"Proof of concept" lysimeter study
Final report

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EXECUTIVE SUMMARY

The Rotorua District Council (RDC) has been exploring options to:
1) reduce the cost of treating leachate from the landfill
2) reduce the deposition of bio-solids into the landfill

It was found by pumping landfill leachate through a column of zeolite chips ammonia and other contaminant ions were successfully removed. If this process was implemented significant water treatment cost savings could be made. However, a use for the nutrient loaded chips would have to be found.

Previous experience has found that if these nutrient loaded zeolite chips were composted with organic matter a fertiliser (composted nutrient loaded zeolite – CNLZ) could be produced. When placed under crops or pasture CNLZ had positive effects on yield parameters. If nutrient loaded zeolite chips from the landfill leachate cleaning process were composted with biosolids then further cost saving could be made.

A proof of concept lysimeter study was undertaken where the equivalent of 0, 5, 15, 30 and 45 t/ha of a standard CNLZ (not derived from RDC materials) was placed 200 mm below the surface of a raw pumice soil and a dairy farm soil sourced from the Rotorua area. A conventional pasture mix was sown on all lysimeters.

It was found over the following 7 months that additions of up to 45 t/ha of CNLZ (540 kg/ha of nitrogen) did not increase nitrate-N leachate.

At the high CNLZ application rate, total pasture dry matter increased by 482% on the raw pumice soil and 36% on the fertilized dairy farm soil.

Cow's urine was applied and the leachate tested for nitrate-N. On the raw pumice soil it was found that nitrate-N leachate reduced by 95% for the 15, 30 and 45 t/ha application rates. On the dairy farm soil nitrate-N leachate showed variable responses with 15, 30 and 45 t/ha application rates showing a 30%, 43% and 41% reduction, respectively. Although in both cases the leachate rates were low.

At the high application rate root dry matter increased by 55% on the raw pumice soil and 74% on the dairy farm soil.

In this study it became apparent that a CNLZ application of about 15t/ha would sustain improved pasture growth for 18 months.

The subsurface addition of CNLZ to soils would provide an option for RDC to reduce wastewater treatment and deposition of biosolids costs. Moreover, the

concept of recycling nutrients "safely" in a way that benefits pastoral farms should not be ignored. Further long-term benefits would accrue from the accumulation of carbon in the soil.

Clearly, the application of CNLZ produced from RDC sources on a broader scale warrants further investigation

INTRODUCTION

Following research where zeolite chips were successfully used to remove ammonia from the Tikitere thermal water outfall it was decided to identify if a similar procedure could be used to remove nutrients from the Rotorua District Council's (RDC) landfill leachate.

In 2007, commercial scale trials identified that indeed zeolite chips could be successfully used to remove ammonium and other nutrients from RDC's landfill leachate.

A zeolite supplier (Blue Pacific Minerals) had previously identified that if nutrient loaded zeolite was composted with organic waste and then used as an "in-ground" fertiliser then significant crop yield increases were achieved.

By using zeolite chips loaded with nutrients from landfill leachate and then composting these with bio-solids and other carbon waste from the landfill a similar product could be produced.

Several years ago, Resource Management Systems Ltd researched placing composted nutrient loaded zeolite (CNLZ) about 200 mm below pasture surface using a specially adapted subsoiler. It was found that by designing a hopper and feeding system, CNLZ could be placed about 200 mm below the surface (See Page 13) Application rates as high as 45 t/ha could be successfully achieved.

It was thought by producing a CNLZ using RDC's resources and placing it at about 200 mm deep in volcanic soils, five significant environmental problems would be solved:

1) Landfill leachate treatment at the RDC Wastewater Treatment Plant may be eliminated.
2) Deposition of bio-solids at the landfill may cease.
3) Farmers using the new system may not require further fertilizer applications for a period of at least two years which would reduce nitrate-N leaching where nitrogen fertilisers were usually applied.
4) Farmers using the new system may experience increased dry matter production from pasture and treated areas may be less drought prone.
5) The new system may lead to carbon accumulation in soils which would act in a positive way to reduce nitrate-N leaching from cows' urine. Increasing

carbon accumulation in soils could be viewed as an option to improve New Zealand's national carbon balance, and reduce greenhouse gas emissions.

In 2007, RDC funded a 'proof of concept' lysimeter study that was undertaken by Resource Management Systems Ltd with technical assistance provided by SCION. The object of the study was to determine if increasing amounts of CNLZ placed 200 mm below the surface influenced points 3 to 5 in the above list.

