# One Size Fits All
# -
# How households, schools, prisons, municipalities and industries successfully use vermicomposting

M. Quintern*[1], M. Morley[2]

Corresponding author: michael.quintern@mynoke.eu

[1] Noke GmbH, Pfaffenstr. 22, 23552 Lübeck, Germany
[2] Noke Ltd, PO Box 347, Seventh Avenue, Tauranga 3140, New Zealand

Keywords : Vermicomposting, household, community, commercial, scalable technology, organic waste

## Abstract

Vermicomposting is the emerging technology for up-cycling of organic waste and residues using earthworms - or more specifically, compost worms. Over recent decades vermicomposting has gained notoriety at all levels of community in converting a wide range of organic wastes ranging from small volumes at household level to fully commercial operations servicing the needs of commercial and industrial operators. Refining new vermicomposting technologies have led to easy use continuous-flow worm farms like the ‘Hungry Bin’ for households. At a commercial scale, newly developed vermicomposting technologies allows for the processing of 70,000 wet tonnes of industrial organic waste per year are now processed on a single vermicomposting facility. The challenge for commercial vermicomposting operators is to establish operations that are competitive for producers of medium volumes of organic wastes.

The success of a medium volume service, is therefore dependent upon understanding the type and volumes of the organic waste resource and matching it to the most appropriate vermicomposting technology available. This paper presents case studies of such a commercial approach and demonstrates how an easy to use, small scale vermicomposting system can be expanded to a modular system to service medium volumes of organic waste through vermicomposting.

The technology of choice has low capital expenditure (CAPEX), low operating expense (OPEX), and is infinitely scalable to match the volume of organic wastes. Industrial scale vermicomposting must respond to seasonal variations in volumes, be able to effectively be integrated into farming, horticulture or forestry, be socially and culturally accepted, and to have a responsive market for large volumes of high market value end product.

## 1 Introduction

To avoid confusion in the terminology, this paper refers to vermicomposting as a technology and process for the management of organic wastes in contrast to vermiculture.

**Vermicomposting** focuses on the conversion of organic waste using compost worms. A wide variety of organic residues are suitable as feedstock for compost worms. Some organic waste require conditioning or blending prior to vermicomposting. **Vermiculture** in contrast, is understood as the breeding of earthworms e.g. for fishing bait. To achieve high numbers of healthy earthworms, high quality feedstock is required. Uniform, often energy rich organic resources are chosen and blended with peat products, which are a scarce natural resource compared to organic wastes. This means that not all organic residues can be used in commercial vermiculture but will be perfectly suitable for vermicomposting. This paper focuses on vermicomposting although some aspects may be relevant for vermiculture.

Vermicomposting is a well-researched and established process and has gained much respect especially during the last quarter of the 20th Century [1]. Various organic wastes have been studied at laboratory scale and with findings having been up-scaled and applied to pilot and commercial scale vermicomposting operations. Small scale systems, medium size commercial operations and industrial scale vermicomposting technology have matured and are vastly growing in applications worldwide.

- Small scale vermicomposting systems are typically low-budget systems with limited throughput compared to well designed, cost effective continuous flow vermicomposters.
- Medium size operations are often developed around vermiculture. Often indoor and highly mechanised, the technology attempts to accelerate a natural process as is found in agriculture. These operations are often described as so called ‘worm farms’ and often operate as a part time business or integrated into farming or waste management enterprise’s where local organic wastes are handled. The business is often controlled and concentrated around the manager and difficulty to multiply and adapt to other locations and other organic waste sources.
- Industrial scale vermicomposting requires a more complex approach to meet the operational and environmental requirements. A significant aspect is in managing logistics associated in the transportation of organic waste into and vermicast from the facility. The integration of a well-designed industrial vermicomposting operation with existing farm or forest enterprises, often result in sustainable organic waste free operations.

