Water, Water, Everywhere

Kenya now has at least seven working Constructed Wetlands, amazing natural systems that recycle hundreds of millions of litres of wastewater, returning it clean to surface systems, creating healthy aquatic ecosystems in the harshest of environments, yielding significant amounts of biomass for mulch, fodder and compost, and providing thriving year-round wildlife and fish habitats. **Dee Raymer** explains this economical, environmentally sound alternative for wastewater management in Africa.

First published in Ecoforum Magazine, the journal of the Environment Liaison Centre International, this article won the 2001 Reuters-IUCN Global Award for Environmental Journalism.

In Kenya, the hopelessly overoptimistic slogan "Clean water for all by the year 2000" vanished quietly into the bad joke cupboard sometime during the mid 1990s. Combined estimates from the Ministry of Water and Natural Resources and UNICEF indicate that 52% of our rural population now has no access to safe or adequate water. This national average belies the grimmer picture in certain areas – in North Eastern Province only 17% have safe water, in Makueni 16% and in Migori and West Pokot, a mere 6%.

During the past year, the majority of Kenyans would have been grateful for *any* water during the many prolonged periods when taps, wells, boreholes and rivers ran dry. Better-informed Kenyans also know that, thanks to a deadly combination of environmental abuse and a thirty-fold population increase since 1900, Kenya has few options for reliable sources of clean water supply in the future. Galloping deforestation (as ever in the run-up to an election) is reducing yields of hitherto reliable resources, and it is said that water from the huge Tana/Galana/Sabaki lifeline river network is no longer fit to drink, untreated, along its entire course.

In real terms, increasingly unsafe and scarce water supplies, combined with our often criminally irresponsible disposal of wastewater, translate into human tragedies. Witness the recent typhoid and malaria outbreaks in Embu district, with critically ill and dying patients, four to a bed or on floors in undermanned, under-equipped hospitals. The Daily Nation of March 5th reported 30-35 hospital admissions daily. More than 700 people with typhoid, malaria, or both, had been admitted up to that point; 90 had died.

Be assured that this outbreak will not be the last of its kind. Even groundwater, assumed by many to be 'safe', is becoming dangerous. *E. coli* counts (the measure of …) in analyses done by the Kenya Industrial and Research Development Institute last year of water from *rural springs* ranged from 35 per 100 ml to 1,800. The World Health Organisation's criterion for potability is zero; a count of 1,800 fails to meet its safe standard for any form of irrigation.

As we continue to pollute our dwindling fresh water resources and the environment with our filthy discharges, some urban and peri-urban boreholes have begun yielding water with *e.coli* counts similar to those in raw sewage from public toilets: it may *look* rather better, but drinking it untreated will soon see you in the doctor's waiting room.

In Nairobi's eastlands, it is not an uncommon sight to see residents drawing water from the Nairobi River and its tributary, the Gitathuru – both scarcely better than open sewers nowadays. Flourishing market gardens are watered directly from these rivers, as well as from sewer mains that are sometimes deliberately fractured for the 'regulated organic nutrients' (the current politically-correct term, I believe, for human shit), within. Can any Nairobian guarantee that they have never eaten any of that very healthy looking produce?

The situation is very simple, and it is dire: if we don't clean up our wastewater for safe reuse, we shall simply run out of clean water altogether.

From toilet to tap, and back again

Most western cities recycle their wastewater (its revolting taste a testimony to the amount of chemical treatment involved). Whether or not we subscribe to the health lobby's view that the principal chemicals used -- alum and chlorine -- are thoroughly detrimental to our long-term health, our collective immune systems are unquestionably under siege from modern technology's liberal chemical contributions to what we eat, drink and breathe.

The viewpoint slowly being forced upon realists was voiced recently by a senior Kenya Wildlife Service officer, describing his revulsion and disbelief on discovering 15 years ago that water from urban toilets, after treatment, eventually comes back out of urban taps. "The whole concept," he said, "was totally unacceptable to me then – but we had not yet approached our present crisis point. Now I see all too clearly that one-time water use is impossible if we hope to have access to any water at all."

So what are the treatment options?

Conventional wastewater treatment relies on machinery and chemicals - long detention in unattractive and expensive concrete ponds, then stirring and aeration using machinery powered by electricity or fossil fuels, followed by chemical treatment to ensure compliance with public health criteria before reuse.