METHODS

In January 2007, 40 lysimeters (made using PVC pipe) 450 mm high and 190 mm in diameter were placed in ground at Waharoa. A 1 m wide x 0.6 m deep trench was excavated between the two sets of 20 lysimeters and 2-liter containers were placed underneath valves that were offset 200 mm from the base of each lysimeter by 15 mm of PVC tubing. After installation was completed the trench was covered with100 mm thick polystyrene sheets to reduce temperature and light effects on the retained leachate.

Two soils from the Rotorua district were used;

1) a poor, infertile volcanic soil within the nursery on Scion campus
2) a sandy, fertile soil from a dairy farm located about 2 km the Rotorua Airport on the eastern side of Lake Rotorua that was under standard dairy farm management with fertilizers being applied

Each soil was excavated from the sites in three distinct horizons; topsoil (0 – 100 mm), underlaying transition (100 – 200 mm) zone and subsoil (200 – 400 mm). Each of the 6 individual horizons were air-dried and then screened at two mm with all stones and coarse roots being discarded.

About 10 mm of washed gravel (1 – 2 mm) was placed in the base of each lysimeter and the subsoil was added and lightly tapped with a batten in an effort to replicate the density found in the field. The transition zone soil was added and the tapping process repeated. CNLZ was added in a fashion designed to duplicate practical field application i.e. mounded on the transition zone soil rather than spread evenly over it.

Five treatments of CNLZ (4 replicates) were randomly allocated to each of the two groups of 20 lysimeters;
Treatments were: 1) 0 tonnes/ha;
2) 5 tonnes/ha;
3) 15 tonnes/ha;
4) 30 tonnes/ha;
5) 45 tonnes/ha.

The topsoil was added, tapped down and a standard ryegrass seed was sown at 30 kg/ha on 17th February 2007. Two liters of water were added to each lysimeter to assist with germination. On the 25th of March, following poor germination, lysimeters containing the pumice soil were resown with ryegrass seed in an attempt to achieve 25 plants/lysimeter.

Lysimeters 1 – 20 contained the pumice soil and lysimeters 21-40 contained the dairy farm soil.

Pasture was clipped at about grazing height on lysimeters 21 to 40 on 19th April and from all lysimeters on the 13th June, 15th October and 25th November 2007 with dry matter being recorded after samples were dried.

Leachate was collected after significant rainfall from lysimeter 21 to 40 on 15th and 27th March and from all lysimeter on 5th July, 12th August and 15th October 2007. Volumes of leachate were recorded with subsamples analysed for nitrate-N.

On 16th October 2007, 280 ml of cow's urine was added to each lysimeter. Leachate was collected on 22th November 2007. However, following very dry conditions on the 15th Feb 2008, 4 liters of water was applied to each lysimeter in 250 ml lots over a period of two days. Leachate was captured, volume was recorded and subsamples analysed for nitrate-N concentration.

Leachate nitrate-N values were multiplied by leachate volumes to give mass of nitrate-N per leaching and then totaled for each treatment on each soil type.

In February 2008, two lysimeters (Treatments 1 and 5) from each soil type were excavated and split into subsoil, transition zone and topsoil. Each soil section was carefully washed over a 2mm screen and roots from each zone were dried and dry matter recorded.

The remaining lysimeters have been left in ground and pasture will be harvested with dry matter being recorded until the effects of the CNLZ are no longer evident. This will provide an estimate of how long increases in dry matter are sustained in response to CNLZ applications. It is hoped DM increases will be sustained for a period of at least two years.

RESULTS

1) Mass of nitrate-N leached prior to addition of cows urine

Pumice soil

Addition of CNLZ (which contained 1.2% N) to the transition zone of the infertile pumice soil did not increase the mass of nitrate-N leached from the profile over a 7 month period. Increased nitrate-N values of the 0 and 5 t/ha on the 12/08/07 are attributed to earthworms entering the leachate containers and contaminating the leachate samples. If these outliers were replaced with values of similar variation to other treatments then the differences in total nitrate-N leached would be within experimental error.

Table 1. Mass of nitrate-N (g) leached from the infertile pumice soil over a 7 month period. Values are means of 4 replications.

