0,16 | 165 |
| Effluent before UV | 06-Sep | | | 121 | 7,6 | 292 | 18 | 2 | 53 | 8.9 | 0.17 | 110 |
| (Biolytix) | 11-Sep | 3520000 | 2240000 | | | | | | | | | |
| | 04-Oct | 385000 | 215000 | 153 | 7,2 | 231 | 40 | 9,2 | 41 | 12 | 0,18 | 99 |
| | 11-Oct | 8010000 | 4800000 | 219 | 8,4 | 313 | 73 | <0,1 | 73 | 8,2 | 0,10 | 115 |
| Effluent after UV | 06-Sep | | | 143 | 7,7 | 260 | 20 | <0,1 | 49 | 6.7 | 0.15 | 100 |
| (Biolytix) | 11-Sep | 73600 | 12400 | | | | | | | | | |
| | 04-Oct | 2200 | 1400 | 112 | 7,6 | 301 | 19 | <0,1 | 44 | 14 | 0,19 | 103 |
| | 11-Oct | 734000 | 346000 | 123 | 7,7 | 334 | 21 | <0,1 | 47 | 14 | 0,12 | 103 |

Tests on the Biolytix System¹⁴:

A. Achieving the Strategic Intentions

- **Faecal coliforms and E coli.** These readings are high. This is a cause for concern if the effluent is used for irrigation of plants and gardens with a school and young people at the center of the development.
- **COD.** This is quite high. The storage tank after UV radiation is probably the problem. The treated water is stored there for a considerable time when not being used for irrigation purposes. The COD present is enough to start secondary contamination in terms of pathogens present. These can form dense colonies of bacteria. This is not very consequential for the growth of plants if the effluent is used for irrigation.
- **pH** is neutral which is good.
- **Ammonia is high and Nitrate is low.** Thus nitrification has not taken place and nutrients have not been lost.
- **Phosphate.** Phosphate removal does not take place. This is available as a nutrient if the effluent is used for irrigation. In surface water, however, it can lead to eutrophication (formation of blue/green algae).
- **TSS.** After UV treatment, results are lower than the general limits.
- **Flouride.** This is lower than the general limits.
- **Conductivity.** The measures are within the general limits.

Strategic Intentions 1 and 3 have been partially achieved. Nutrients have not been lost so the effluent can be used for irrigation purposes. The pathogens have not sufficiently been removed and this is a cause for concern when the effluent is used for irrigation. **Strategic Intention 4** could be a cause for concern if the unused effluent is allowed to seep into the groundwater system or the adjoining dam. COD and Phosphate levels are high as well as pathogen readings.

B. Operational Issues

- There is a more concentrated stream of effluent (black water) as there is limited grey water flowing into the Biolytix system (not many baths or showers except for the Guest House).
- There is a process of improvement taking place in terms of treatment of the effluent.

¹⁴ Discussion with Dr Jac Wilsenach (CSIR) and Prof Mark Swilling (Sustainability Institute), 29 November 2006.

The system is probably overloaded. It was designed for input of 10kl/day. The school had increased from its initial enrolment of 250 to 475. There are more businesses occupying premises at the SI. The MPhil students have increased in number and other events and courses for groups are continually being held at the SI.

- The UV radiation and sand filter needs to be more effective. Backwashing of the filter needs to take place more regularly and/or the sand needs to be replaced.

Generally, for improvements to take place and to fulfill the aims of the EcoVillage for irrigation and the re-use of nutrients, the effluent of the Biolytix needs to be processed through the Wetland so as to remove the pathogens. This option has been followed since the beginning of 2007. However, if the wetland is working to the optimum it was designed for, then nutrients will be lost and the stated intentions in terms of irrigation will not be achieved. This option can be used during the rainy season which is usually in the winter months and irrigation of the gardens is not required.

