Industrial scale vermicomposting of pulp and paper mill solids with municipal biosolids and DAF sludge from dairy industries

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SUMMARY

The Carter Holt Harvey Kinleith pulp and paper mill has undertaken huge efforts to minimise its landfilled organic wastes over the last decade. Besides increasing fibre recovery rates options for alternative uses of pulpmill solids have been evaluated over time. In 2008 a feasibility study of industrial scale vermicomposting of Kinleith pulpmill solids was been initiated. After proofing of concept, Noke Ltd. started operating its industrial wormfarm at full scale, vermicomposting all primary solids from Kinleith mill. In 2010 trials of mixing the secondary biological solids from the oxidation ponds with the primary solids were successful. Today 36,500 tonnes per year of mixed primary and secondary solids are diverted from landfill and are vermicomposted on the MyNOKE® wormfarm. The pulpmill solids are converted to approximately 5000 m^3 of organic certified vermicast. Vermicast is land applied to nurseries, kiwi fruit orchards, maize paddocks, pasture, and for erosion control. From 2013 dewatered sludge, here called ‘recycled paper solids’ from Carter Holt Harvey’s recycling paper plants will be combined with other fibrous mill wastes, municipal biosolids, and with dissolved air flotation (DAF) sludge from milk processing plants for vermicomposting.

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INTRODUCTION

New Zealand’s central north island pulp and paper industries produce approximately 150,000 tonnes of fibrous wastes per year. The predominant source of this waste is biosolids from the waste water treatment systems, plus some fibre losses and wastes from the pulp and paper processes. Until 2006 more than 95% of these carbon rich fibres were landfilled and less than 5% were composted.

The Kinleith mill has been working on ways to reduce waste to landfill for more than a decade. This began with projects to optimise process efficiencies and improve productivity, resulting in initial reductions of some 7tpd on average. Various options for alternatives to landfilling of the remaining material have been investigated, including burning and land application in association with high nitrogen containing waste, as well as composting and vermicomposting.

Direct application of pulp and paper solids to land is conducted at small scales with potential risks on soil and water ecosystems *(1, 2)*. If applied to farmland nitrogen and phosphate fertiliser application have to be increased to avoid nutrient immobilisation *(3)*.

Vermicomposting of various industrial organic wastes have been studied for four decades *(4)*. In earlier publications paper wastes with a C:N ratio of up to 200 were used as a carbon rich blending agent for nutrient rich wastes such as biosolids, food wastes *(5)*, manure *(6)*, and other industrial wastes *(6)*. A decade later solids from pulp and paper mills *(8 -11)* were used as carbon rich fibre for blending in vermicomposting. Solely vermicomposting of paper wastes or pulp and paper solids, without adding external nutrient rich wastes, has not been done commercially so far. Lake weeds have been trialed as a nitrogen source successfully *(12)*.

In 2008, when laboratory scale work indicated some promise for Kinleith wastes, land was sourced within reasonably close proximity to the biosolids dewatering ponds. Extracted material was laid in windrows. The decision was made to delay the process and allow the mass of worms to build naturally and migrate as the food sources depleted, rather than purchase worms. The initial work was so successful that eventually all of the dewatering ponds sludge was removed to the now expanded vermicomposting operation.

There is a growing market for vermicompost products within the vicinity of the mill. New Zealand’s central north island is a highly intensive primary industries region. Local activities include, dairy farming and horticulture nurseries, which rely on maintaining stable soil humus contents for sustainable production.

PULPMILL SOLIDS CHARACTERISATION

The Kinleith pulp and paper mill utilises approximately 130,000 tpa of recycled paper product. Losses to the mill sewer system from the recycle plant operation and paper machine cleaner system now average around 15 tpd (dry basis) of rejected fibre material so called primary solids. This is removed in the primary clarifier and pumped to one of two gravity dewatering ponds.