## 2 Vermicomposting technology and systems

### 2.1 Hungry Bin for households and small enterprises

The Hungry Bin is a continuous flow vermicomposter or worm-composter specially designed to provide an ideal living environment for compost worms within an easily managed and clean handling process. (Figure 1 A). Organic waste is applied at the top and the resultant vermicast and the nutrient rich liquid; often referred to as ‘worm tea’ is harvested at the bottom without the need to manage heavy trays. The Hungry Bin is a closed system, does not leak liquid to the ground and does not attract rats, mice or flies. Being fully portable allows relocation on the owners premises as required. The tapered shape compresses the castings similar to a soil profile for ease of handling while providing natural separation of the compost worms from the casting.

As a modular system multiple Hungry Bins (Figure 1 B) can be combined in racks to serve medium to semi large organic waste volumes from 3 t/a to approximately 200 t/a.


Figure 1. A: Hungry Bin domestic continuous-flow vermicomposter. B: Modular rack of 8 Hungry Bins for small enterprises.

The vermicast and liquid fertiliser can be used onsite where it offsets some of the costs associated with purchases of potting mixes and mineral fertilisers. The organic waste reduction at a household level is highly beneficial to communities with limited waste separation systems and where the beneficial utilisation of the nutrients is problematic, e.g. where centralised anaerobic digesters systems struggle with digestate disposal.

### 2.2 Medium scale vermicomposting

Medium scale vermicomposting, typically referred to as ‘worm farms’ are generally based on under cover open bed or raised-bed technology. The typical windrow technologies are described by Edwards [2] Table 1 and either requiring regular feeding on top of the windrow or to the side as wedge windrow technology. Windrows are usually covered with plastic or the whole ‘worm farm’ is enclosed in netting to prevent birds from preying. These systems are usually labour intensive and process up to 2,000 t/a [3].

### 2.3 Industrial scale vermicomposting

The vermicomposting technology developed by Quintern Innovation Ltd. is based on the Windrow approach and described as low-technology vermicomposting systems. Windrow vermicomposting in general is characterised as low CAPEX and easy to manage. The drawbacks of conventional Windrow Vermicomposting Systems [2] include a large footprint, labour-intensive, slow processing time, considerable nutrient losses, and need for separation of earthworms from vermicompost. Most of these drawbacks have been resolved by Quintern [4] (Table 1). The key improvements have been achieved by avoiding continuous feeding practices to reduce labour costs and processing time. The footprint has been significantly reduced by minimising the non-productive areas of the vermicomposting site. The Quintern Windrow Vermicomposting Technology has been developed and proven over the last decade and is successfully operating at an economic industrial scale.

Table 1. Characteristics of the Quintern Windrow Vermicomposting Systems [4] in comparison to conventional Windrow Vermicomposting Systems described by Edwards [2].

| | Quintern Vermicomposting | Conventional Windrow Vermicomposting |
|---|---|---|
| **Benefits** | Low CAPEX* | Low CAPEX* |
| | Low OPEX** | |
| | Easily managed | Easily managed |
| | Not labour intensive (mechanised) | |
| | Reduced footprint | |
| | Retention of nutrients through wider C/N ratio | |
| | Harvesting vermicompost without earthworm separation | |
| **Drawbacks** | | Labour-intensive |
| | | Large footprint |
| | 6 to 12 months processing time | 6 to 16 months processing time |
| | | Loss of nutrient through leaching and volatilisation |
| | | Impossible to harvest vermicompost without earthworm separation |

*Capital expenditure, ** Operating expense

To manage the nutrient losses through leaching and gaseous losses from vermicomposting sites, the C/N ratio of the feedstock is carefully adjusted, which reduces the potential of enriching the underlying topsoil with nutrients and humic acids. Operating on the same location over multiple years can create a hot spot of nutrient into the soil ecosystem. To address this potential risk, the authors adopted a strategy of integrating vermicomposting into farm and forest management practices. Similar outdoor pig ranging, with extreme high nutrient accumulated hot spots [5], the vermicomposting sites will rotate either on the farm [6] or within forests. After a certain time of vermicomposting on one specific site, new windrows will be established in new locations on the farm or forest block. On the former vermicomposting site, the vermicast will be harvested and in agriculture a so-called ‘catch crop’ with high nutrient demand, such as maize, is planted. In forest systems, the new plantation benefits from the vermicast residues by boosting root development of young trees and addressing the demand for nutrient of trees as it is highest in the first years of plant growth.