After installation, a number of factors conspire to thwart the works. High operational costs, mechanical breakdowns, the frequent unavailability of spare parts (or the budget to buy them), power cuts, the human error factor and the need for large technical workforces bode ill for reliable and sustainable operation of such systems in a developing country context. History shows all too clearly that such high-tech and inappropriate solutions to wastewater management and treatment tend to hiccough erratically from aid package to aid package, punctuated by long periods of breakdown.

On March 10th, several weeks after the start of Embu's typhoid outbreak, the Daily Nation reported municipal councillors admitting that raw sewage has been allowed to "flow untreated into rivers for a long time." The same admission was made last year in Kisumu (only this time the economically vital Lake Victoria served as receptacle for the foul discharge), and probably could be made in other towns all across the country.

There are alternatives, however. Millions of years before we came along with our technological obsessions, nature had already developed an elegant means of water purification. She evolved the wetland, whose complex ecology cleans up dirty water using efficient biological processes. It has taken us a long time to appreciate that neither concrete, machinery nor rigid drawing-office shapes need to be involved.

The first generation of wetlands used in dealing with wastewater were natural swamps that simply provided handy dumping grounds for sewage. While the practice is now banned in most countries due to its extremely negative effects on existing wetland ecologies, marked improvements noted in water quality as it progressed through the wetlands began to interest researchers.

At the Max Planck Institute in Germany during the late 1950s, Dr Kathe Siedl began investigating the workings of submerged gravel beds that proved remarkably effective in breaking down heavy biological loadings in polluted water. The gravel bed hydroponics (GBH) system, planted with pollution-tolerant aquatic plants, has become the first element in many designs for constructed wetlands.

Whereas the discharge of wastewater into natural wetlands causes serious ecological disruption, constructed wetlands (CWs) are a different matter, being purpose-designed for each situation and installed where no wetland existed previously. There is no ecology in a new CW so, as conditions modify and life forms arrive (my goodness, how they do!) each can choose the part of the system it prefers – more tolerant organisms at the start where polluted water enters the system, and less tolerant ones further along as the natural purification process progresses.

CWs come in all sizes, from domestic to municipal scale, and there are numerous design options, but all CWs operate on the same principals of natural water purification. Water passes through a succession of connected ponds, and along the way microbes, plants and other life forms use our pollutants as nutrients (see 'How it works', page). The concept of constructed wetlands differs radically from that of any other wastewater treatment system; as a biological system, its efficiency relates directly to the health of its ecology and biodiversity. A CW is designed specifically to replicate the clean-up functions of a natural wetland by offering habitat to as many life forms as possible, whether micro-organisms, plants, invertebrates or vertebrates.

Gaining ground

Constructed wetlands now recycle wastewater all over the world, from Lakeland in Florida, USA (pop. 79,000) to Lallaing in northern France (pop. 15,000). The city of Auckland, New Zealand is partially served by a CW.

While temperate southern Africa has over 120 constructed wetlands, the concept is very new in tropical Africa, somewhat ironically, as the climate here is ideal for maximum biological activity nearly year-round. One Kenyan installation that came on-line in 1994 now handles up to 80,000 litres of wastewater daily (a residential person equivalent of 1,200) from the busy Carnivore Restaurant and Splash water park in Nairobi.

There are now at least seven fully-operational CWs in Kenya – the one just mentioned and another at the Karen Country Club in Nairobi. Two hotels have employed them: one treats sewage from Olonana luxury tourist camp in the Maasai Mara, another at the Amboseli Serena. Another CW installed by Eastern Produce Ltd in Nandi Hills handles tea factory and toilet effluent. In Naivasha, horticultural giant Homegrown Ltd. has installed both an agro-chemical buffer for the Lake and a CW that treats water from a commercial laundry operation and a horticultural pack-house.

All of these systems comply with responsible discharge criteria and, between them, return over 500,000 litres of clean water daily to various surface water systems, nearly 200 million litres per year. In some cases the discharge is actually cleaner than the receiving waters. If a significant percentage of major water users, particularly in industry, were to follow suit, we might not have a water crisis.

Two new CWs, one each at Timau and Kericho, should have come on-line by the time this issue of *Ecoforum* goes to press. Funding is being sought for another at the Kenya Wildlife Service headquarters in Langata, to discharge to one of the dams of the Nairobi National Park, and several more are at advanced discussion stage. Before long, I imagine that water discharged by some CWs may have to be recovered to drinking water standards. To ensure compliance with public health guidelines, ultraviolet in-line treatment units could be installed between CW and storage tanks as a healthier alternative to chemical bombardment.