The wastewater treatment system for the mill produces approximately 12 tpd (dry basis) of secondary biological solids from the oxidation ponds. This material had traditionally been dredged and landfilled at an average consistency of 4% initially. While these types of solids are notoriously difficult to settle, they can be combined with primary solids from the clarifier. At Kinleith, this is done primarily by pumping secondary solids from the oxidation ponds back to the clarifier inlet and removing the combined solids in the clarifier. Further material is also dredged separately and mixed mechanically (Fig.1). One key factor at Kinleith was that the mill's primary clarifier was operating at less than a third of its design flow after significant reductions in the wastewater flows. No polymer-based settling aids would be able to be used as these could potentially be harmful to the vermicomposting operation. Testing showed that the clarifier had not lost a significant amount of efficiency by recycling secondary solids and the vast majority of solids entering were now going to the dewatering ponds and subsequently the vermicomposting operation. Today, all of the primary and secondary solids generated from the operation (Fig. 2) of the wastewater treatment system are vermicomposted instead of being landfilled.

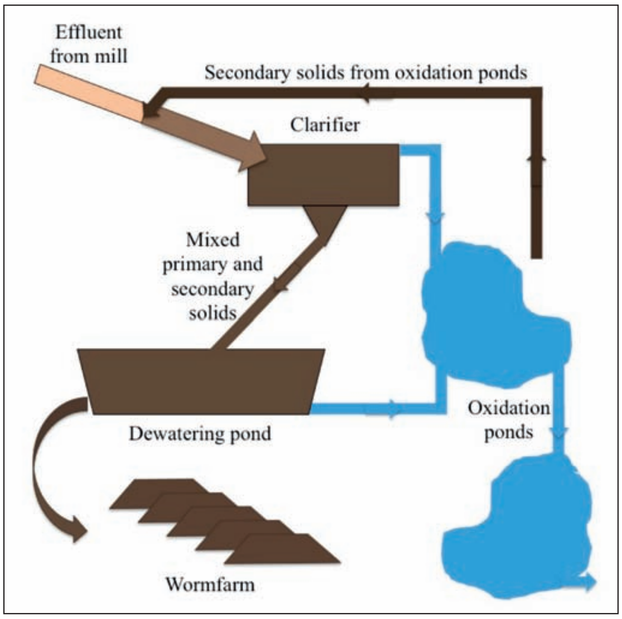

Fig 1. Generation of mixed primary and secondary solids; the secondary solids are added into the effluent stream before entering the clarifier from where sediments are pumped into sedimentation ponds and taken to wormfarm.

Fig 2. Dewatered primary solids in sedimentation ponds

The chemical and physical characteristics of the various waste solids at the Kinleith mill are summarised in Table 1. The mill is operating two alternating sedimentation ponds, which are emptied in a three months interval. The solids content of 17.8% of the primary solids allows easy loading, transportation and handling at the wormfarm. The secondary solids with a regular water content of <4% require blending as discussed. Primary solids are generally high in

Table 1. Characteristics of primary, secondary, and recycled paper solids from Kinleith pulp and paper Mill.

Parameter Solids	Primary Solids	Secondary Paper	Recycled Solids
Dry Matter %	17.8	18*	26.9
Total Carbon %	37.6	17.0	35.0
Total Nitrogen %	0.5	0.53	0.48
C:N ratio	75	32	70
pH		8.5	
Total Phosphorus mg/kg	509	1,203	228
Total Sulfur mg/kg	3200	5000	705
Total Potassium mg/kg	1060	1203	141
Total Calcium mg/kg	24,200	42,000	58,900
Total Magnesium mg/kg	2440	863	1954
Total Sodium mg/kg	1130	1582	122
Total Manganese mg/kg	103		56
Total Arsenic mg/kg	<0.021	<0.021	0.5
Total Boron mg/kg	0.28	0.12	<6
Total Chromium mg/kg	<0.011	<0.011	6.6
Total Cadmium mg/kg			0.21
Total Copper mg/kg	50	<0.011	47
Total Lead mg/kg	0.038	<0.0021	9.21
Total Mercury`mg/kg			0.06
Total Nickel mg/kg	0.012	<0.011	6.0
Total Zinc mg/kg	1.2	1.2	62

* Dewatered sample taken from a sedimentation pond, fresh secondary solids DM <4%

organic matter (37.6%) but relatively low in nitrogen (0.5%). Secondary solids show a lower carbon content (17%) than, but similar nitrogen content (0.53%) to the primary solids. Metal concentrations of both fibres are well below the limits for land application *(13)*.
The recycled paper solids show similar carbon and nitrogen concentrations to the primary solids. Slightly higher metal concentrations (Table 1) are still below the limits for safe land application *(13)*.