## 3 Vermicomposting Technology Matrix

Choosing the best technology for vermicomposting organic residues and waste, depends on the type and volume of organic waste, location, environment and the type of market for the end product (Table 2). There are likely to be variations in the volume and type of organic wastes arising from households due to food preferences, number of occupants and culture. The Hungry Bin is capable of buffering volumes and to a certain degree variations in the types of organic waste. Peaks of inputs can be tolerated where weekly volumes average out 2 kg/day. Larger quantities of acidic fruits may require pH buffering using ordinary garden lime, wood ash or soaked cardboard. Higher amounts of cooked food such as pasta should be mixed with cardboard and remaining organic residues at the surface of the hungry bin.

With larger volumes, up to 50 kg/day modular racks holding multiple Hungry Bins will provide a clean and easy to manage vermicomposting system. This continuous flow system is labour efficient ensuring a clean processing area that is rodent and odour free. The footprint, can be regulated by changing the numbers of Hungry Bins according to the volumes of organic waste being processed as required.

Table 2. Type of organic waste producer, type of organic waste, produced volumes and recommended vermicomposting technology.

| Organic Waste Producer | Type of Organic Waste | Produced Mass | Vermicomposting Technology |
|---|---|---|---|
| Small household<br>Medium household | Kitchen scraps, tissue Paper, cardboard | 0.25 to 2.0 (kg/d) | Single Hungry Bin |
| Large household<br>School (class)<br>Council office<br>Canteen / prison | Food waste, tissue paper, coffee ground, tea bags, paper towels | 2.1 to 300 (kg/d) | Modular Hungry Bin |
| Winery, distillery<br>Olive oil mill | Fruit wastes, grape mark, olive mill pomace, leaves | 1 to 4,000 t/a seasonal | Windrow vermicomposting |
| Milk Plant | Waste activated sludge, DAF | 1 to 100 (t/d) | |
| Rendering plant | Paunch contents, hair | 1 to 100 (t/d) | |
| Municipal WWTP | Sewage sludge / biosolids | 0.2 to 35 (t/d) | |
| Pulp & paper mill | pulpmill solids / rejected fibres | up to 250 (t/d) | |

DAF: Dissolved Air Flotation sludge; WWTP: wastewater treatment plant

Waste volumes of more than 50 kg/day as generated from supermarkets, large hotels, resorts, food and restaurants and commercial / industrial plants require processing in rural areas where windrow vermicomposting systems can be integrated in farming or forest management. The centralised rural location allows end users to easily access the vermicast with minimum logistics disruption. Extra value is afforded when organic wastes can ideally be transported as backloads in closed containers or bags or in a semi liquid consistence processed by food waste processor.

## 4 Case Studies

### 4.1 Individual households

Individual households typically produce organic waste volumes between 0.5 and 2 kg per day depending on the size of households, culture and their food preferences. [7]. The benefits for vermicomposting will be different for each stakeholder. For the individual household the initial investment of a 'Hungry Bin' worm farm – if not subsidised - can pay for itself within one year by reducing waste disposal fees and savings from reduced fertiliser and potting mixes through utilising the self-made vermicompost and liquid fertiliser for gardens and pots. Non-recyclable paper waste such as tissue or food wrapping paper can be vermicomposted in the Hungry Bin. Compared to most 'on-the- ground' conventional composting boxes the Hungry Bin is rodent free and traps any liquid from infiltrating the soil by collecting all liquid and solid products.

For communities this is the ideal onsite solution as it deals with household organic at source. Municipalities benefit through cost savings in waste collection and reduced operational costs at traditional processing centres. In Auckland City, New Zealand, some 30,000 Hungry Bins are used to vermicomposting organic wastes from households reducing the organic waste volume of the city by approximately 21,900 t/a.

Figure 2. Hungry Bin used at domestic apartment household in Auckland City.

