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THE FUTURE OF WATER, SANITATION AND HYGIENE:
INNOVATION, ADAPTATION AND ENGAGEMENT IN A CHANGING WORLD

**Effective wastewater treatment and re-use:
learning from Lynedoch**

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Decentralised wastewater treatment presents the opportunity for remote communities to benefit from the convenience of waterborne sanitation. To offset the water demand of full waterborne sewage systems, the Lynedoch Eco Village in the Western Cape of South Africa has adopted an innovative approach to wastewater treatment, using low energy, low technology treatment processes and reclaiming treated effluent for toilet flushing and irrigation. This approach, combined with rainwater harvesting, enables flush toilets to be provided with a minimal supply of fresh water. Now in its 10th year of operation, valuable lessons can be drawn from the Lynedoch case study to inform the effective provision of decentralised wastewater treatment systems. This paper concludes with ten key recommendations that should be considered in the design of sustainable decentralised wastewater treatment systems.

Introduction

Waterborne sewage systems offer an effective means of discharging waste from urban communities. Yet with increasing urbanisation and limited water resources, the high water demands created by a conventional sewage system are increasingly becoming unsustainable. The practice of discharging greywater down the drain (from the bath, shower, sink etc.), while clean drinking water is used to flush toilets is inefficient and wasteful.

Increased urbanisation and a limited water resource, requires a more prudent approach to water and wastewater systems. Sustainable water use and wastewater recycling is incorporated into developments worldwide with an increasing popularity. Examples from around the world are discussed in comparison with the Lynedoch Eco Village in South Africa. This paper considers the key elements which are incorporated in 'sustainable' developments which can also benefit poor urban communities where water efficiency is not just a fashionable aspiration but is essential for improved sanitation facilities.

Background to the Lynedoch Eco-Village

Surrounded by vineyards, the Lynedoch Eco-Village is located near to Stellenbosch in the Western Cape of South Africa and was founded in 1999. The Eco-Village aims to be an economically viable example of a liveable, ecologically designed urban system. This mixed use development was constructed on the site of the old Drie Gewels Hotel, most of the historic buildings and water infrastructure were retained.

Currently, the Lynedoch Development comprises a pre-school and primary school with over 360 children and staff, the Sustainability Institute employing 30 staff, and hosting up to 70 students and numerous conferences, a guest house, 17 residential properties (a combination of low income and middle households), office facilities for four independent organisations, a plant nursery and vegetable garden. Later phases of development will see the number of residential properties increase to over 100. The incorporation of solar water heaters and the reclaimed water systems helps to reduce water and energy bills, making the provision of these services affordable to the low income households.

The water and sanitation system at the Lynedoch Eco-Village was designed by Bart Senekal Consulting engineers with consideration of the following: (Dowling, 2007) –

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- The scarcity of future water supply;
- the absence of existing bulk municipal sewers;
- the increasing cost of centralised water and wastewater treatment due to the need for new infrastructure, and tighter environmental constraints; and,
- the desire to achieve eco-efficiencies, such as water re-cycling and nutrient capture.

Examples from around the world

The use of reclaimed water is widespread, with a common focus on agricultural applications. The examples discussed below consider the use of reclaimed water primarily for toilet flushing, whereby the use of reclaimed water is used to supplement domestic water supply.

Rouse Hill, Sydney, Australia (www.sydneywater.com.au)

The Rouse Hill Development Area is one of the largest planned communities in the world using reclaimed water, currently serving over 25,000 dwellings over an area of 13,000 ha. The project was initiated to address environmental concerns about the impact of treated effluent discharging to the Hawkesbury-Nepean River.

The wastewater is treated in a biological nutrient removal wastewater treatment plant, and then fed to a reclaimed water plant consisting of screens; grit removal; primary sedimentation; and a biological reactor.

The reclaimed water is treated by ozonation for virus inactivation, microfiltration, and disinfection using sodium hypochlorite.