So far all CWs in Kenya have been implemented with private sector initiative and investment. Public sector officials and others from large organisations supposedly concerned with health and environment have seen them and many appear to be dumbfounded. That nature can effect better and cheaper water purification than concrete and machinery, while offering an attractive habitat for birds, wildlife and many small aquatic creatures whose natural habitats are under increasing threat seems, at least initially, to be beyond their willing acceptance.

Large scale horticultural producers and processors have already discovered (possibly to their initial surprise) that there are tangible financial benefits to be reaped from eco-friendly CWs. Environmental Impact inspectors from their overseas client companies are enthralled by them. Approval thus earned reflects favourably in securing market share for their export produce, particularly during less buoyant trading times, and future budgets are being earmarked for further CWs on their farms and estates.

As with solar power, there is significant initial capital outlay, but operational costs are modest; one or two staff, trained on the job, manage routine work successfully on existing CWs. Casual help is sometimes enlisted to help with seasonal harvesting of abundant plants. In a community system, if properly controlled, sheep and goats could surely do much of the mowing!

As a community-based concept, CWs have almost limitless potential in Africa. A system could be hand-dug with pooled community labour, offering year-round growth potential for food crops in designated seepage zone areas. Napier grass as supplementary stock feed for dry weather would thrive, thatching and handcraft materials could be harvested sustainably, and aquaculture in the later, cleaner ponds of the system as a source of protein and income. Water of reliable quality would be available to all, perhaps under the control of a village committee.

A further aspect often overlooked is a CW's educational potential – students at all academic levels tour them and are thrilled. Municipalities in other countries that have them report keen community pride in their CWs, many of which double as wildlife and bird sanctuaries. Some have become famous stopover points along major bird migration routes. They offer recreational possibilities as well as being extremely pretty; used in housing schemes, CWs could be incorporated into public spaces as hard-working ornamental components. With CWs, wastewater treatment can come out of hiding and be admired, a major shift from our normal out-of-sight-out-of-mind attitude.

We have here the option of a positive and eco-friendly way forward in dealing with East Africa's current and future water crises. Those in the private sector who have pioneered the way are convinced, and repeat business is coming in from those who, in a manner of speaking, took the first plunge. Commercial companies may be more agile in their approach to problems than monolithic institutions where inertia and the status quo too often substitute for dynamic, informed decision-making, but they too would do well to follow, albeit at their more leisured pace, the private sector's trailblazing.

How it works

With the exception of the riparian buffer scheme on a commercial farm in Naivasha, which cleanses horticultural runoff through some 2 kms of varied-depth, intensively planted lagoons and oxbow channels, CWs in Kenya consist of four basic design elements – a gravel-bed hydroponics (GBH) section followed by a series of three gravity-fed open ponds or ‘surface cells’ (SCs).

From the septic tank, which handles primary digestion of solids, sewage is piped into the GBH, which is simply a sunken, walled rectangular pond lined with gravel. Dimensions of the GBH are determined by the daily volume of wastewater. Alternating baffle walls are built across it at regular intervals, to about two-thirds of its width, which force water into taking a serpentine flow-course through the GBH, maximising the flow-distance while eliminating stagnant areas. (GRAPHIC OF BAFFLE WALLS and flow)

An even layer of substrate (graded crushed ballast 60-80 cm deep, depending on the type of wastewater being treated) is spread throughout onto a well-compacted base, to about 15 cm below the top of the baffle walls. Influent water is distributed across the width of the first channel by a spreader pipe.

The substrate does not, as many people imagine, provide physical filtration of pollutants, but a home for bacteria. During the time a GBH takes to fill, the ubiquitous, mainly anaerobic bacteria that feed on and digest sewage begin to colonise all surfaces of the substrate.

As soon as the GBH is filled and discharging into the first surface cell, planting may begin. Only a fairly restricted range of species will tolerate the harsh conditions – reeds, bullrushes and sedges being the chief contenders. These are planted into the substrate with their roots in contact with the water just beneath, and may need initial support until firmly rooted. Once established, they remove some 10% of pollutants as nutrients, but their major contribution to the workings of the GBH is the unique adaptation evolved by emergent swamp plants, to oxygenate their own root systems – which is why they can grow standing in water, where terrestrial plants would drown. This creates habitats for aerobic bacteria within the lower levels of the substrate and enhances the performance of the GBH, removing huge amounts of ammonia, total suspended solids, biological oxygen demand (BOD) and chemical oxygen demand (COD).

