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INSTRUCTIONS TO CANDIDATES

All questions are based on the abridged article which follows on pages 2, 3 and 4 of this insert.

This insert consists of 4 printed pages.

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THE WORM THAT EARNED

Heaped up in the corner of the shed is an elephant-sized mound of brown, crumbly powder. Hesitating slightly, I thrust my fingers in, scoop up a handful and take a cautious sniff. To my surprise, it's as pleasant-smelling as a bag of peat from your local garden centre, the sort of thing you'd happily dust from a freshly-picked carrot before taking a bite. Who'd suspect that just weeks ago this stuff was flushed down the toilet?

Here at the Redlands Shire water plant, 30 kilometres south of Brisbane, Queensland, 40 tonnes of sewage sludge arrive every day. And every day, 40 tonnes of hungry worms set to work, devouring every last lump, converting it into top-grade soil conditioner.

These wrigglers are farmed by a small, Sydney-based outfit called Vermitech. The company has succeeded in doing what has stumped many others: it has expanded worm composting from a backyard hobby to a profitable, large-scale business. Its compost is already being used on fruit and vegetables shipped to supermarkets across Australia, and new studies appear to show that 'vermicompost' is endowed with qualities that are surprising even the most ardent worm fans.

Worm-based sewage recycling is nothing new. People have been doing it on a small scale for years using manure worms - smaller, wrigglier cousins of the earthworm. The idea is to mix these worms with sewage sludge - the solids left over after raw sewage has been through the treatment plant. As the worms chomp on the sludge and break it down in their gut, they digest the harmful bacteria it contains and turn it into a much less objectionable mixture that can be spread on flower beds or crops.

There's certainly no shortage of worm food. New York City, for example, creates almost a million tonnes of sewage sludge each year. It's difficult to dispose of, and environmental regulations mean it can no longer be dumped at sea or buried in landfills. Drying the sludge into pellets or sterilising it with quicklime is expensive, and you've still got to get rid of the final product. Feeding it to the worms seems like the perfect solution.

In practice it's not that simple. Sewage sludge contains bucket-loads of pathogens such as *Salmonella* and faecal coliform bacteria that must be destroyed before the waste can be used on food crops. One answer is to combine worm treatment with traditional composting. You mix the sludge with plant debris and incubate it in heaps up to 15 metres high. As bacteria digest the sludge, they produce heat, warming the pile to 70 °C and killing pathogens. Once cooled, the mix can be fed to the worms to make a clean product that's welcome on the fields.

Unfortunately, precomposting makes the whole process time-consuming and too expensive to be profitable. It's also inherently unnatural, says Mike Lotzof, CEO of Vermitech. "When you go out into the forest," he says, "you don't see 15-metre compost heaps steaming away, you see very small amounts of material deposited at different times." So Vermitech is trying to do things the way nature does, but with a level of automation far beyond the shovels and wheelbarrows of traditional vermicomposters.

Vermitech's worm beds are roughly 1 metre across, 1 metre deep and 70 metres long. "A single bed is a replication of the earth," says Lotzof, "We have a surface and we have a subterranean area that's been designed for the worms' biology." Each day, a thin layer of sludge is spread on top of the bed, and an equal amount of processed product is scraped from the bottom. The worms stay in the top third, feeding on the fresh sludge and laying eggs. It takes about 40 days for material to move through the bed, giving eggs time to hatch and mature so that the young worms aren't harvested out of the bottom.

As the worms swallow the sludge, their powerful gizzards grind it into small pieces, releasing nutrients and allowing soil microbes to proliferate. The worms then digest most of those microbes, along with the dangerous pathogens, and absorb them. Any pathogens that might survive are simply outcompeted by benign soil microbes that flourish in the worm casts.

Wandering through the rows of worm beds, I'm surprised at how odour-free the place is, even in the steamy Queensland air. Lotzof explains that before they spread the sludge on the beds, they add a secret deodorant that binds any smelly, volatile chemicals. Then they aerate the sludge so thoroughly that it has little opportunity to turn anaerobic and smelly.