9.3 Vertically Constructed Wetland Influent/Effluent (2006)

Table 1.2 Test Results: Vertically Constructed Wetland – Lynedoch EcoVillage

| Standards Required | Faecal coliforms | E coli | COD | pH | Alkalinity as CaCO ₃ | Suspended solids | Nitrate (N) | Ammonia (N) | Ortho-phosphate | Fluoride (F) | Conductivity | |
|---------------------------------|------------------|---------|---------|---------|---------------------------------|------------------|-------------|-------------|-----------------|--------------|--------------|-----|
| | /100 ml | /100 ml | mg/l | | mg/l | mg/l | mg/l | Mg/l | mg/l | mg/l | mS/m | |
| Vol irrigated (DWAF) | | | | | | | | | | | | |
| ≤ 2000 cu m | ≤ 1000 | ≤ 1000 | ≤ 75 | 5,5-9,5 | | ≤ 25 | ≤ 15 | ≤ 3 | ≤ 10 | ≤ 1 | 70-150 | |
| ≤ 500 cu m | ≤100000 | ≤100000 | ≤400 | 6-9 | | ≤ 25 | ≤ 15 | ≤ 3 | ≤ 10 | ≤ 1 | ≤ 200 | |
| ≤ 50 cu m | ≤100000 | ≤100000 | ≤5000 | 6-9 | | ≤ 25 | ≤ 15 | ≤ 3 | ≤ 10 | ≤ 1 | ≤ 200 | |
| Wastewater limits (DWAF) | | | | | | | | | | | | |
| General | 1000 | 1000 | 75 | 5,5-9,5 | | 25 | 15 | 6 | 10 | 1 | 70-150 | |
| Special | 0 | 0 | 30 | 5,5-7,5 | | 10 | 1,5 | 2 | 1-2,5 | 1 | 50-100 | |
| Design Expectations | | | < 50 | | | | | <1,2 | <0,2 | | | |
| Wetland | | | | | | | | | | | | |
| Test Results (CSIR) | | | | | | | | | | | | |
| Lynedoch sample | Date | | | | | | | | | | | |
| Influent Wetland | 01-Nov | 7720000 | 2960000 | 206 | 8,4 | 212 | 43 | <0,1 | 49 | 3 | <0,1 | 71 |
| Effluent Wetland | 06-Sep | | | 68 | 7,7 | 337 | 8 | 34 | 0,56 | 1.4 | 0.44 | 150 |
| | 11-Sep | 22 | 0 | | | | | | | | | |
| | 04-Oct | 416 | 10 | 76 | 7,6 | 307 | 7 | 88 | <0,1 | 2,5 | 0,40 | 125 |
| | 11-Oct | 320 | 0 | 27 | 7,6 | 290 | 10 | 88 | <0,1 | 2,7 | 0,31 | 165 |

Tests on the Wetland System¹⁵:

It must be stressed that the water samples were taken from the sump before the water enters the storage dam where the final phase of polishing is meant to take place. The system was designed to include the dam. As mentioned above this stage has not yet been implemented.

¹⁵ Discussion with Dr Jac Wilsenach (CSIR) and Prof Mark Swilling (Sustainability Institute), 29 November 2006.

A. Achieving the Strategic Intentions

- All readings are good and within the general DWAF limits, except for **Nitrate**.
- **Ammonia is low and Nitrate is high.** The readings show good Nitrification and limited denitrification. The system is designed for denitrification. To achieve this *Arum* lilies and *bloedriet* need to be planted on the surface of the filter. The effluent at present is thus good for irrigation water but not necessarily for recycling in toilets.
- **Phosphate.** Some is still in the effluent and can lead to algae growth in toilets if the water is recycled. Iron filings have been put in the wetland for Phosphate take out.

Strategic Intentions 1 and 3 have been achieved and intention 2 partially achieved. Intention 4 has been achieved to a high degree.

B. Operational Issues

- The system is under-loaded. The specifications were for 36 houses and it is only treating effluent from 12 houses. Thus, the Biolytix effluent can be processed through the wetland system to remove pathogens.
- Since denitrification is not taking place, it is recommended that the wetland system be connected to the Biolytix system. Nitrate will be available in irrigation (Figure 1.4).
- The surface of the wetland needs to be planted with more plants to achieve denitrification. A start has been made in January 2007 as is illustrated in the photograph above (Figure 1.8).