Discharge from the GBH enters a level control chamber that determines the top water level within the gravel bed, and from here it is piped or channelled by gravity to a collection chamber before entering the first surface cell. Water entering SC1 is, for the first time, exposed to sunlight and air. The rapid appearance of green algae, which cannot survive in heavily polluted water, bears witness to the efficiency of the GBH breakdowns. These microscopic plants and the oxygen they produce freely during daylight hours, kick-start the further breakdown of both biological and chemical pollutants, while providing an important early link in the food chain.

Pollution removal processes occurring in a wetland are so many and varied that we may never understand them all, but thanks to copious research already undertaken, we *do* know the conditions that enable them to take place and are therefore able to design the SCs for maximum efficiency by contouring the bases. Because of this, a healthy, well-designed CW will always out-perform a natural wetland, using a smaller area.

Good SC design ensures that, by offering a wide range of habitats, both aerobic and anaerobic, biodiversity is encouraged. Water is made to take the longest possible path between influent and effluent, while shallows and deeps ensure thorough mixing and turning along the way. By replicating a full range of conditions found in a natural wetland, a CW aims to attract a similar diversity of life forms, and each has its role to play in the purification process.

So where do the pollutants go? Some, including heavy metals, are taken up as nutrients or adsorbed onto base sediments and submerged parts of plants. Progressively rising levels of dissolved oxygen facilitate further chemical and biological breakdowns and transformations. In the shallows, UV rays from sunlight kill pathogens and there is evidence to suggest that the roots and stems of many aquatic plants exude disinfectant substances. Another removal pathway relies on passing nutrients up the food chain until they leave the system as nutrients rather than pollutants: kingfishers, for example, eat fish that have eaten daphnia that have eaten green algae that has fed on nutrients in the water. These processes continue throughout the SCs, usually three in number.

A well-designed CW’s energy sources are gravity, sunlight and a diverse ecology. It has no need of machinery, chemicals, electricity, fossil fuels or a large technical workforce. It outperforms conventional systems and is, moreover, attractive, eco-friendly and educational. And no, it is not all done by smoke and mirrors, but rather by understanding nature’s aeons-old technology and having the sense to turn it to our advantage.

Establishing the wetland ecology

The challenge facing the environmental manager of a new constructed wetland is to establish a healthy and diverse wetland ecology as swiftly as possible – a fascinating exercise and perpetual learning process. To begin at the beginning: while the bacteria that perform startling breakdowns within the first element, the gravel bed hydroponics section (GBH) are ubiquitous in sewage, it can take months for their populations to build up to appreciable levels in a new environment. The quality of processing will suffer meanwhile. If, however, a new GBH is ‘seeded’ a few days after filling commences, using water discharged by a mature GBH, the process is speeded enormously.

With early ‘seeding’, plantings of front-line pollution-tolerant GBH species such as *Typha latifolia* (bullrush), *Phragmites australis* and *Cyperus spp*. (sedge grasses) will establish fairly soon once final top water level (TWL) is reached. This may otherwise take several months, since early conditions may be too harsh even for these hardy plants.

Once TWL is reached in the first open pond, or surface cell (SC1), planting there can begin, Vegetation forms the baseline of the ecology; besides taking up pollutants as nutrients, it offers habitat and shelter to many life forms of all sizes. Emergent plant species help to oxygenate the water, as do the microscopic plants that constitute green algae. Since oxygen brings life, terrestrial runner grasses which *de*oxygenate the water should not be allowed to invade it. The rather tedious task of removal is much reduced once riparian plantings that tend to keep it back have become properly established.

Tall clumping plants such as *Phragmites* or the very pretty *Arundo donax variegata* need generous spacings between them, to allow establishment of a diversity of smaller plants between, and since a well-planted and managed CW is extremely pleasing to the eye, to leave viewpoints open. Virtually any plants that are found in sunny damp or seasonally waterlogged situations are useful in a CW context – plaintains, the bushy polygonums, smaller reeds, rushes and sedges, arum lilies and even cannas if one would like the odd splash of colour. Sourcing a range of them in the first instance may involve some local travel, armed with plastic bags, buckets and *jembes* (hoes). Most of these plants, once established by the water's edge, will extend into the shallows and outwards within the boundaries of the seepage zone.