Tokyo, Japan

To allay concerns of how the future water demand could be met for the rapidly growing metropolitan area of Tokyo in Japan, the Tokyo Metropolitan Government (TMG) require all newly constructed large buildings, to be equipped with dual plumbing systems and use reclaimed water for toilet and urinal flushing. (Suzuki et al., 2002) ; The reclaimed water is supplied by major wastewater treatment plants, the reclaimed water is distributed through widespread network of reclaimed water pipes. Conventional wastewater treatment processes are used to achieve the required target for coliform concentration of “no detect” with 10 per 100 mL as a maximum (MLIT, 2005).

Table 1. Reclaimed water quality guidelines for urban uses in Japan (Asano, 2007)

	Unit	Toilet/urinal flushing	Spraying on street and ground	Recreational uses and water features
Total coliform	No./100mL	No detect	No detect	No detect
Turbidity	NTU	2	2	2
pH	pH unit	5.8 8.6	5.8 8.6	5.8 8.6
Appearance	-	Not unpleasant	Not unpleasant	Not unpleasant
Color ^b	CU			<10
Odor ^b	-	Not unpleasant	Not unpleasant	Not unpleasant
Chlorine residual	Mg/L	0.1 (free), 0.4 (combined)	0.1 (free), 0.4 (combined)	0.1 (free), 0.4 (combined)
Treatment requirements		Sand filtration or equivalent	Sand filtration or equivalent	Coagulation, sedimentation and filtration or equivalent

Lynedoch Eco Village, South Africa

The Lynedoch case study demonstrates an efficient and innovative approach to water and wastewater. This combines on-site wastewater treatment with a dual water system which provides clean water to taps and reclaimed water to toilets. All wastewater is treated on site through a system of low energy anaerobic and

aerobic processes, septic tanks / biogas chambers, Biolytix filter and a vertical flow wetland. The treated effluent is fed directly into the reclaimed water main for toilet flushing and irrigation. Compared with the above examples the Lynedoch case study uses simple treatment processes with no ozonation or disinfection. Consequently the operation and maintenance burden is significantly reduced at the acceptance of a lower water quality.

Water demand

Seasonal irrigation demands and a transient population mean that the water and waste-water demands at Lynedoch are highly variable. The daily load on the wastewater treatment works can be less than 10kl per day associated with the residential properties to nearly 30kl per day when the site is fully occupied. Similarly the demand on the reclaimed water system can fluctuate from 7kl/day to over 40kl/day during the summer period when the irrigation demands are high. The peak irrigation demand can be supplemented by groundwater abstraction from the two on-site boreholes; however, high salinity and poor yields prevent the prolonged use of groundwater.

In the event of high demand or low supply, the reclaimed water system may be supplemented by the municipal water supply. Future residential development phases will also lead to a significant increase in the base demand

Water strategy

The primary aim of the water and wastewater systems at Lyndoch is sustainable water use; the figure below was developed by Maluti GSM Consulting Engineers as a tool to illustrate the mechanisms and outcomes associated with the developments water strategy. A clear understanding of this water strategy provides a useful tool to support the operation and maintenance processes and steer future development and upgrades.