10. FINANCIAL ISSUES

10.1 Infrastructure Development Costs

Comparison is made between the water and sewerage infrastructure costs of the N2 Gateway Development (Cape Town) and the Lynedoch EcoVillage Development.

Table 1.3 Capital Costs - N2 Gateway Development¹⁶

| | Units | Cost P/Unit | BUDGET |
|---|---------------|----------------|---------------------|
| Bulk and Link Engineering Services | | | |
| Water | | N/a | R52 910 000 |
| Multi Storey Units | | | |
| Site Infrastructure | R16727 | R4 500 | R75 272 400 |
| Single Residential Units | | | |
| Site Infrastructure | R7 169 | R15 108 | R108 309 765 |

Lynedoch EcoVillage¹⁷

a. Table 1.4 Capital Costs - Biolytix System (capacity 10kl/day)

| ITEM | QUANTITY | UNIT COST (R) | TOTAL COST (R) |
|------------------------------|----------|---------------|---------------------|
| 5 kl cylindrical tanks | 8 | 4,625 | 37,000 |
| Pre-fabricated Concrete Sump | 3 | 15,000 | 45,000 |
| Purchase of pumps | 3 | 15,000 | 45,000 |
| Labour | | | 10,000 |
| Pipe work & Others | | | 63,000 |
| Total Cost | | | 200,000 |
| Average cost | | | 20 per litre |

b. Table 1.5 Capital Costs - Vertically Constructed Wetland (capacity 20kl/day)

| ITEM | QUANTITY | UNIT COST (R) | TOTAL COST (R) |
|---------------------|----------|---------------|---------------------|
| Labour and material | | 300,000 | 300,000 |
| Total Cost | | | 300,000 |
| Average cost | | | 15 per litre |

¹⁶ N2 Gateway Project Business Plan, obtained from Prof Mark Swilling (Sustainability Institute).

¹⁷ Costings for Infrastructure Development, Lynedoch EcoVillage, obtained from Prof Mark Swilling (SI).

| | |
|---|--------------------|
| Infrastructure Costs: Sewerage (Biolytix & Wetland): | R500 000 |
| Water and Fire: | R164 948 |
| Total (42 houses, Guest House, SI, School) | R664 948 |
| Trunz Filter system¹⁸: | R350 000 |
| Total with Trunz Filter system: | R 1 014 948 |

Thus, the average unit house cost for infrastructure, would be less than R15 000 (664948/45). This compares favourably with the unit costs of site infrastructure for single residential units of the N2 Gateway Development (R15 108).

With the Trunz system the average costs would be approximately R22 554.

The above costs include the capital costs for the Biolytix, Vertical Wetland and Trunz systems. For more reflective comparison purposes, the costs of the bulk systems for water and sanitation infrastructure for the N2 Gateway Development and a portion of the capital costs of the sewerage treatment works to which the bulk systems are connected, would need to be included. This would show that on-site treatment such as at the Lynedoch EcoVillage is even more cost effective in terms of capital costs,

10.2 Operating Costs:

According to the Code of Conduct of the LHOA, homeowners are charged a service fee for the use of potable water and recycled water.¹⁹

Non-subsidized households: % of household levy = % of R240.

Subsidized households: % of household levy = % of R120.

Biolytix System: The advantages of the Biolytix system in terms of operating costs are as follows (Biolytix Australia, 2006: Competitor Comparison):

- the typical power is less than 140 watts/day which is about 10% of the energy needed to run a comparable aerated treatment system, which typically uses 100 watts/kl of treated sewerage.
- the Biolytix system only needs to be serviced once per year.

¹⁸ Capital Cost obtained from local distributors Wertech CC, Somerset West, on 1 October 2007.

¹⁹ Annexure "A" Code of Conduct, Memorandum of Association of a Company – Lynedoch EcoVillage Home Owners Association and information obtained from the Sustainability Insititute, Lynedoch.

The sand filter needs to be backwashed for cleaning purposes. There is need for electricity and for care of the pumps.