The free-floating water lettuce, *Pistia stratiotes*, is very useful but prefers the cleaner end of the system. Unlike the other 'floaters' – *Eichornia crassipes*, the infamous water hyacinth - it is not classed as a noxious aquatic weed, although it increases rapidly during rains, when harvesting becomes necessary (no more than a quarter of the free water surface should be covered). The wading birds love it. It may also be used as supplementary livestock feed, a good green manure and makes excellent compost.

Birds are attracted to a new CW from an early stage. Water birds introduce a suprising range of small organisms via feet, feathers or gut, while the seedeaters will contribute seed of many new plant species – if you can persuade them to linger. The intelligent manager will effect this by providing assorted purchases with rock or logs groupings near the water and, most effectively, a few dead trees or large twiggy branches stuck into the ground at intervals. Nature requires only a little encouragement to work on your behalf! Bird diversity, of course, increases with more interesting habitats and nesting sites as vegetation matures. 153 bird species have so far been recorded in and around the Splash CW in Nairobi.

As soon as water in SC2 reaches discharge level, planting may begin there and, similarly, in SC3 once that has filled. Should any desirable plant refuse to grow at SC1, it is always worth trying it again further long the system where conditions are better.

When selecting trees for planting, indigenous species, having an established niche in the ecology, are always preferable to exotics. Except in very large CWs, avoid the water-greedy and invasive-rooted Ficus (fig) family. Do not plant trees on embankments where their roots might cause weaknesses or even leaks, and keep any trees with heavy leaf-fall to the downwind sides of SCs.

Frogs have an astonishing ability to locate new water, and are the first aquatic vertebrates to arrive. Any early tendency to overbreed will be checked in due course by the arrival of hammerkops, herons, green water snakes (non-poisonous!) or even marsh terrapins.

Once shorelines are fully vegetated, fish may be introduced. I prefer to use omnivorous species since they will not impact too heavily on any one aspect of the ecology, and have found a good mix to be guppies (*Poecilia reticulata*) as a small fish and Nile tilapia (*Oreochromis niloticus*) as a larger one. These are by no means the only options. Introduce fish halfway along SCs 2 and 3. SC1 is usually still too polluted to ensure their survival.

While those of a more “bunny-hugging” bent may dislike the idea of multiple murders taking place at all levels within the food chain, it is these that stabilise an ecosystem, whose dynamic balance depends on a food supply for each species. In nature everything eats something else. Within the pyramid of life (many smaller creatures at the base, giving way to fewer, larger species towards the apex) predators occur higher than their prey, take longer to reproduce and are generally less pollution-tolerant.

Problems stemming from imbalances arise when conditions for predators are impossible and prey flourish unchecked. The unmanaged discharge of polluted water, for example, makes mosquitoes very happy. Their larvae are not dependent on water quality for survival, and polluted surroundings ensure the absence of the robber flies, frogs, many carnivorous aquatic vertebrates, birds and most certainly fish that would otherwise control them.

In a healthy ecosystem predators control the pests. This explains the importance of biodiversity – that several controls and workers for each problem or process are present. A number of organisms all working on one particular process make for speed and efficiency. If any mishap should befall one, plenty of back-up remains and the system continues to work. In a weakened or damaged ecology such safeguards may be scant – or entirely lacking.

The environmental manager’s job is not to interfere but to encourage, as well as to note all new arrivals, the gaps they fill and interactions between them and the existing life forms. Each, as a brick in the strong wall of a healthy ecology, has a function within the system, or it would not be present (remember the maxim that in nature everything is connected to everything else?). Given favourable nudging, the ecology will establish a healthy balance; ignorant interference is unhelpful.

A surprising degree of biological maturity may, with good and sympathetic management, be achieved within a year. Aquatic Ecology professors and lecturers from several overseas universities state that significant biological maturity in a new CW takes 3-5 years. In Kenya, aided by tropical conditions, we have proved otherwise!

While our climate is certainly a help, I know of one installation here done to plans bought from overseas, which has developed no significant ecology in five years. The engineer, seeing it as a purely engineering exercise, simply walked away – imagining no doubt that all else would occur spontaneously. It probably will, given time.