Date	5/7/07	12/8/07	16/10/07	Total
0 t/ha	0.33	37.19	2.21	39.73
5 t/ha	1.54	11.74	1.68	14.98
15 t/ha	2.86	2.17	2.72	7.75
30 t/ha	0.43	1.95	4.35	6.73
45 t/ha	0.71	4.03	1.08	5.62

No leachate was taken from the infertile pumice soil on the 16/03/07 despite reasonable rainfall. It was found that this soil, when compared to the dairy farm soil retained much more moisture.

Dairy Farm Soil
The mass of nitrate-N leached from the sandy dairy farm soil also shows no significant trend (Table 2). It can be concluded that addition of CNLZ at rates as high as 45 t/ha (1.2% N =540 kg/ha) is quite safe in terms of nitrate-N leaching.

Table 2. Mass of nitrate-N (g) leached from the dairy farm soil over a 7 month period. Values are means of 4 replications

Date	16/03/07	5/7/07	12/8/07	16/10/07	Total
0 t/ha	54	0.48	1.27	8.21	63.94
5 t/ha	46	0.8	0.46	2.48	49.74
15 t/ha	57	0.48	0.64	1.77	59.89
30 t/ha	80	1.62	0.21	2.81	84.64
45 t/ha	72	0.74	0.31	4.47	77.52

2) Dry matter harvested from lysimeter prior to addition of cows urine: (See appendix 1)
Pumice Soil
Over the 7 month period there were significant increases in the dry matter harvested from lysimeters that had CNLZ applied. The infertile pumice soil control treatment produced 2,900 kg/ha DM whilst the 45 t/ha CNLZ treatment produced 13,922 kg/ha, an increase of 11,022 kg/ha DM; a 482% increase in DM production (Figure 1).

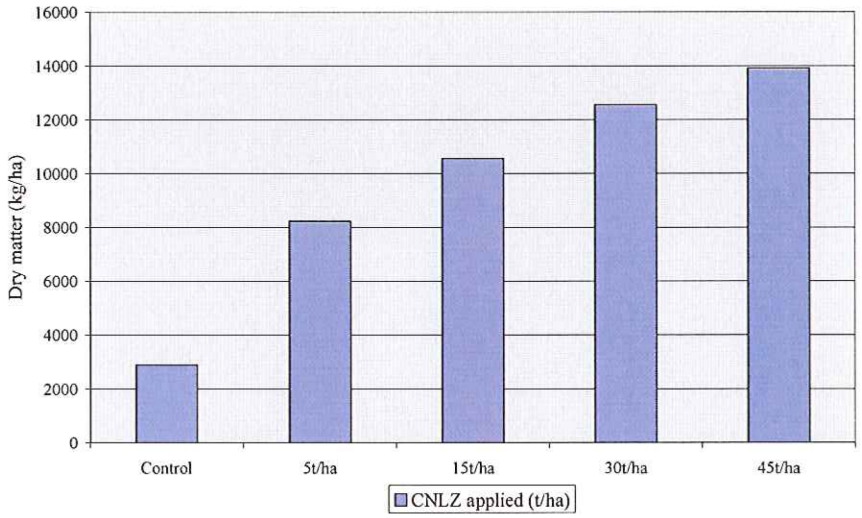

Figure 1. Dry matter production (kg/ha) from the infertile pumice soil over a 7 month period. Values are means of 4 replications

Dairy Farm Soil

The dairy farm soil had been fertilized according to normal dairy farm practices and CNLZ applications were not expected to achieve significant pasture dry matter increases. Surprisingly, application of 45 t/ha of CNLZ resulted in DM production to 14,951 kg/ha DM, an increase of nearly 4,000 kg/ha DM or 36% over the control treatment (Figure 2).

