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The treatment of waste water through constructed wetlands

Introduction

Wetlands in nature play a great role as a means of cleansing polluted water. They support a most diverse community of life forms. This diversity of physical and chemical niches present in wetlands results in a continuum of life forms from the smallest microorganisms to the largest trees. This biological diversity creates inter-specific interactions, resulting in greater diversity, more complete utilization of energy inflows and ultimately to the emergent properties of the wetland ecosystem.

Aquatic plants have adapted themselves for life under submerged conditions, i.e. they are able through their arenchyma (hollow structured tissue) to bring oxygen into otherwise anaerobic places. Through this they are able to support aerobic micro-organism communities that feed on the nutrients and pollutants in the water and help to selectively destroy pathogenic bacteria. Certain plants exude chemicals that crack complicated chemical structures of pollutants into the simple building blocks of nature that are then able to be incorporated within the cell structures of plants or dealt with appropriately otherwise.

Numerous researchers mainly in Europe and North America have over the last few decades studied natural wetlands and successively used the intrinsic principles to construct wetlands for the treatment of the most diverse effluents: domestic, industrial and agricultural.

Thousands of constructed wetlands over the globe treat "waste" waters to a very high final effluent quality, better than any traditional sewage work can achieve.
We have case studies of constructed wetlands for:

- Domestic effluent
- Pulp and paper
- Abattoir and meat processing
- Landfill leachates
- Mine drainage
- Urban run-off
- Feedlot run-off
- Dairy
- Petrochemical
- Food processing plants (potato, maize)
- Breweries
- Tanneries

- Sugar refineries
- Sludge de-watering/processing
- Etc.

The largest constructed wetland to date – 3000 ha – treats agricultural run off from maize and cotton farms to protect the sensitive natural swamplands of the Florida Keys, USA.

Constructed wetlands have the following advantages:

- Flexible design, according to needs.
  Every wetland is modelled on the type of effluent it receives and what the requirements are for the final discharge. E.g. for a discharge into a natural stream you want an effluent that has a minimal nutrient content to avoid euthrophisation, yet for use in agricultural applications you would be quite happy to have some nutrients in the final effluent! Every situation is different, so we also look at what other technologies can be used to create a sustainable, holistic method of the purification needs (e.g. composting, filtering of effluents with a high SS count etc.)
- Attractive landscape feature.The closer a constructed wetland can emulate nature the more stable and self-perpetuating it will be. So they make marvellous landscape features.
- Lower cost than conventional systems.
  Soft engineering and low maintenance reduces costs considerably.
  Wetlands live a very long life, if properly constructed, many decades with minimal capital outlay.
- Recycled water can be used for irrigation – you use your water at least twice!
  As mentioned above, nutrients within the effluent are beneficial for irrigation. Alternatively water can be cleansed to such a high standard that it can be used in water features, safely infiltrated into the soil or led into a nearby stream.
- No putrid smells. The use of Effective Microorganisms (EM) as well as initially a mostly aerobic process makes it pleasant to visit the site. – Invite your friends to a coffee beside the sewage plant!
- Works in all climates all year round.
  Although at a reduced rate, these systems work in the snow as well! We have case studies of constructed wetlands in every climate from desert to tropical islands.
- Minimal or no extra energy input.
  Provided there is enough slope most of the operation can be done without external energy input. At the most a pump is needed, that will ideally be driven by solar power.
- Minimal maintenance (from an unskilled person)
  It's like a garden. Some weeding is necessary and cutting of old reeds....
- Attractive to wildlife – birds, amphibians etc.
  It is well documented that at the edge, where two biospheres, microclimates meet, the bio-diversity of plant and animal species is greatest. A wetland is such a zone and one can observe a breathtaking adaptation happening within this sphere. The amount of life suddenly happening on ones property/operation is truly amazing.