VERMICOMPOSTING OPERATION

The wormfarm commenced with an intensive program of breeding compost worms in November 2008. From April 2009 primary solids were delivered to the worm farm on a regular basis. Since January 2010 All primary solids have been vermicomposted at the MyNOKE® wormfarm since January 2010 and all secondary solids since October 2010. Table 2 shows the annual volumes of mixed primary and secondary solids delivered to the wormfarm.
In 2011 the worm farm had reached a footprint of 19.8 ha. For minimising transportation all worm farm sites are located within a 6km distance to the dewatering ponds. 10.8 ha are operated on old log yard sites and a 9 ha block is located on a nearby organic certified dairy farm.
The feedstock (mixed pulpmill solids) is applied in windrow technology onto the wormfarm for vermicomposting according to the best practice standards *(13)*. Windrows are not covered, not sealed toward soil, and no irrigation is used. Windrows are inoculated with compost worms *(Eisenia foetida)* (Fig.3) and left for vermicomposting for a period of 12 months. Vermicompost is thereafter harvested and replaced by fresh feedstock. The volume reduction during vermicomposting is between 78 and 85%.
The high water holding capacity of the fibrous feedstock does not require any irrigation in the central north island climate. Even a six weeks drought in summer 2010-11 did not harm the vermicomposting operation.
The C:N ratio of the mixed pulpmill solids is far higher than suggested for successful vermicomposting *(14)*. A higher C:N ratio of the feedstock leads to a reduction in nitrogen losses during vermicomposting, as nitrogen will remain limited for microbiological growth. The groundwater monitoring at a commercial wormfarm in central north island, where pulpmill solids are vermicomposted with municipal biosolids is not showing any significant leaching of nitrogen. The vermicast produced from feedstock with a wider C:N ratio remain with a relatively wide C:N ratio of 29 (Table 3) is seen as a more stable soil conditioner and therefore most favorable for most purposes such as potting mix substitute or land applied in areas sensitive to nutrient leachate *(15)*.

Table 2. Delivered wet tonnes of primary and secondary solids from two dewatering ponds and vermicomposted at the MyNOKE® wormfarm.

	Year			
Origin	**2009**	**2010**	**2011**	**2012**
Pond 2A	7025	27585	14708	15219
Pond 2B	5284	8737	21612	13882 +7300*
Total	12309	36322	36310	36401

* estimated for Nov and Dec 2012

VERMICOMPOST AND LAND APPLICATION

Pulpmill solids are completely digested by earthworms and the received product is pure earthworm casting. The New Zealand standard for composts, soil conditioners and mulches *(13)* defines vermicast as the solid organic product resulting from the transformation of compostable organic matter in a controlled vermiculture process, where 90% passes the 1.8 mm sieve.
Vermicompost is defined as a mixture of vermicast and partially unprocessed organic matter.

Fig 3. Compost worms *(Eisenia foetida)* feeding on mixed primary and secondary solids.

Fig 4. Screened (5 mm) MyNOKE® organic Wormicast produced form pulpmill solids coming off a conveyor.

The mature vermicast from mixed primary and secondary pulpmill solids from Kinleith pulp and paper mill is recognised as a premium soil conditioner and sold under a specific brand as MyNOKE® organic Wormicast. The wormfarm has been organic certified since 2010. Pulpmill solids have been certified as non-synthetic product and therefore as organic allowed input. The vermicast organic certification covers following standards:

- AsureQuality Organic Standard V4
- MAF Official Organic Assurance Programme Technical Rules for Organic Production V7.1
- USDA National Organic Program (NOP)
- IFOAM

The product characteristics are shown in Table 3. With an organic matter content of 33.6% a total of one-third of the product is pure humus as stabilised earthworm casting. The high content humus leads to a high cation exchange capacity with a 100% base saturation as a result of the high content of bivalent cations such as calcium and magnesium. Soil amended with vermicompost stores the carbon applied with the soil conditioner *(16)*. This makes the vermicast a highly demanded soil conditioner to increase nutrient and water holding capacity of soils. Additional benefits of the vermicompost may lead to better germination of seeds *(17-19)* and especially of pine trees *(20 -22)*, suppression of diseases *(23-25)*, suppression against plant stress *(26)*, higher yields *(27)*, and other beneficial uses *(28, 29)*. Main customers sectors for the vermicast are kiwifruit orchards, nurseries, dairy farms (pasture renewing), erosion control, hydro-seeding, and maize growers.