Table 3. Technical parameter, performance and payback of 1 Hungry Bin worm composter for one individual household.

| | Unit | Price / Unit [€] | Costs / year [€] |
|---|---|---|---|
| Hungry Bin | 1 | € 265.00 | - (€ 265.00) |
| Compost worms | 2 kg | € 19.00 | - (€ 38.00) |
| Waste disposal fee<br>Saving on waste levy* | 12 times / a | € 3.28/month | € 46.20 |
| Organic waste consumption | 2 kg/d<br>730 kg/a | | |
| Vermicast produced<br>(Waste reduction 95%) | 36.5 kg/a | € 5.00/kg | € 182.50 |
| Liquid fertiliser produced | 26 l/a | € 5.00/l | € 130.00 |
| **Total install cost** | | | **€ 303.00** |
| **Total rebate / year** | | | **€ 358.70** |
| **Payback** | | | **0.85 year**<br>**10 months** |

* example Ansbach Germany

The Ministry for Climate Protection, Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia (NRW) strongly recommends that cities and districts encourage households to conduct onsite composting and onsite utilisation by reducing the waste levy. Now, 80% of the communities in NRW are following their advice [8]. Table 3 provides an overview of the performance and payback of 1 Hungry Bin per household and shows that each Hungry Bin can reduce the organic waste by 730 kg/annum and achieves pay back after approximately 10 months.

### 4.2 Medium scale vermicomposting – Small to Medium Enterprises

For stakeholders with slightly higher organic waste volumes, the modular 'Hungry Bin' worm farm offers multiple benefits. Within this group belong schools, kindergartens, offices, small to medium enterprises, restaurants, cafes, hotels, hospitals and even prisons. Organic wastes from kitchens, canteens and restaurants and the associated volume of paper towels, no longer incur the high disposal costs associated with landfills. The onsite vermicomposting units are a visual statement of the stakeholder's environmental policy and enhances both their green and corporate image. Vermicompost resulting from this can be upcycled to school (Figure 3 A) and kindergarten gardens; used on municipal public amenities (parks and gardens) or can be made available to students, staff and customers.

A 'Hungry Bin' modular vermicomposting installation of 200 units has been installed at Mount Eden Prison in Auckland (Figure 3 B) to process more than 200 kg of organic wastes daily. Saving the facility more than $200,000 per year in waste disposal fees plus providing worm humus which is then used to grow vegetables on site. In prisons, meaningful jobs and work skills are created by vermicomposting kitchen and canteen wastes and upcycling in prison vegetable gardens.

20 Hungry Bins are installed at the Auckland City Council's office carpark. The organic wastes and paper towels of 500 staff are converted of worm humus and fertiliser for staff to take home. Ripe Café in Auckland's Ponsonby district produces 200 kg of food scraps a week, which are vermicomposted in 16 Hungry Bins on site.


Figure 3. Modular Hungry Bin rack used at A: a high school; B: 200 Hungry Bins at a prison in Auckland City.

### 4.3 Industrial scale vermicomposting

Industrial organic wastes from the processing of wood pulp, fibres, fodder, milk, meat, fruits and vegetables are generally highly consistent in their make ups. Volumes are normally constant but can fluctuate as, for example in the olive oil or wine industry. The benefits of vermicomposting to these industries include low CAPEX, low OPEX and volume reductions of waste streams up to 80%. Valuable soil conditioner and fertiliser are produced that can be used locally and promoting leadership in maintaining healthy soil humus levels and reduced needs for imported fertilisers. The vermicomposting operations are easily integrated into farm or forest management and are designed to rotate on the land similar to crop rotation to avoid nutrient losses.

Compared to thermal composting, vermicomposting has significantly higher volume reductions and results in a superior and higher value product. This reduces transportation costs, reduces odour emissions and being a low temperature process does not create steam.

Anaerobic digestion is not a competing technology to vermicomposting as this technology converts some of the carbon into biogas. The remaining digested sludge is high in volatile ammonium and requires careful and sometimes costly management in its disposal. Dewatered sludge from digesters can be added to vermicomposting operations though.