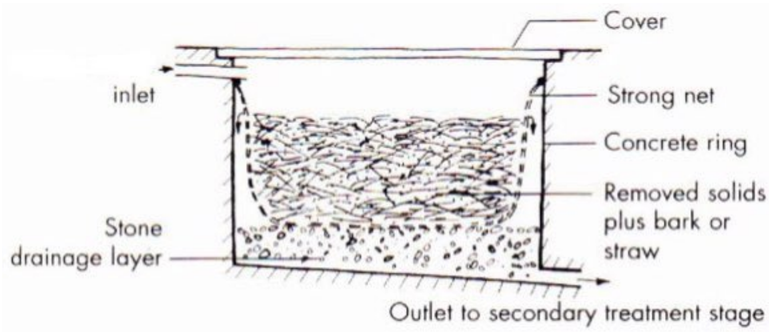
- Educationally stimulating. With the above in mind a wetland has research and recreation possibilities for all ages and is a true asset.
- And many more...

Why over-engineer solutions, when nature shows us a more simple and effective way?

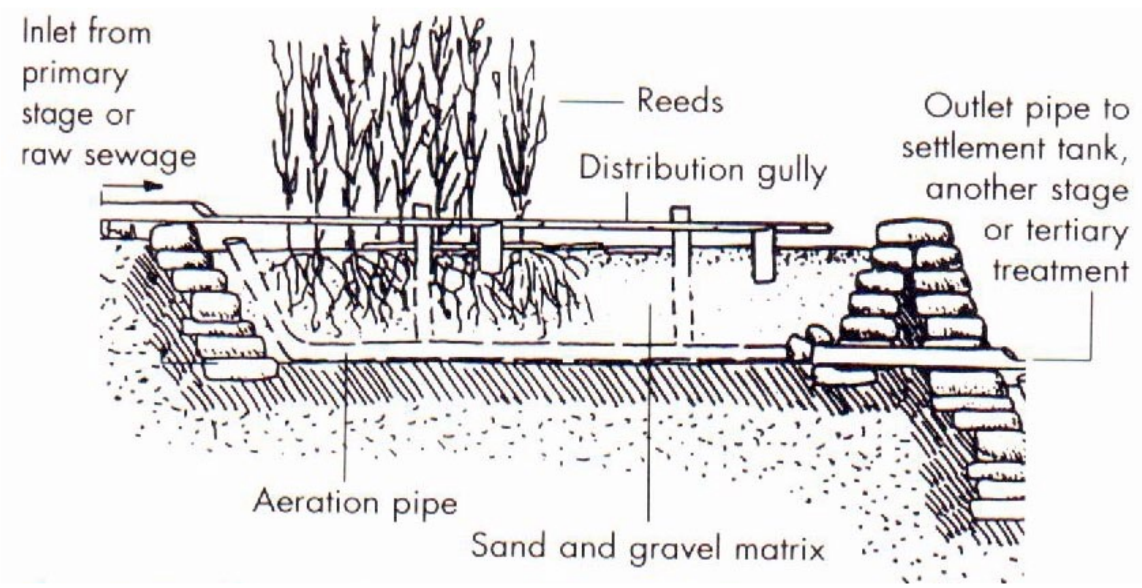
<u>A typical system:</u>

Process:

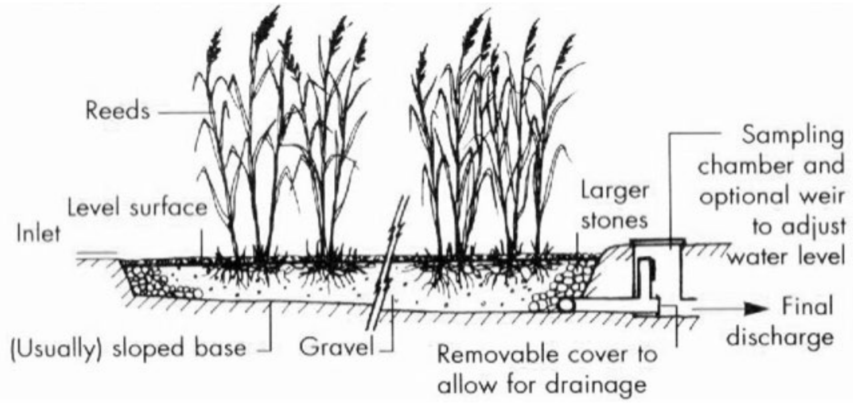
To keep the waste in an aerobic condition initially (to avoid any smells), all wastewater will gravitate over a 'biolytic/bark filter'. The filter will condition the waste water and all possible solids be composted by the huge range of organisms present in the system. This will have to be a watertight sealed brick structure (underground).