Wetland System: The advantages of the wetland system would be (Wood and Pybus, 1992: i):

- low operating costs.
- low energy requirements (electricity for the pump).
- low maintenance costs.
- can be established close to the site of wastewater production.
- robust process which is able to withstand a wide range of operating conditions.

Trunz Filter system²⁰: Some of the advantages of this system are:

- occupies limited space.
- is powered by its own wind and solar panel generated electricity.
- energy consumption is 350 W/h.
- its mass is approx. 910kg - 1000 kg.
- can process 20 000 litres of water per day.

Monthly maintenance and operating costs for the operating costs of the Biolytix, Wetland and the Trunz filter systems per month, are approximately as follows²¹:

| | |
|---------------------------|------------------------|
| Plant Maintenance | R350 (not every month) |
| Pump and Pipe maintenance | R200 (not every month) |
| Electricity | R150 |
| Labour | R572 |
| Total | R1272 |

**Average for 12 houses, SI, approx. R40 - R80 per month
school and businesses**

²⁰ Information obtained from <http://www.trunz.ch>. Accessed 30 September 2007.

²¹ These costings were obtained from the administration of the Sustainability Institute (SI), 26 September 2007.

Table 1.6 Percentage Savings in Water Use – Lynedoch EcoVillage

| Month | Recycled water | Municipal water | Total water | % recycled used (Savings) |
|-----------------|-----------------------|------------------------|------------------------|----------------------------------|
| April 2006 | 42204 | 32361 | 74565 | 57% |
| May 06 | 50445 | 23145 | 73590 | 69% |
| June 06 | 36816 | 97990 | 134806 | 27% |
| July 06 | 76058 | 109619 | 185677 | 41% |
| August 06 | 81655 | 68199 | 149854 | 54% |
| September 06 | 97455 | 63103 | 160588 | 61% |
| October 06 | 54404 | 43996 | 98400 | 55% |
| Nov 06 – Jan 07 | 376405 | 243114 | 619519 | 61% |
| Total | 815442 (l) | 681527 (l) | 1496969(1,5 MI) | Av 54% |

Among the strategic intentions in the design and operation of the water and sanitation system of the Lynedoch EcoVillage, was to achieve a saving of 40% in the use of the Municipal water. The average percentage use of recycled water shows that this has been achieved over the months the readings were taken. This compares favourably with a new housing development in the United Kingdom (UK) where the aim is to achieve a 33 % saving in use of water (BedZED: 20). The savings in water use help in achieving savings in the cost of water as set out in section 6.1.

12. IMPLICATIONS

The implications of operating a water and sanitation system, as has been installed at the Lynedoch EcoVillage, are now discussed.

12.1 Conventional Bulk Water and Sanitation systems

These conventional wastewater systems are part of conventional urban planning and a centralized approach to the treatment of wastewater. This enables a large population in an urban area to be serviced in terms of water and sanitation. Generally these are the systems that are put in place for most urban and city developments. These systems concentrate on transport of

wastewater (sewer infrastructure) and end of pipe treatment (sewage works). However disadvantages of these systems are as follows (Wilsenach, 2006:3-28).

- Receiving waters of effluent are endangered despite the general quality of treatment. Water quality of effluent is generally not pure enough to be recycled for domestic use (toilet flushing).
- Large retention dams have usually to be built to cope with oversupply of effluent to the treatment works. This is usually due to the fact that sanitation services and urban drainage (rain water) are coupled together.
- Large scale centralized wastewater treatment plants require high investment, energy, operating and maintenance costs. Generally, however, transporting wastewater in sewer networks for large populations in cities is efficient. Investment and maintenance costs, when calculated per capita, are usually fairly low. Costs will increase if sanitation services and urban drainage are to be uncoupled.
- Use is made of water to transport waste over distances. This requires use of often diminishing water supply in countries where water scarcity is a problem.
- Leaks and breakdowns often occur with the result that groundwater and receiving water bodies become contaminated (ref. to Cape Town in the introduction). Groundwater can be polluted. The mixing of faeces with water contributes to the spread of waterborne diseases.
- Maintenance of such large systems requires finance and adequately skilled people to maintain the systems (ref. to Cape Town in the introduction). This is often a problem in developing countries.
- Nutrients and organic matter in wastewater are generally not recycled leading to a systematic deterioration of soil quality.