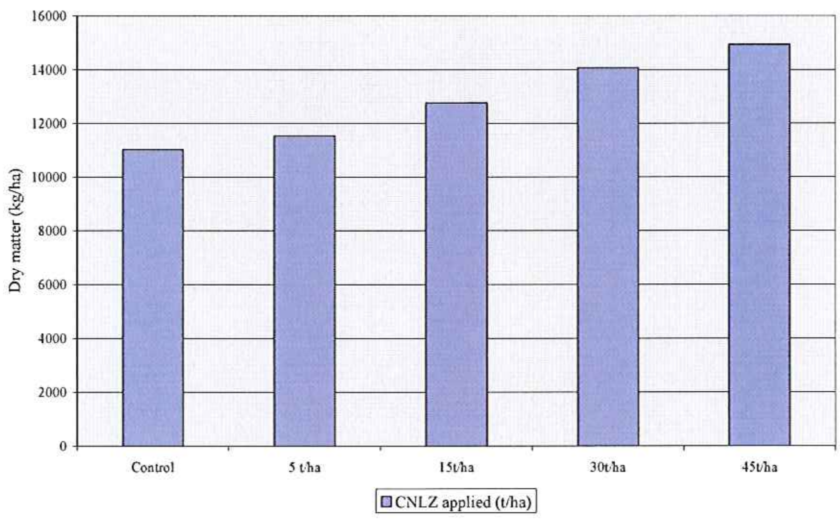

Figure 2. Dry matter production (kg/ha) from the sandy dairy farm soil over a 7 month period. Values are means of 4 replications

3) Nitrate-N leached after application of cows urine

Cow's urine (280 g) was applied to each lysimeter on 16th November 2007. R.J. Hills Laboratories determined that the urine contained 0.053 g/m^3 nitrate-N + nitrite-N and 50.2 g/m^3 of ammoniacal-N. This equated to an application rate of 0.0148g of N/lysimeter or 4.936 kg /ha of nitrogen. Large proportion of nitrogen is expected in organic form in fresh cow urine. Unfortunately, total nitrogen of the urine, which includes nitrogen in organic form, was not determined.

This result was very low for fresh cow's urine, despite rechecking their calculations (re-analysis was not done because the sample had reached storage expiry date) Hills confirmed their original result. Standard values for cows urine are the equivalent to an application of 1,000 kg/ha of nitrogen. Unfortunately, this test result has caused some delay in the development of this report and it has been concluded that the Hill's Laboratory must be incorrect.

Whilst some rainfall occurred soon after application of the urine, meaningful results weren't obtained until February 2008. At this date the pasture was starting to wilt because of extremely hot and dry conditions. It was decided to flush the lysimeters with 4 liters of water over 2 days, collect and test the leachate and terminate the experiment.

Pumice Soil

On the infertile pumice soil it can be seen that by adding CNLZ reductions in nitrite + nitrate-N leaching were achieved (Figure 3). Although the mass of nitrogen leached was very low the 5 t/ha application rate of CNLZ showed a 68% reduction and the three higher CNLZ application rates all showed a 95% or better reduction in mass of nitrate-N leached.

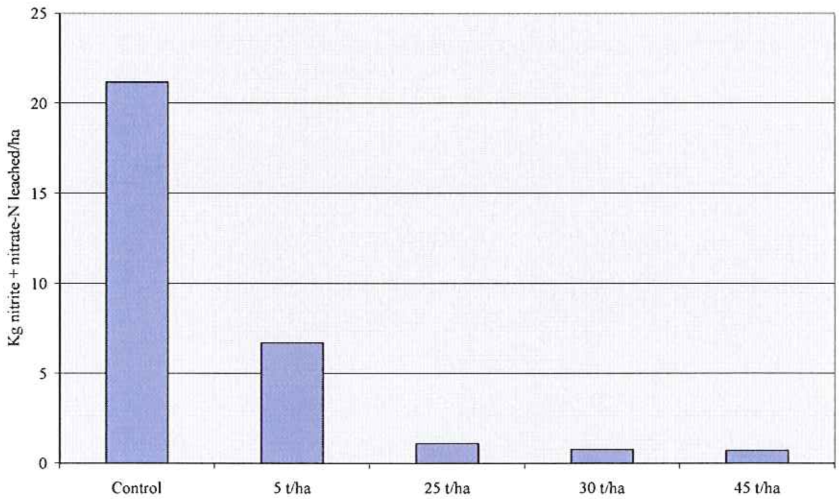

Figure 3. Total mass of nitrate-N leached (g) from an infertile pumice soil over a 3 month period. Values are means of 4 replications

Dairy farm soil
In the dairy farm soil it can be seen that by adding CNLZ some reductions in nitrate-N leaching were achieved (Figure 4). Although the mass of nitrogen leached was very low the 5 t/ha application rate of CNLZ at 15, 30 and 45t/ha showed a 30%, 43% and 41% reduction respectively.