The partially treated effluent will be distributed over the surface of a vertical flow wetland. As the word indicates, that effluent trickles through the wetland vertically, thus being treated aerobically. This will be a 1m-deep structure, filled with different gravel media and planted to the common reed, Phragmites.



The effluent now flows into a second vertical flow wetland planted to typha capensis.
The partially treated effluent now gravitates into a horizontal flow wetland, which is planted with a variety of aquatic plants (Schoenoplectus, Acorus, Cyperus, Mentha etc.).



Two final options are to either collect the treated water in a reservoir/pond and pump out to where it is needed to irrigate the garden or direct it into swales, to infiltrate into the ground and water e.g. some trees, shrubs.

There are different possibilities in establishing a wetland on your property through us and cost varies greatly and needs to be investigated on an individual basis, so please

<u>Advantages of the reed bed process</u>

Reed bed systems have a number advantages opposed to conventional wastewater treatment options, including:

1. Low operational and maintenance costs
2. Simple construction, minimal mechanical or electrical equipment.
3. Established at localities where wastewater is produced and is to be subsequently re-utilised.
4. Being a 'low technology' system it can be established, operated and maintained by relatively unskilled personnel
5. The system is compatible with common agricultural practices of crop production and water circulation.
6. Technically they are robust , adaptable and are able to withstand fluctuating operating and loading conditions.

Cresset House Constructed Wetland , 2012

System Principles

Primary Treatment

The wastewater treatment facility to be constructed for you is comprised of septic tanks for the primary reception of domestic ablution wastes from the residential sector and kitchen.
The separated solids and associated wastes discharged into the septic tank provide an adequate retention time for the solids' slow degradation, digestion and solubilisation such that the discharge from the septic tank to the Reed bed system is minimised in organic strength and solids content.
The septic tank effluent discharge from each septic tank is reticulated to the Bark filter and Reed bed system for treatment and subsequent re-use.

Bark Filter/Biolytic filter

It is recognised that in an institutional based situation there may be occasions where excessive levels of disinfectants, detergents and associated cleaning compounds may be discharged into the wastewater system. It is also recognised that there will be occasional peaks in waste water loads as a consequence of visitors and open days. Each of these aspects could potentially result in upsets of the performance of the septic tanks and the Reed bed system.
To balance out loads to the Reed beds, a bark filter is provided, through which the primary wastewater percolates. The bark is soaked with a microbial inocculant (EM – Effective Microorganisms), aiding the pre-treatment.

Reed bed Units

The process design for the Reed bed system has been modelled on treatment systems in the UK and Europe based upon their extensive experience with the development of such systems throughout the world.
The system is essentially a series of shallow, (1.0m) concrete (or bricked) ponds containing a bed of porous sand and gravel laid in independent and distinct layers commensurate with a conventional horizontal slow sand filter, in which the emergent aquatic vegetation is planted, the common reed, Phragmites australis.
The bark filter effluent is introduced into the wetland through an adjustable inlet chamber via a series of distribution pipes to the full surface of one or more of the primary reed bed units. This happens in sequence, dependent upon the volumes received, recycle ration, and position in the operation cycle. The wastewater drains vertically through the system of graded filtration media to be collected in the base collection pipe work for transfer to the secondary reed beds where the sequence is repeated.
Wastewater discharged from the secondary Reed beds is directed via a series of Flowforms to impart aeration to the wastewater as it descends into the storage fishpond. From the pond the treated wastewater may either be recycled to the Flowforms or be routed to the irrigation reservoir for controlled re-utilisation around fields, trees, shrubs and open spaces.