A number of industrial scale vermicomposting case studies involving municipal and industrial processes in New Zealand are discussed. Municipal wastes from Maketu, a small coastal community of 250 households produces 0.5 tonnes biosolids per day. Te Puke, a semi-rural community of 8,000 persons produces 900 tonnes p.a., and Rotorua and Hamilton with combined populations of 218,000 and diverse industrial footprints, produce 10,000 and 13,500 tonnes of biosolids respectively p.a. Industrial wastewater treatment plant sludge and wet organic residues are presented for 2 dairy operators, Miraka - 2,500 t/a and Fonterra Co-operation Group - 30,000 t/a [9], a kiwi fruit processor, Seeka - 5,000 $m^3$/a and a large pulp and paper producer, Oji Fibre Solutions - 100,000 t/a [10]. These operators have diverted their dissolved air flotation (DAF) sludge’s and waste activated sludge’s away from traditional landfill disposal to vermicomposting up-cycling [11]. A new community facility at Taupo in New Zealand’s North Island commenced operations in February 2017. (Figure 4). With a PE of 33,000, up to 10,000 tonnes of various organic wastes including biosolids, paper and kitchen wastes, lake weeds and pulpmill solids will be vermicomposted.


Figure 4. The new Taupo Vermicomposting Operation A: receiving municipal biosolids; B: mixing biosolids with pulpmill solids; C: compost worms stabilising organic wastes.

In New Zealand, commercial scale vermicomposting has increased the up-cycling of dewatered sludge both municipal [12] and industrial operators [13] from 2,000 tonnes in 2008 to 200,000 tonnes in 2017. Currently 60,000 tonnes of vermicast are produced in New Zealand per year to improve soil fertility and to restore soil organic matter. Vermicast is applied to pasture and cropping in agriculture, horticulture, orchards, nurseries, as well as to forestland. The aim is to improve the health of productive soils resulting in increased plant growth, [14] water and nutrient holding capacity and erosion protection. Vermicomposting operations are easily integrated into agricultural, horticultural and forestry management systems to maximise the environmental and economic benefits of the vermicomposting technology. This ‘vermicomposting-crop-rotation’ concept, developed by Quintern Innovation, provides for better on farm nutrient budget planning while reducing operational and environmental monitoring costs.

## 5. Outlook

Vermicomposting of organic residues and waste has been successfully established at small, medium and large scales and for a wide range of organic wastes. Access to vermicomposting technology and its economic, cultural, and environmental benefits are available to a wide range of organic waste producers ranging from individuals, to small and medium enterprises as well as to large processing operators, local government and central government policy makers. The successful case studies described demonstrate these. These experiences are able to be replicated globally.

The rapid uptake of vermicomposting has led to an increase production of vermicast and vermicompost globally. In some regions the production of bulk vermicast is larger than those of compost from thermal composting plants. End users such as farmers, vegetable and fruit growers are widely preferring vermicast over general compost for following reasons:

i.) Lower product prices due to lower capital and operating costs of vermicomposting compared to thermal composting.

ii.) Lower transportation and application costs due to higher humus quality and plant growth value per tonne of product. Vermicomposting achieves a volume reduction of the organic residue of approximately 65 to 85%, while volume reduction of thermal composting achieves only 30 to 40%.

iii.) Increase in soil function and potential reduction in nitrogen leaching. Water holding capacity and root depth of the soil profile improves as vermicast has a high humus quality that increases soil organic matter contents in the soil. Naturally produced plant growth stimulators in vermicast such as gibberellins and auxins boost root growth and nutrient uptake [15], [16] . Vermicast is the choice of organic soil conditioners for agriculture and horticulture in sensitive water catchment areas.

Ongoing research continues to improve our understanding of optimising application rates and combining vermicast with mineral fertilisers to various crops in specific regions. This will help farm advisors and managers to support land utilisation of organic residues including vermicast to farm land in the future.

Vermicomposting is not the silver bullet for all organic residues but offers communities wide application benefits from individual households to large industries. With low CAPEX and OPEX, vermicomposting is a low risk technology with wide economic and environmental benefit for developing countries as well as highly intensive agricultural countries where anaerobic digestion is a nutrient ‘disposal’ method. While digestate from anaerobic digesters has pronounced economic barriers in its disposal, high quality vermicast has strong market value and can be sold and distributed without restrictions.