12.2 Alternative Sanitation Systems

The problems in conventional systems have led to alternative approaches. These systems aim at achieving sustainability by not only concentrating on sanitation and environmental protection but also on nutrient and water recycling. Some aspects of these systems are as follows (Wilsenach, 2006: 18-28).

- These systems can promote the concept of uncoupling sanitation services and water drainage.

- These systems often reflect value systems and there is often a strong normative element in implementing new techniques. The mixing of faeces in wastewater leads to the spread of waterborne diseases and this should be avoided. Further, toilets should not flush with high quality drinking water. There is need for ‘service water’ in a second network. This, however, will require increased investment and savings in water use would have to justify such increased investments.
- These systems are usually employed in decentralized community projects where self-reliant communes aim at addressing environmental problems. Stratified suburbs and industrial areas in contemporary urban design do not allow decentralized systems. Specialisation, separateness and individualism are emphasized in such urban design and lay-out.
- The effect of these systems is only marginal at present and it is yet to be shown that these will work in developing countries. Both conventional and alternate systems will require finance, capacity and political will to sustain these systems.
- There is need for valid comparison between existing and new alternative systems with the following criteria
 - cost of capital infrastructure and operation and maintenance
 - reliability in terms of proposed re-use application
 - fail-safe operating systems

12.3 Lynedoch EcoVillage Water and Sanitation System

The Lynedoch EcoVillage Water and Sanitation System would fulfill to a greater degree what alternative water and sanitation systems set out to achieve.

- The system as described and analysed in the preceding paragraphs is set within a community based eco-village. The Lynedoch EcoVillage aims to achieve ecological, social and economic sustainability. The residents and homeowners, the school, the businesses and Sustainability Institute all subscribe to these ideals. The decentralized water and sanitation system is part of the means to achieve environmental sustainability. The whole EcoVillage would know that treatment of grey and black water is on-site and the Code of Conduct of the LHOA would stress the community responsibility for these facilities.
- Capital infrastructure costs for the water and sanitation system and the operating and maintenance system compare favourably with conventional systems. In terms of cost

effectiveness, the capital costs are a one-off cost and could be recovered in any community development project through the sale of the properties.

- There is a strong value and normative element in the aims of the EcoVillage in terms of water saving, water recycling and recycling of nutrients. The black and grey water is not transported via long sewer lines where leaks and breakages can occur. The treatment systems are on-site and decentralization of treatment is achieved. Prevention of leakage into the ecosystem is achieved.
- The residents and occupiers at the EcoVillage have thus the ‘luxury’ of using flush toilets and not waterless toilet systems. Water saving is emphasized with dual-flush toilets and low-flow showerheads and taps.
- The tests conducted through the services of the CSIR have shown that there is an improvement in the quality of the treated effluent. There is conformance with some of the standards set out by the Department of Water Affairs and Forestry. With some operational changes, a greater degree of conformity can be achieved, especially in the Biolytix system. Water saving and water recycling of treated wastewater have been achieved. Nutrients in wastewater can also be recycled for the irrigation of gardens and common green areas. There is thus a favourable comparison with existing systems of water and sanitation but also an added emphasis on the re-use application of water and nutrients.
- The design and operation of the water and sanitation systems at the EcoVillage has thus far achieved a high safety record.
- The system is thus replicable but it has to be situated in a closed community development project or housing project where users subscribe to the aims set out to be achieved by such an alternative water and sanitation system. There is no reason why such a system cannot be replicated in a developing country. It is not a system that can only be used by a first world ‘green’ community development.
- In general, with the recommendations discussed above (sections 9.2 and 9.3), the effluent of the Biolytix system can be used for irrigation and the effluent of the Wetland system can be recycled through the toilet systems of the buildings of the EcoVillage.
- The spaces (land area) necessary for the Biolytix system and the Wetland system, are both favourable. The Biolytix system occupies a bottom corner of the EcoVillage development.

The Wetland system is at the bottom end of the development and will form part of the landscaping.