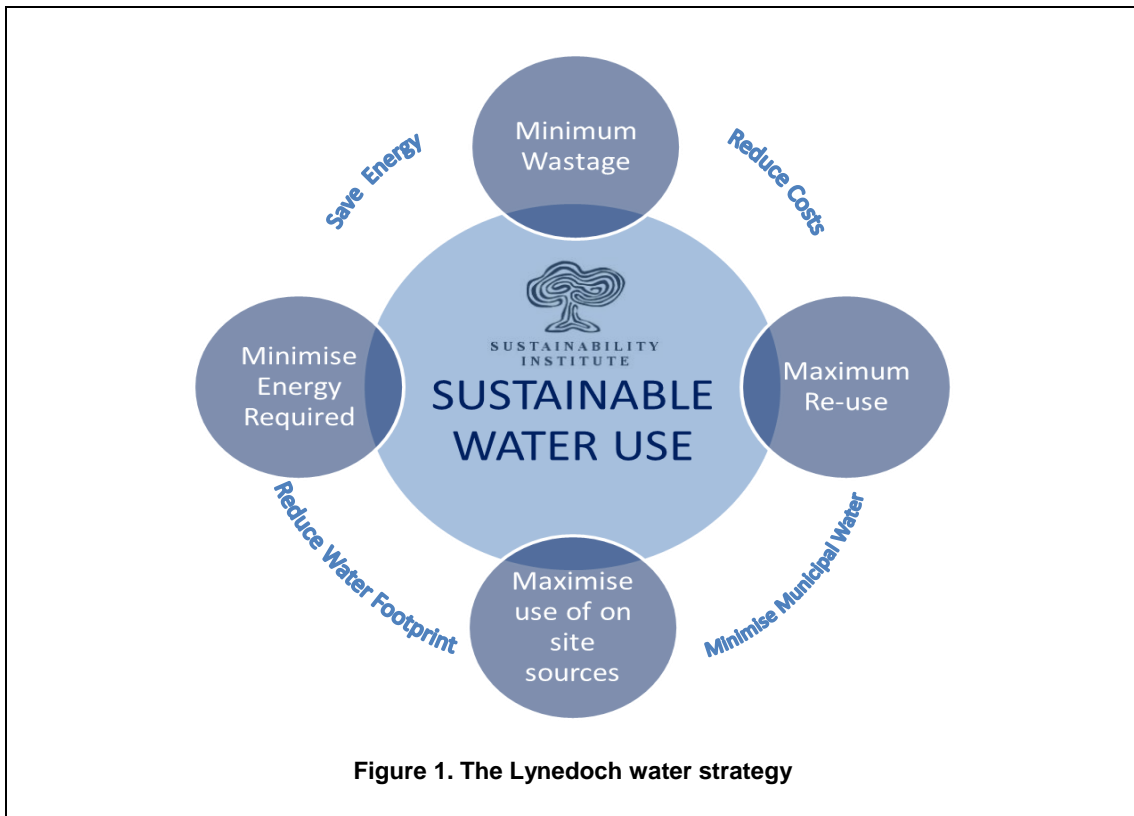


Figure 1. The Lynedoch water strategy

To achieve minimum wastage should involve the use of water efficient devices, attending to leaks promptly, effective irrigation, and appropriate operation of infrastructure to prevent unnecessary overflows.

Maximum re-use involves using the reclaimed productively. The recently installed water metering programme has enabled accurate measurement of clean and reclaimed water consumption; this indicates a surplus of reclaimed water, and consequently additional buildings will now be connected to the dual water system.

Maximising the use of on-site sources of water has involved the establishment of a widespread rainwater harvesting system which diverts all surface run-off from the roofs and hard surfaces into a storage reservoir. The overflow from the reclaimed water system is also diverted into this reservoir. This water is primarily used for irrigation.

Minimising the energy consumption involves a passive water treatment process and seeks to minimise unnecessary pumping. A biodigester linked to a few of the houses is also used as a means of generating energy in the form of biogas which is used for cooking.

Water supply and wastewater infrastructure

Water supply:

All potable water is from a municipal supply. A dual water supply system was installed to reduce consumption of municipal water by reclaiming the treated wastewater for toilet flushing and irrigation. At a household level, the clean water consumption is proven to reduce by as much as 40%. All irrigation is from borehole water or reclaimed water.

Water efficient devices:

The Lynedoch Village Homeowners Association specifies that all new properties are to be fitted with water saving taps and shower-heads, and dual flush or manual flush toilet systems. Manual flush systems require the user to press the handle for the full flush duration, allowing greater control over the volume of water required.

Wastewater treatment:

The wastewater from households is collected in either biodigestors or septic tanks as a primary settlement process to remove solids. The removal of solids at the top of the system enables the pipework downstream to be narrow bore at just 110mm thereby reducing infrastructure costs. This system also prevents non-biodegradable waste from flowing downstream which would otherwise clog the secondary treatment process.

The wastewater from the main Sustainability Institute building and the guest house discharge into a Biolytix filter. The Biolytix filtration process is a self-sustaining, aerobic treatment process where oxygen-breathing bacteria and other larger organisms (generally earth worms) decompose sewage and organic wastes. (www.biolytix.co.za). This is a primary treatment process which utilises the natural formation of a humus layer to aid filtration and aeration.

Following on from these separate primary treatment processes, the effluent is combined and discharged into a vertical flow constructed wetland. The intermittent discharge onto the surface of the filter medium maximises the aeration process. Reeds are also planted into the filter bed. The dry surface of the wetland helps to minimise odours.