An early maturing ecology is encouraged, as in any pioneer situation, by soil improvement, establishing vegetation and managing it. In the first instance this requires mulching all exposed soil and making new plantings with compost, to speed a baseline for the ecology. On slopes, mulch may be secured by making light brushwood ‘fences’ (10 cm high is sufficient) at intervals along contours, and securing these with wooden pegs. They prevent erosion of newly disturbed soil and will trap any loose seed, also offering protection and a little shade to seedlings as they germinate. Undesirable weeds such as datura or Mexican marigold should be uprooted before they can set seed, and left to lie as additions to the mulch. Ripe seeds of any desirable plants may be scattered to await germination with rain.

The primary object is to cover the ground with vegetation, and in this context two useful plant species are the vigorous succulent *Aptenia cordifolia* and the sweet potato (*Ipomea batatas*). Both will be crowded out in due course by taller vegetation, but in the interim help to modify conditions.

Ongoing management of the vegetation is the single most important maintenance task and does not require a degree in rocket science. Dying vegetation repollutes the water, while harvesting of plants that have passed their best leads to fresh growth and increased nutrient uptake. Establish and manage the vegetation right, and all else will follow.

‘Biological indicators’ are a vital monitoring tool. The presence of fish fry shows that adults are happy enough to breed, for example, while the absence of kingfishers from a surface cell they used to frequent may indicate a problem with the fish. If a water sample shows no significant change, the answer may lie in over-predation; pieces of piping, some roof ridge tiles or a few small wire mesh cylinders placed in the shallows will provide refuges for the fish.

Various ‘biotic indices’ exist – lists of aquatic invertebrates, classified from 1–10 depending on their sensitivity to pollution, with 10 being the most sensitive. Knowing the scores of even a few offers valuable information on the health of any given body of water. Most water bugs and beetles are rated at 5, while dragonflies, depending on species, rate 6-8. The presence of these in and around an SC shows that you are *at least* halfway there in terms of water purification.

As diversity builds up and biological maturity approaches, improvement in a CW's performance is mirrored by a change in samples taken in clear bottles from various points along the system. The more variation in colour, the less stable the ecology; as the various pinks and greens of early days gradually give way to clearer water, the environmental manager knows that this is the indication of a good job, well executed.

How Much?

The first question most people ask on seeing a Constructed Wetland for the first time is, "How much does one cost?" To which the appropriate answer might be, "How long is a piece of string?" The cost of any CW is determined by one constant and a number of variables.

The Constant

This is relatively straightforward, determined by the volume of daily discharge from the septic tank preceding the first part of a CW system. In better-class housing with baths or showers and flushing toilets, daily usage of water per person is in the region of 90 litres. On this basis, for each person using the system, and depending on effluent quality, a total surface area of between 4.5 and 5.0 square metres should be allowed. The maximum occupancy figure is used in calculation. While this does not take into consideration any allowance for paths, leeways and accesses between and around the various elements of the CW, it will be evident that even many backyard gardens could accommodate small domestic CW systems. Each house in Camphill Village in Gloucestershire, UK, for example, has its own.

The volume of excavation may be calculated at 55% of the total surface area, so that the volume of soil to be excavated from 45 square metres would be 24.75 cubic metres.

The Variables

- Septic tank: where no septic tank exists, one of appropriate size would have to be installed and, on commercial premises, grease traps on the kitchen wastewater line.

- Method of excavation: earth moving machine time is expensive but, provided work can be supervised knowledgeably, smaller systems may be hand-dug at a considerable saving. Hand-dug open ponds for a CW commissioned in 1997 and dealing with 30,000 litres of wastewater throughput daily on an almost level site cost 220,000/- ($US   at 1997 rates). The same work if machine-dug could have been expected to cost nearly three times as much. The total cost of this particular installation, with the client using his own labour and resources to install the gravel bed and pipe connections, was probably in the region of Kshs 450,000 ($US).

- Site characteristics, which include: a) Topography – the steeper the site, the more extensive the earthworks to create lower-side embankments and thus the higher the cost, and b) Geology – excavation into rock underlying shallow soils is expensive, and into rock alone, probably prohibitive.

- Water storage: a final storage reservoir or pond may be required, at additional cost.

- Provision of storm-water overflows: potential catchment for a system serving 1,000 people would be 30,000 litres during a 6mm storm, and 5.4 million litres in the course of an average rainfall year in the Nairobi area.

- Plumbing: the length and type of plumbing connections required from the septic tank to the CW will affect the total cost. A pump, secure housing, electrical connections and additional plumbing will be needed if treated water is to be recovered. Since a CW is usually gravity-fed, final discharge will be at its lowest point.