The Hungry Bin worm composter is a clean and easy to use mobile vermicomposting system that can be utilised widely from small entities such as kindergartens and primary schools, as examples through to large offices, hospitals and hotels. Its use both educates and raises awareness of environment stewardship, nutrient and humus cycles, organic waste management, climate change and last but not least the life cycle of earthworms.

## References


1. Sherman, R., Arancon, N. Q. & Edwards, C. A. *Vermiculture Technology: Earthworms, Organic Wastes, and Environmental Management* CRC Press, Taylor & Francis Group, Boca Raton, London, New York, (2011).
2. Edwards, C. A. in *Vermiculture Technology: Earthworms, Organic Wastes, and Environmental Management.* Eds Edwards, C. A., Arancon, N. Q. & Sherman, R.. 79-90. CRC Press, (2011).
3. Sherman-Huntoon, R. Latest developments in mid-to-large-scale vermicomposting. *BioCycle* **41,** 51-54 (2000).
4. Quintern, M., Morley, M., Seaton, B. & Hamilton, R. How we transform industrial organic waste into vermicompost and champion environmental sustainability . *8th International Conference on Waste Management and the Environment* **8,** 147-159 (2016).
5. Quintern, M. Integration of organic pig production within crop rotation: Implications on nutrient losses. *Landbauforschung Völkenrode.* 31-40 (2005).
6. Quintern, M. & Sundrum, A. Ecological risks of outdoor pig fattening in organic farming and strategies for their reduction - Results of a field experiment in the centre of Germany. *Agriculture, ecosystems & environment* **117,** 238-250 (2006).
7. Edjabou, M., Petersen, C., Scheutz, C. & Astrup, T. Seasonal generation of food waste in Denmark. *Sardinia 2015 15th International Waste Management and Landfill Symposium* 1-5 (2015).
8. Anonymous *Abfallwirtschaftsplan Nordrhein-Westfalen - Teilplan Siedlungsabfälle* Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen, Düsseldorf, Germany, (2015).
9. Quintern, M., Morley, M. & Seaton, B. Full-scale vermicomposting of sludge from milk plants with pulp and paper mill sludge. *WASTES 2015--Solutions, Treatments and Opportunities: Selected papers from the 3rd Edition of the International Conference on Wastes: Solutions, Treatments and Opportunities, Viana Do Castelo, Portugal, 14-16 September 2015* **41,** 241 (2015).
10. Quintern, M. Full scale vermicomposting and land utilisation of pulpmill solids in combination with municipal biosolids (sewage sludge). *7th International Conference on Waste Management and the Environment* **7,** 65-76 (2014).
11. Quintern, M., Seaton, B., Mercer, E. & Millichamp, P. Industrial scale vermicomposting of pulp and paper mill solids with municipal biosolids and DAF sludge from dairy industries. *Appita* **66,** 290-295 (2013).
12. Quintern, M. Industrial scale vermicomposting of municipal biosolids by blending with fibrous industrial wastes. *Eurasia 2014 Waste Management Symposium* 1-9 (2014).
13. Quintern, M. & Morley, M. How to engage communities and industries for full-scale vermicomposting - case studies from New Zealand . *10th International Conference on "Circular Economy and Organic Waste" ORBIT 2016* **10,** 1-7 (2016).
14. Zandonadi, D. B. & Busato, J. G. Vermicompost humic substances: technology for converting pollution into plant growth regulators. *International Journal of Environmental Science and Engineering Research* **3,** 73-84 (2012).
15. Zandonadi, D. B., Canellas, L. P. & Façanha, A. R. Indolacetic and humic acids induce lateral root development through a concerted plasmalemma and tonoplast H+ pumps activation. *Planta* **225,** 1583-1595 (2007).
16. Zandonadi, D. B., Santos, M. P., Dobbss, L. B., Olivares, F. L., *et al.* Nitric oxide mediates humic acids-induced root development and plasma membrane $H^+$-ATPase activation. *Planta* **231,** 1025-1036 (2010).