Treatment mechanisms

In the bark filter, as the waste water passes through vertically, organic load reduction proceeds to a point where ammonia reduction can be initiated and as ammonia oxidation proceeds the oxygen tension within the reed bed voids and wastewater also increases. Where organic carbon remains available nitrate can be simultaneously removed and the overall alkalinity of the wastewater and local internal reed bed environment is maintained nominally neutral.
The primary function of the bark filter is that the bark and associate fill material provides a natural odour treatment facility, an organic bio filter, which can effectively limit the release of odours, such that the system can be positioned relatively close to the community, for which it is to serve, without too much problem in terms of odours.
The bark filter therefore functions primarily as an anaerobic in-situ contact chamber and attached growth bio filter. The media provides support and attachment surface for the mass of microorganisms, which are able to anaerobically reduce the organic pollutants of the wastewater into innocuous CO2, CH3, H2S etc and new microbial cells.
The media also acts as a simple filter (based on a typical natural forest soil profile with its associated micro and macro flora and fauna) for the retention of influent suspended solids and generated microbial solids, which are then themselves degraded and stabilised over an extended period within the filter, such that outflow SS (suspended solids) levels are generally limited.

Reed beds
Although the plants are the most obvious biological components of the reed bed, the wastewater purification is accomplished through a combination of biological, physical and chemical interactions between the plants, the substrata and the microbial community.
The primary role of the plants is to provide surfaces for bacterial growth, filtration of solids, improve wastewater flow through the system and transfer oxygen to the root zone.

Oxygen supply from the vegetation/air pipes
Vegetation provides oxygen via its root zone to encourage oxidative degradation of the wastewater organics and nitrogen compounds passing through the reed bed. In practice the amount of oxygen that can be reliably expected to be released by the plants is appreciated to be limited in most reed bed systems and restricted to the immediate environment around the plant roots i.e. generally $<$ 1mm radius dependent upon the local oxygen demand and microbial activity.
To enhance the oxidative conditions within the reed beds a network of open aeration pipes are provided within the base of the system through which atmospheric oxygen can diffuse.

Secondary reed beds
The secondary reed beds can essentially operate as a low rate nitrification bio filter column. Whereby nitrifying bacteria are able to compete for sites on the gravel support media with the aerobic heterotrophs. Adequate oxygen to support a degree of nitrification can then be supplied via direct diffusion from the atmosphere as well as that produced by the plants themselves.

Tertiary reed beds
A diversity of plants with an equally diverse root profile are planted here aiding further nitrification and elimination of harmful bacteria, should there still be any present, through their antibiotic exudates.

Pond or reservoir
The effluent flowing into the pond or reservoir is ideally aerated through Flowforms to enhance irrigation water quality. Fish can be grown here (Tilapia), which are feeding on the algae and adding valuable fertiliser to the irrigation water.

Expected fertilising properties of effluent
We would expect the treated sewage effluent to act as an excellent soil additive providing a nominally neutralised pH with supplemented calcium and magnesium from the wastewater components, i.e. salt elements such as Ca, Mg, Na and Cl will not be removed in the treatment process and will remain in dissolved form in the treated effluent irrigation water.

In addition to the irrigation water having a better salt balance than borehole water we will still have plant nutrients in the form of P and N in the treated effluent waters. P in particular will only be slightly removed through the Reed bed system and we would expect ± 5 – 10 mg/l PO4-P in the final effluent. Some nitrogen will be removed during passage through the reed bed system by biological nitrification and denitrification. This will vary dependent largely on the ambient temperature, but as an average we may expect ± 10 - 25 mg/l as total N, i.e. NO3 + NH3.
As a simple mass balance over a year (allowing ± 100 l/person @ 500 persons for 300 days/year = 15 m litres/year) we may expect ± 75kg PO4 and ± 150 kg TN to be available as a fertiliser supplement. In addition to this we would have some additional organic carbon available in the effluent, i.g. ± 75 mg/l, dependent upon the amount of algal development in the pond system. The organic carbon components will assist in creating additional humus since the carbon can be converted into biomass and soil microbial cells. Assuming the ± 75 mg/l organic carbon is converted at a rate of 1:0.2 under semi-aerobic soil conditions, which binds with an equal amount of inert soil mass we may create ± 225 kg soil humus/annum from the irrigated treated waste water.

We would therefore expect a definite increase in plant production and soil conditioning from lands being irrigated with treated effluent waters. We do still need to be aware that the water has not been disinfected in the reedbed/pond system and that there will still be microorganisms present. In treating the final effluent with Effective Microorgansims however, all harmful bacteria will be eliminated.