- Professional fees.

In contrast to the example given above, a larger installation in 1996 (50,000 litres per day) machine-dug on a medium-steep slope, and where both pumps and extensive pipework were needed to consolidate wastewater from two different sources in a collection chamber above the gravel bed, the overall cost was Kshs 3.6 million ($US 72,000 at 1996 rates).

Let the Naysayers Neigh

Naysayers and environmental illiterates will, alas, be with us always (I believe the Flat Earth Society still exists?). There are those of a certain inflexible mentality, sometimes further handicapped by highly technical training, who refuse to believe that the CW concept can work. Whether this is due to intellectual rigidity, a genuine belief that nothing new can exist beyond the scope of their training, or a perceived threat to their percentages, we may never know.

I was extremely fortunate that a series of bright postgraduates, all working on their MSc theses, conducted their practical research programmes at the Splash CW during its first three successive years of operation – Kelvin Khisa (Moi University, School of Environmental Sciences), Daniel Nzeng'ya (Moi U, SES) and Jane Nyakang'o (IHE, Delft, Netherlands). Their studies, as well as layman's observations – show conclusively that a well-designed and managed CW can and does work superbly. I myself learned a great deal from our collaboration.

I have only two slight concerns about the successful future of CWs in eastern Africa: the quality of design and of management. Engineers can prove a hard nut to crack when it comes to understanding the ecological requirements of design; contours on plans indicating – as on any map – varying degrees of slope, have been executed as rigid benches (see picture). Verticals and horizontals are emphatically not required! But even with a good engineering design, the engineer's part ends with completion of the works, when environmental management takes over. A CW is a two-part exercise.

One installed CW “designed” by someone who thought they knew it all does not and cannot work as it is, since it fails to meet many of the ecological criteria. Base contours are lacking, while precipitous embankments preclude the establishment of any sort of ecology. A mule is unlikely to win the Derby, and unfortunate instances like this can do much to discredit the CW concept. CW design is not particularly difficult, but it does require reasonable appreciation of ecological requirements.

Management is less difficult and devolves around identifying the right person, with ecological sensitivities, to train on the job. Educational levels are not significant – of the two best hands-on CW managers I know in the country (so far!), one is a graduate of Egerton College, the other of Standard Four!

John K.M. Wandaka, Lecturer in Environmental Studies, Tourism Dept, Utalii College:
“Our recent visit [to the Splash wetland] was an eye opener in many respects. I have visited many wastewater treatment plants, but the constructed wetland seems unique in that the water is biologically purified without need of expensive machinery, electricity or fossil fuels. It works so well that some fauna from the adjacent Nairobi National Park find this a better place and *defect* to the wetlands! The birdlife is impressive. There seems to be an ecobalance between the various organisms found there.

“It is a valuable learning resource; the Hotel Management students that I brought along were very impressed, as evidenced in their vote of thanks.”

Richard Fox, Services Director, Homegrown (K) Ltd, Naivasha, and Civil Engineer:
“In Kenya, the focus on water management has been almost entirely directed towards the supply cycle, with relatively little attention paid to disposal. The introduction of the Environmental Management and Co-ordination Act, 1999, will require all operators of trade and industrial undertakings to apply for an effluent discharge license and, if granted, ensure that they comply with the standards imposed. In our experience, constructed wetlands have proved to be an extremely effective and low-cost means of treating a wide range of effluents.

“Their informality in terms of plan layout renders them particularly suitable for location in areas unsuitable for either growing or building. They have transformed these areas into oases of vegetation, aquatic and bird life. The presence of these natural flora and fauna in the mature areas of the wetlands, both in and along the margins of the ponds we have constructed, are a striking demonstration of the natural processes at work. The quality of effluent achievable offers very real opportunities for recycling.”

Simon K. Koech, Accountant, Eastern Produce (K) Ltd, Nandi Hills:

“I have come to be very attached to the CW at Chemomi. Every lunch hour I rest in that park and appreciate it. It provides a very conducive environment for relaxation, and is really great – unlike the sewage areas of other institutions.

“The CW has provided two great benefits, one in cleaning the waste discharge from the [tea] factory, and two in providing an ecofriendly area which has turned into a park. The few people who have realised the importance of conserving and protecting the environment like this need to be encouraged and indeed emulated. I have become interested in learning more of environmental issues with a view to putting them to practical use in my village at home…”