When functioning properly the combination of the primary and secondary treatment processes is capable of treating the waste to the standard required by the Department of Water Affairs (DWA) such that the treated water can be used for irrigation. There is no specific guideline which relates to the required water quality for toilet flushing, however a guideline was developed based on the DWA Class II and domestic water quality requirements, this accepts low levels of faecal coliforms and E-coli in the water used for toilet flushing. The primary water quality parameters are described in Table 2 below.

There has also been a trial demonstration of the Trunz Filter, this ultrafiltration package plant is designed primarily to filter river water for potable uses. In this application the Trunz filter was used to filter the wetland effluent prior to being used for the reclaimed water. Since the primary and secondary treatment phases are capable of filtering the wastewater to an acceptable standard for re-use, it is considered that the relatively 'high-tech' Trunz filter exceeds the required treatment standard and is therefore not required in the treatment process.

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Table 1. Water quality monitoring											
		Ammonia	Chemical oxygen demand	Conductivity	Dissolved oxygen	Faecal coliforms	E Coli	Dissolved iron	Nitrate (N)	Ortho Phosphate (P)	pH
Unit		mg/l	mg/l	ms/m	mg/l	/100ml	/100ml	mg/l	mg/l	mg/l	
Location	Reference guideline	Maximum allowable content (min. DO) or acceptable range									
Biolytix effluent	No specific guideline (to secondary treatment)	75	150	200	9	N/A	N/A	N/A	N/A	N/A	5,5 – 9,5
Wetland effluent	DWAF irrigation	3	75	150	1.4	1000	1000	20	15	10	5,5 – 9,5
Toilet cistern	DWAF class II and domestic (adapted)	10	75	150	1.4	20	1	1	10	10	6,0 – 9,0

Pumping:

For all its merits, the wastewater treatment system at Lynedoch fails to take advantage of the 30m drop in level that is available at this site. The multiple stages of pumping represent a significant maintenance burden. Space constraints meant that the bulk reclaimed water storage could not be placed at the highest point on the site and therefore requires a booster pump to supply reclaimed water to the homes, if this pump fails, the municipal backup must instantly be used despite there being reclaimed water available.

Water metering:

The water metering programme was recently established by Maluti GSM to improve the understanding of the water and wastewater systems and Lynedoch. The water balance generated through the metering programme enables the identification of leaks and inefficiencies in the system. In addition, the metering enables accurate billing. This metering process confirms that household reclaimed water consumption (toilet flushing) represents between 17% and 51% of the total household consumption, with most households falling between 30% and 40%. Interestingly the volume of reclaimed water consumed at the low income and middle/high income households is similar; however, clean water consumption is significantly greater in the middle/high income households.