Please note: should the effluent from the wetlands not be utilised for irrigation purposes, but led into natural aquatic environments, we can certainly bring it to a higher quality effluent with additional treatment stages.

Maropeng constructed wetlands, 2006

Treatment potential of constructed wetlands

From the experience in the UK and South Africa of the type of constructed wetlands we build, we can expect the following analysis of final effluent discharge.
In comparison are figures from DWAF's South African Water Quality Guidelines.
These readings are to be expected in the second growing season, when the plants and microorganisms have reasonably established themselves.

		Reed bed UK, Midrand	Recreational use	Agricultural Livestock	Agricultural Irrigation
			TWQR		
pH	mg/l	6,8 – 7,5	6.5 – 8.4		6.5 – 8.4
Chloride as Cl	mg/l	36 – 40		0 – 1500	≥140
Ammonia as N	mg/l	0.05 – 0.1			≥ 5
Phosphate as P	mg/l	8,7 – 11			
Kjeldahl Nitrogen as N	mg/l	1,8 – 2,4		0 - 100	
COD as O	mg/l	10 – 20			
Suspended Solids	mg/l	3 - 15			≥ 50
E.coli	/100ml	0	Full contact 0; Intermediate contact 0 - 1000	0 - 200	≥ 1
Coliform	/100ml	0	As above	0 - 200	≥ 1
Strep. faecalis	/100ml	0	Full contact 0; Intermediate contact 0 - 230	0 - 200	

Maintenance and running cost

As a constructed wetland works within the rhythms and cycles of nature a certain amount of man-hours are necessary during the establishing time of the system, which is usually a cycle of 4 seasons. In that time the beds have to be kept weed free, so that the aquatic plants can establish quickly. We expect this to be about 2 hours per week for the first year.
The wetlands will need daily attention for five minutes to change pipes and to check that everything runs fine.
After the first year the work involved is changing the distribution of effluent from bed to bed (five minutes in the morning), checking that there is EM in the supply tank, occasional weeding and cutting of reeds in late winter, which would take approximately 3 man-days.
EM is the only input and will be a negligible cost.
Normal wear and tear for the pumps, if used will have to be factored into the running budget.

We trust that these notes have been of interest and assistance. For more information, do not hesitate to contact us.
Kind regards

Thomas Linders

Some Constructed Wetland projects I designed and some built:

1995 Cresset House - Sewage treatment for 130 residents built

1996 Kuthumba Ecovillage - Greywater wetland design for the individual homes

1997 House van der Bilt - Sewage treatment for family home built

1998 Wildrocke Farm - Sewage treatment for family and staff quarters, design and built

1999 Family Hidden - pond and wetland rehabilitation and Flowform installations

2001 House Holtz - Sewage treatment for family & staff design and built

2001 McHarry - Sewage treatment for family home, design and built

2001 Duigan Family - Sewage treatment for home, design and built

2002 Yeats Family - Sewage treatment for family home, design and built

2002 Lethabo - Sewage treatment for Guest lodge and wedding venue, design and built

2002 House Zietsman - Sewage treatment for family home, design

2002 House Haarman - Sewage treatment for family home, design and built

2003 Lefika Farm - Sewage system for Dairy, design and building supervision

2003 Parceval Herb Farm - Sewage system for Laboratory and herbal tincture production company, design and building supervision.

2004 Camphill Schools - Sewage treatment for 120 residents, design

2005 Maropeng, Cradle of Humankind - Sewage treatment for Hotel, Restaurant, Museum and Interpretation centre treating 110'000 litres per day, design and building supervision

2005 Sterkfontein, Cradle of Humankind - Sewage treatment for Restaurant and museum facilities, design and building supervision.

2007 Ditton's Farm - Sewage treatment for Home and School, design

2011 eThekwini Municipality - Design of constructed wetlands for Biogas digester effluent for an agro-ecology project, design.

2012 Coffee Bay Backpackers - Sewage system for back packers lodge and chalets, design

2017 Al Dhaid Safari Park, Sharjah, UAE - Design of constructed wetland for crocodile ponds

2017 Al Dhaid Safari Park, Sharjah, UAE - Conceptual design of constructed wetlands for Treated Sewerage Effluent for re-use in the park & and stormwater treatment/attenuation.