Vermitech has had to implement strict quality control processes - conditions in the worm bed

are carefully monitored and samples are regularly shipped to an independent lab and tested for pathogens. The worm treatment produces a 100 to 1000-fold reduction in levels of faecal coliforms, as well as cutting numbers of *Salmonella*, gut viruses and parasitic worm eggs. The end product is so good that the New South Wales and Queensland environmental protection agencies allow its use on food crops.

As well as disposing of sewage sludge, vermicompost seems to have benefits for farmers too. The day after my visit to Redlands, Steve Capeness, a Vermitech horticulturalist, drives me from farm to farm on the land north of Brisbane. It's a low-lying region of tea tree and eucalyptus swamps, punctuated by the sheer spires of exposed lava cores - like fossilised teeth - the remains of long vanished volcanoes. In the past, flood waters deposited silt across the region, creating a rich loam that supports a large vegetable and pineapple industry.

Decades of intense agriculture have taken their toll, however, and farmers say the soil is giving out in places. They tell me about small, loosely controlled trials of vermicompost. The farmers using the compost aren't seeing superplants, but they do believe they're getting consistently higher yields, less plant disease and bigger profits.

Peter Stephens, a plant pathologist with the Queensland Horticultural Institute in Stanthorpe, is conducting more rigorous studies on Vermitech's behalf. He's found that carrots fed as little as 2 tonnes of vermicompost per hectare weigh more than twice as much as untreated carrots 66 days after planting. Stephens doubts this is due to the extra nutrients vermicompost provides. "Two tonnes per hectare is virtually nothing," he says. "I think it could be due to plant hormones." Indeed, the soil microbes that flourish in the casts extruded by worms produce a variety of hormones such as indoleacetic acid, gibberellins and kinetins, and other compounds such as humates, which are known to modulate plant growth.

Clive Edwards, a soil ecotoxicologist at Ohio State University in Columbus who originally developed some of the methods now used by Vermitech, is also investigating plant hormones. He has found that vermicompost hormone extracts consistently produce the same level of increased growth as the vermicomposts themselves.

Edwards believes that the plant hormones and the soil microbes which produce them may be the crucial difference between vermicomposts and traditional, worm-free composts. "Whenever we do a trial," says Edwards, "we always put at least one traditional compost in there as a comparison, and every time we've had much, much better results with vermicompost." He suspects the high temperatures that occur during traditional composting kill the beneficial soil microbes. "We've done studies on the microbial communities in the two materials," Edwards says, "and there's no comparison. We get a much more diverse microbial community in vermicompost than we do in traditional compost."

Controlled trials also suggest that vermicomposts may suppress plant disease. A recent study by Stephens, for example, found that the severity of the fungal disease clubroot was significantly reduced in broccoli plants treated with one of Vermitech's products. Edwards has seen similar results for other diseases in studies using vermicomposts. No one is sure of the exact mechanism, but Edwards believes the beneficial soil microbes that flourish in worm casts may be out-competing the plant-pathogenic ones.

While much of the benefit from traditional composts stems from the nutrients they provide, vermicomposts serve instead to inoculate the soil. "What we're doing is growing bacteria, lots of bacteria," says Capeness. In other words, a little goes a long way. Farmers spread as much as 10 tonnes of traditional composts per hectare. But vermicomposts are often used at rates as low as 1 tonne per hectare - so little that you might not even spot it as you walk across a field.

This avoids one of the serious drawbacks associated with recycled sewage sludge: it contains significant levels of heavy metals such as cadmium. Environmental agencies impose strict limits on how much of these metals can be deposited on land. Using one-tenth as much compost as normal means you take 10 times as long to hit that limit - several centuries in some cases.

The Redlands plant processes about 15 000 tonnes of sludge per year, and Vermitech hopes to open a larger plant in Sydney towards the beginning of 2002. This could reduce the costs of the city's sludge management by up to 25 per cent per tonne compared with current methods, Lotzof claims.

Vermicomposting is also being investigated in the US. In small-scale studies, Bruce Eastman, manager of the Orange County Environmental Protection Division in Orlando, Florida, has attained pathogen destruction similar to

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Vermitech's. He's now organising a larger study with help from the US Environmental Protection Agency. "They've indicated to me that they would be willing to accept vermicomposting as an alternative stabilising methodology (for sludge) once we've come up with the standard operating procedures," Eastman says.