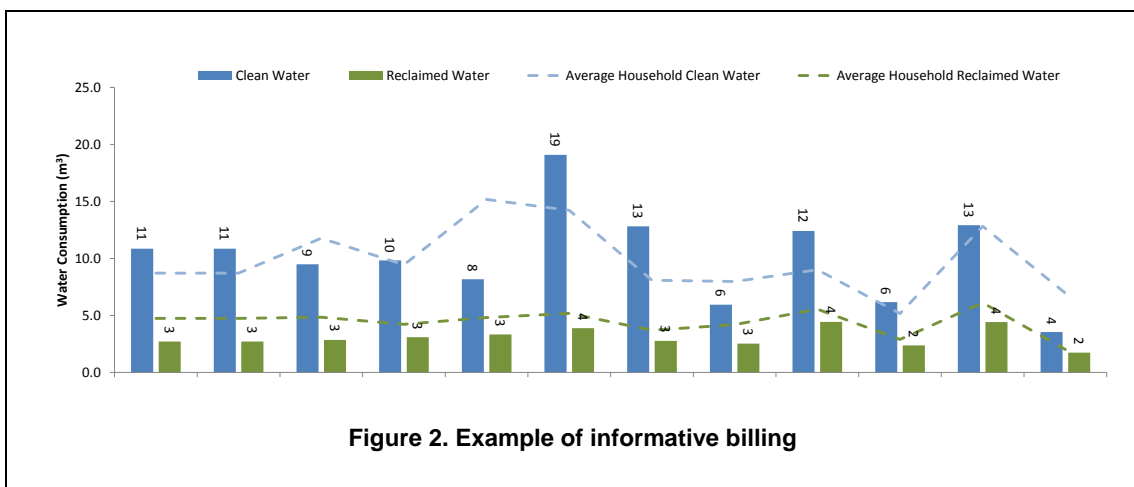


Figure 2. Example of informative billing

The informative billing process was developed as part of the Lynedoch metering programme enabling consumers to track their monthly consumption and compare it to the average household consumption. Space is also given on the bill to inform consumers of the site's water balance and to communicate information related to water efficiency. This informative billing process seeks to encourage more efficient water use.

Water quality issues

Consistency of water quality is a particularly important issue on a reclaimed water system. Preventing exposure to the risk of faecal contamination must be addressed at a technological and social level, ensuring there are sufficient safeguards and sufficient understanding to prevent a risk to public health. At Lynedoch the pipes supplying the clean water are colour coded and operate at different pressures to prevent mis-connection.

While the green credentials (and cost savings) associated with the use of a dual water system results in a greater acceptance to the extent that occasional discolouration of the reclaimed water is tolerated by the community. However to minimise the risk of contamination and to prevent the growth of algae, some form of rudimentary disinfection could be incorporated without placing a significant operational burden.

Recommendations

With consideration of the strengths and weaknesses of the Lynedoch case study, the following recommendations can be applied to the successful implementation of decentralised wastewater treatment system.

Develop a water strategy

From the outset the water strategy should be clearly identified. This will help inform key decisions about the scheme design to ensure that the infrastructure and process design is fit form purpose and aligns with the aims of the water strategy. Water source and water demand issues must be appropriately addressed to secure sustainable water management practices.

Let it flow

Scheme design should work with the topography of the development area. Unless the site is completely flat, this will result in the demarcation of areas for bulk water storage (at the top of the site) and wastewater treatment (at the bottom of the site). The space allocated for the wastewater treatment system should make provision for the required head to transfer wastewater between the treatment stages without unnecessary pumping. The ideal reclaimed water system will pump only once from the bottom to the top of the site, all water and wastewater transfer in between should be by gravity. This will not be possible on flat sites.

Plan for growth

With consideration of the above, the system must make allowance for future growth. This will involve identifying the catchment which can strategically be served by the treatment works and allowing adequate space for extension of the plant within the demarcated area.

Design with the operator in mind

All systems need to be maintained. Parts of the works requiring frequent maintenance and cleaning must be easily accessible, and the operator must have the appropriate equipment to perform the required tasks. It is particularly important that the system is designed with consideration of the skill level of the local operators. High technology systems which require apparently less maintenance could result in catastrophic failure of the treatment works while the operator waits for expert assistance or specialist parts.

Appropriate technology requires appropriate maintenance

Even the appropriate technologies such as the Biolytix and wetland require appropriate maintenance. This must take the form of both preventative maintenance (such as routine checks and cleaning), and responsive maintenance, following an observed decline in effluent water quality or capacity (such as replacing filter media). This approach will reduce the occurrence of emergency maintenance tasks which are likely to cause disruptions in supply. It is fundamental that the operator is given the necessary training and support for him to fulfil appropriate maintenance procedures.