- The Trunz filter system can replace the need for a storage dam (for polishing) which could occupy much needed space in a development. The Trunz filter system occupies little space. The capital costs of the Trunz system when added to that of the Biolytix and Wetland systems, do put the capital costs of the total system at a disadvantage when compared to conventional systems. The Trunz filter was not originally part of the design of the water and sanitation system of the Lynedoch EcoVillage.

Some advantages of an alternative water and sanitation system that have not been achieved at the Lynedoch EcoVillage would be –

- Separation of black and yellow water at source so as to achieve greater pathogen removal and nutrient re-use. Urine diversion (UD) toilets have not been used and the system is not set up for separate treatment of black and yellow water. However, in stating this, it might not be financially advantageous to use UD toilets. The present system does recycle nutrients. The gardens and open areas at the EcoVillage are not that extensive to warrant such expense for UD and there are no agricultural and market gardens on the development requiring the use of such fertilizer.
- The use of biogas digesters for the treatment of black and grey water so that methane gas (biogas) can be used as an energy source for domestic use. The biogas digesters could replace the septic tanks in the design of the system. Again, the financial outlays to install such systems might not be offset by the gains in using biogas. As it is, householders in terms of the LHOA constitution use only gas cookers and purchase gas canisters/containers locally.

The important issues discussed above for the Lynedoch EcoVillage Water and Sanitation System are summarised in tabular form below.

Table 1.7 Summary of Investigation Results

| Effluent Quality | Biolytix vs DWAF limits | Wetland vs DWAF limits |
|---|--|--------------------------------------|
| Pathogen removal | Not fully achieved | Achieved |
| COD load | Not fully achieved | Achieved |
| N (NH ₄ ⁺) | Not Achieved | Achieved |
| N (NO ₃ ⁻) | Achieved | Not Achieved |
| P | Not Achieved | Achieved |
| TSS | Achieved | Achieved |
| Recovery of Nutrients | Biolytix System | Wetland System |
| Nitrification (NO ₃ ⁻ formation) | NH ₄ ⁺ not removed | NH ₄ ⁺ removed |
| Nutrient recycle – PO ₄ ³⁻ | Limited removal | Mostly removed |
| Denitrification (N ₂ formation) | Not achieved | Limited |
| Water Savings | Savings for irrigation | Savings for toilet systems |
| Capital Costs vs conventional systems | Favourable | Favourable |
| Maintenance & operational costs vs conv. systems | Comparable | Comparable |
| Space requirement | Favourable | Fits into the landscape |
| Administration & operation | Within a closed development | Within a closed dev. |

13. CONCLUSION

It could be argued that such community development projects or housing projects are more the exception than the norm. Thus the provision of water and sanitation is usually locked into the common bulk systems approach. The linear approach of transport of sewerage via sewers and end of pipe treatment at sewage works generally continues to be implemented in cities and urban areas. Engineers need to think holistically and eco-logically in terms of urban design, building design, water and sanitation provision, energy and transport. This is necessary to achieve social, economic and ecological sustainability. This paper has set out to show the enormity of the

problem in providing safe water and sanitation to the world's growing population. Alternative systems would seek to save on water use and avoid capital expensive bulk sewer systems and treatment works by employing on-site treatment systems and at the same time seek to achieve the recycling of water and nutrients. The paper has discussed various options in this regard.

The Lynedoch EcoVillage development and the water and sanitation system of the development have been discussed as a case study. It has been shown that the alternative system in the EcoVillage can achieve all the intentions that have been sought in the design in terms of water savings, recycling of water for toilet flushing and for re-use of nutrients and at the same time preventing the eco-system from being contaminated – provided the recommended operational issues are implemented. It has been stressed that such a system can be replicated but that would need to be done in a community based project or development.

In summary, such alternative water and sanitation systems can be used -

- Where connection of a development to a centralised bulk servitude system is impossible.
- Where a development takes place 'over' the existing infrastructure which cannot meet the design aims and capacity of the development.
- Where centralized systems cannot keep up with development.
- Where a community development project wishes to use recycled resources.
- Where ownership is established such as in a closed development.

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