With the growing population of compost worms the production of mature vermicompost increased from 2798 m^3 in 2011 to estimated 5000 m^3 in 2012.

Table 3. Characteristics of MyNOKE® organic certified vermicast produced from pulpmill solids from Kinleith pulp and paper mill.

Parameter	MyNOKE® organic vermicast
Dry Matter %	40 - 49
Bulk density kg/m^3	745
Organic matter %	33.6
Total Carbon %	19.5
Total Nitrogen %	0.65
C:N ratio	29
pH	7.04
Total Phosphorus mg/kg	1310
Total Sulfur mg/kg	4430
Total Potassium mg/kg	804
Total Calcium mg/kg	71,300
Total Magnesium mg/kg	3420
Total Sodium mg/kg	869
Total Manganese mg/kg	259
Total Arsenic mg/kg	7.0
Total Boron mg/kg	8
Total Chromium mg/kg	26
Total Cadmium mg/kg	0.50
Total Copper mg/kg	53
Total Lead mg/kg	38
Total Mercury mg/kg	0.12
Total Nickel mg/kg	14.2
Total Zinc mg/kg	127

FUTURE DEVELOPMENTS

Currently only a mix of primary and secondary pulpmill solids is vermicomposted *(30)*. To be able to vermicompost recycled paper solids and other fibres with a very wide C:N ratio of above 70 (Table 1) nitrogen and other nutrients have to be added. Feasibility studies have been conducted successfully by adding regional nutrient rich organic wastes to the recycled paper solids prior to vermicomposting. Municipal biosolids from a large community has a C:N ratio of 6.4 (Table 2) and would be available continuously throughout the year at a total of 13,000 tonnes per year. 10,000 tonnes of dissolved air flotation (DAF) sludge from a milk processing plant would be available over a period of 10 months and has a C:N ratio of 5.2. The low pH value of 3.9 of the DAF sludge requires buffering prior to vermicomposting. This can be achieved by utilising either rejected lime or wood ash from Kinleith mill.

The results from the feasibility study lead to a commercial operation starting on the 1 February 2013. MyNOKE® wormfarm started vermicomposting a combination of up to 30,000 tonnes of recycled paper solids and other pulpmill solids with 13,000 tonnes municipal biosolids per year on a 15 ha block. A similar operation has operated since 2010 in the Bay of Plenty region vermicomposting 11,000 tonnes of municipal biosolids in combination with pulpmill solids *(32)*.

Table 4. Characteristics of DAF sludge from a central north island milk plant and municipal biosolids.

Parameter	DAF sludge milk plant	Municipal biosolids
Dry Matter %	13.0	21
Total Carbon %	5.2	30
Total Nitrogen %	1.0	4.7
C:N ratio	5.2	6.4
pH	3.9	
Total Phosphorus mg/kg	2100	
Total Sulfur mg/kg	1100	
Total Potassium mg/kg	1100	
Total Calcium mg/kg	1900	
Total Magnesium mg/kg	510	
Total Sodium mg/kg	930	
Total Manganese mg/kg	0.39	
Total Arsenic mg/kg	<0.020	107 (20)*
Total Boron mg/kg	<0.10	
Total Cadmium mg/kg	<0.00040	0.76
Total Chromium mg/kg	0.037	92
Total Copper mg/kg	0.17	270 (100)*
Total Lead mg/kg	0.0089	23
Total Mercury mg/kg	<0.0020	1.29 (1.0)*
Total Nickel mg/kg	0.042	33
Total Zinc mg/kg	0.33	490 (300)*
Electric Conductivity mS/m	210	

* where limits exceed those for Grade a biosolids shown in (31).

CONCLUSION

Vermicomposting of pulp and paper mill solids is an economic and environmental technology to convert organic wastes from pulp and paper mills. Mixing of primary solids with secondary solids enhances vermicomposting. It has been successful demonstrated that nitrogen rich organic wastes from local communities can be combined with pulp and paper solids for vermicomposting.

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