The bottom line

If architecture is ‘design for living’, one of its greatest challenges is how to live with the masses of waste we excrete. Four pioneers in green sanitation design outline solutions to a dilemma too often shunted down the pan.

Every year, on average, each of us excretes 50 litres of faeces, rife with pathogens and heavy metals. Multiplied by Earth’s population of 7 billion — and rising — that constitutes not so much an elephant in the room as a herd of mammoths. Sustainable solutions are urgently needed, particularly for the 2.6 billion people who lack adequate sanitation and the 1.1 billion practising open defecation. Rich countries, meanwhile, often have hidden sanitation issues of their own. There is no single design solution to sanitation. But there are universal principles for systematically and safely detoxifying human excreta, without contaminating, wasting or even using water. Ecological sanitation design — which is focused on sustainability through reuse and recycling — offers workable solutions that are gaining footholds around the world, as Nature explores on the following pages through the work of Peter Morgan in Zimbabwe, Ralf Otterpohl and his team in Germany, Shumuga Paramasivan in India, and Ed Harrington and his colleagues in California.

In compost-based ecosanitation, excreta is reframed as a resource: fertilizer. Much of the research on this has focused on upping nutrient levels and finding faster, more effective ways of removing heavy metals and pathogens such as viruses. Meanwhile, research-based, ecological processing of waste water is vastly improving water-based systems, bringing them closer to the ecosanitation ideal.

Environmental sustainability is only part of ecosanitation, however. Defecation is as culture-laden as other behaviours, so the designs must also be socially sustainable — tailored to local customs and strictures, whether in Malawi or Manhattan.

The developed world may think it has cracked the problem, but trouble is gurgling away underground. ‘Flush and forget’ sanitation systems constitute one of the more bizarre hangovers from the Victorian age. In older toilets, up to 25 litres of drinking water go down the pan per flush, although ‘low-flow’ toilet designs are coming into their own and, in 1995, the US federal government set a 7-litre-per-flush limit.

Aside from wasted water, the faeces-laden ‘black water’ from flush toilets is not always treated. Many older US and UK sewage systems, for instance, mix toilet waste water with storm water in so-called combined sewage outflows, which can overflow after heavy rain. The US Environmental Protection Agency estimated in a 2004 report to Congress that 850 billion gallons of untreated water were entering US waterways every year.

Sewage sludge — the semi-solid mush left after wastewater treatment in sewage works — can be as problematic. Although it can contain significant traces of pharmaceuticals and heavy metals even after treatment, it is widely used in the West as a soil conditioner and fertilizer on cropland, with uncertain effects on human health.

In the packed cities and scattered villages of the developing world, the challenge is even more daunting. Thousands of children die every day from a lack of basic sanitation or clean water. Open defecation contaminates soils with the eggs and larvae of soilborne intestinal worms, or helminths, as well as other pathogens. More than one billion people are infected with these helminths, which cause, among other problems, weakness and malnutrition.

So a toilet can be transformative. A clean environment means better health — and that, in turn, is a springboard to development. As governments debate the finer points of global development challenges at Rio+20 next week, they might find it worth asking why sanitation fails to the bottom of most policy agendas.
PETER MORGAN

Inspired by ant turrets and the flight paths of flies

Environmental scientist and designer of the Blair VIP toilet, Harare

"The designer knows he has reached perfection, not when there is no longer anything to add, but when there is no longer anything to take away," I recalled this anonymous quote when, as a young biologist in Rhodesia (now Zimbabwe) in the 1970s, I was working for the health ministry's Blair Research Laboratory — named after former health secretary Dyson Blair. Blair had persuaded me to change fields, from schistosomiasis control to technological solutions for public health, and tasked me with designing new toilet systems for use in rural areas.

Open defecation was then common, and the existing pit toilets bred blowflies of the genus Chrysomya, as well as other fly species that carry enteric disease. In a survey conducted between March 1974 and April 1975, we counted more than 20,000 flies emerging from a single pit toilet.

It had long seemed to me that simplicity could be related to elegance of design. My first innovation, called the Blair toilet after Dyson (and later dubbed the Blair ventilated improved pit, or BVIP toilet), is simple: a pit, lined with bricks for stability; a concrete sanitary slab with one hole for squatting, and another fitted with a vent pipe stretching from the slab to above roof level; and a spiral superstructure that obviates the need for a door but guarantees semi-darkness (see 'Air traffic control').

The design harnesses natural principles. The turrets of ant nests — the most elegant of nature's chimneys — inspired the vent. The natural behaviour of flies, which are attracted by odour and light, determined the other design features. When air passes over the top of the vent, suction draws more air through the squatting hole into the pit, then sends the odours up through the vent. Some flies are drawn to those odours; others, entering the pit through the squat hole, are drawn to the light from the bottom of the vent. Either way, the flies are trapped and die, because the vent is fitted with a non-corrodable screen, usually made of aluminium.

The concept is simple and it works. From October to December 1975, weekly counts of fly output were taken from two Blair toilets and two unventilated pit toilets: a total of 13,953 flies were trapped from the unventilated toilets and only 146 from the ventilated toilets (P. R. Morgan Cent. Afr. J. Med. 23, 1–4; 1977). A family BVIP will last 10–15 years, and once it is abandoned, the superstructure materials can be recycled. The excreta gradually dries, and can be used as compost.

The BVIP is now the backbone of Zimbabwe's sanitation programme, with half a million family toilets built so far, and is widespread in other African countries. A multicompartament unit was designed for schools. More recently, I have drawn up a cheaper, upgradeable family unit, which can be built in stages — allowing them to ascend the 'sanitation ladder'.

I devised other toilets to speed up the composting process. The Arborloo is an unlined pit 1 metre deep, which is fitted with a circular brick or concrete rim and a sanitary slab. As it fills, soil, ash and leaves are added to accelerate composting and control flies and odour. After a year, the toilet superstructure is moved to a new pit, and a tree is planted in a layer of soil on top of the old pit, to provide shade, fuel or fruit. Thousands of these have been built in Malawi and about 70,000 in Ethiopia.

The Fossa Alterna is another variation: two shallow pits are dug and used alternately, swapping at annual intervals. By the time one pit has filled, the compost in the other will be mature and ready for use.

Perhaps working in an area for which I have not received formal training has given me freedom of expression in observing, exploring and researching. I had to use instinct and plain logic. And it pays to adapt natural principles honed over millions of years.