Prevent a ‘flush and forget’ mentality

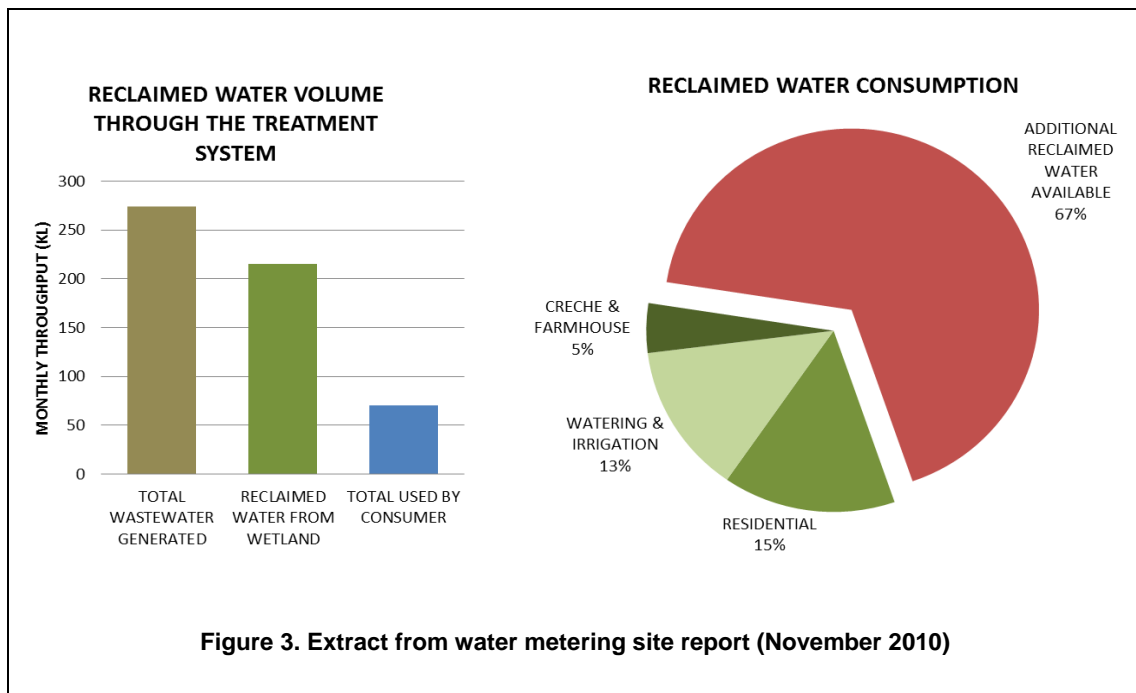
To minimise the non-organic waste handled at the treatment plant, it is worthwhile designing a system which requires the homeowner to take responsibility for their own waste at source. Incorporating household septic tanks or trash screens will require individuals to ‘clear out’ the screens or ‘cut out’ the disposal of non-degradable wastes.

Stormwater storage

Effective stormwater capture can help reduce dependency on potable water sources. The harvested rainwater can be used for bathing or other household uses. It is generally not suitable for continual drinking water due to the low mineral content. Rainfall patterns and surface area will determine the volume of water that can be captured and the size of tank needed to store the available water. In most climates the size of tank required is too large to make it affordable as the primary water source. Rainwater harvesting can, nonetheless supplement water requirements at a household level. At a larger scale, storm water capture can be a valuable water source. Again dealing with storage at source enables households to manage their own consumption, while communal storage might result in a collective cost saving and the capture of water from wider areas (roads as well as roofs).

Metering & monitoring

Metering and monitoring is required to inform the effective operation and maintenance of the system. A water balance will identify leaks and inefficiencies in the system. The sample output from Lynedoch, is presented in Figure 3, this identifies a significant surplus of reclaimed water which is not being used. This information supports the installation of a dual water system to buildings which do not currently use reclaimed water.



The water quality monitoring is essential for securing the water quality of the reclaimed water. A declining quality should trigger prompt and appropriate maintenance.

Greywater separation

Greywater separation is not currently utilised at Lynedoch. Greywater separation can reduce the pressure on the primary treatment processes. If greywater is dedicated to toilet flushing the risk of faecal contamination is significantly reduced. The centralised treatment of greywater will require additional pipework, but may result in cost savings elsewhere. Since only 30 – 40% of household consumption is used for toilet flushing, the volume of greywater produced should be sufficient to provide the toilet flushing demand on residential schemes.

Informative billing

Appropriate action by the consumer is fundamental to the sustainability of the water and wastewater system.

The process of informative billing helps to engage the consumer with the system, and can be applied even where consumers are not billed for their water use.

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The original scheme design was completed by Bart Senekal Consulting Engineers. The Bio Digester was designed and constructed by Agama Energy. Maluti GSM consulting engineers have developed the water metering programme and are currently working with the Lynedoch development to improve the wastewater treatment and reclaimed water system.

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