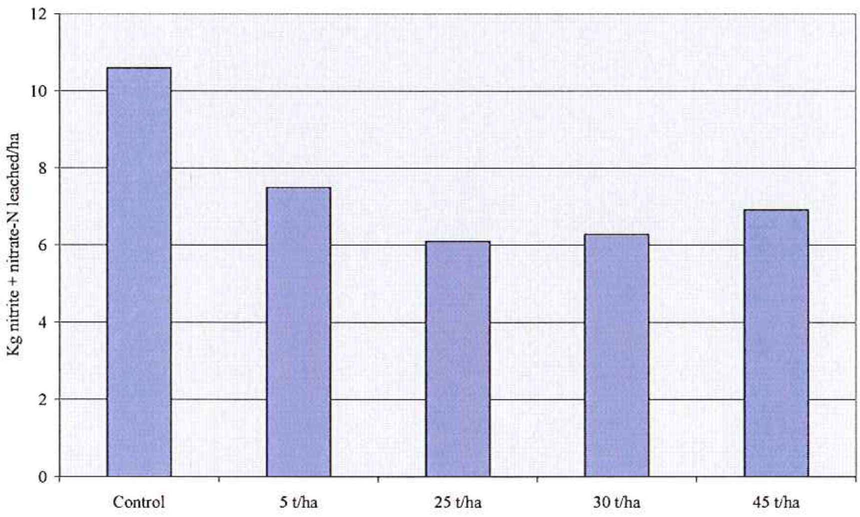

Figure 4. Mass of nitrate-N leached (g) from the dairy farm soil over a 3 month period. Values are means of 4 replications

4) Root dry matter

After the final leachate was taken the control and 45t/ha CNLZ treatment from both soil types were excavated with root mass being collected from the three zones: topsoil, transition zone and subsoil and dried. (see Appendix 2)

Pumice soil
In the infertile pumice soil it can be seen that by adding CNLZ increases in root dry matter were recorded (Figure 5). Unfortunately, because of poor germination in the control, natural germination of yarrow and couch followed and has therefore increased the root dry matter. However the high treatment rate of 45 t/ha shows a 43% increase in root dry matter in the topsoil. The transition zone showed an increase in the control and this again was due to the natural infestation of yarrow and couch. Despite the weed infestation effect the higher CNLZ rate showed 191% increase in total root dry matter over the control.

Overall, total root dry matter from the three zones went from 14,361 kg/ha in the control to 22,246 kg/ha in the 45 t/ha treatment rate; an increase of 7,885 kg/ha or 55%

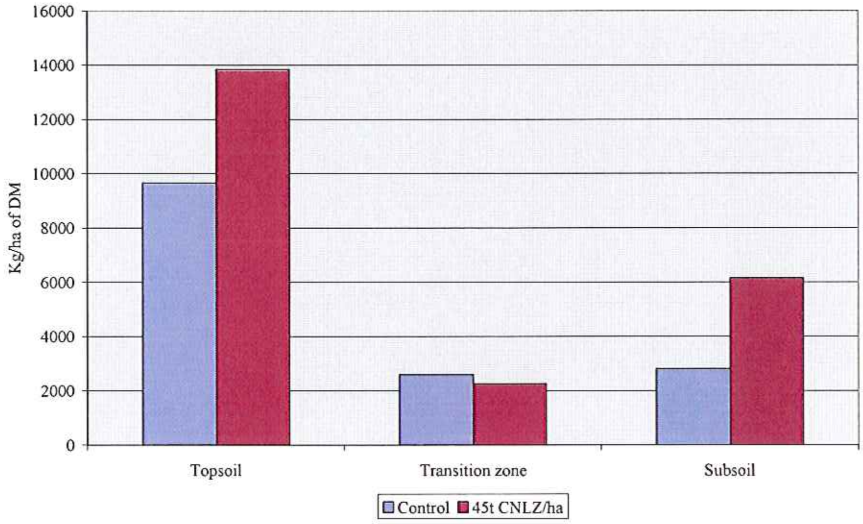

Figure 5. Excavated dry root mass of control and 45t/ha treatments from the pumice soil.

Dairy Farm Soil

On the dairy farm soil it can be seen that by adding CNLZ increases in root dry matter were recorded (Figure 6). Root dry matter in the topsoil of the high treatment rate of 45/tha showed a 77% increase over the control. Similarly, the higher CNLZ application rate showed an increase of 59% in the transition zone and 62% in the subsoil.

Overall, total root dry matter from the three zones went from 17,283 kg/ha in the control to 30,096 kg/ha in the 45 t/ha treatment rate; an increase of 12,813 kg/ha or 74%.

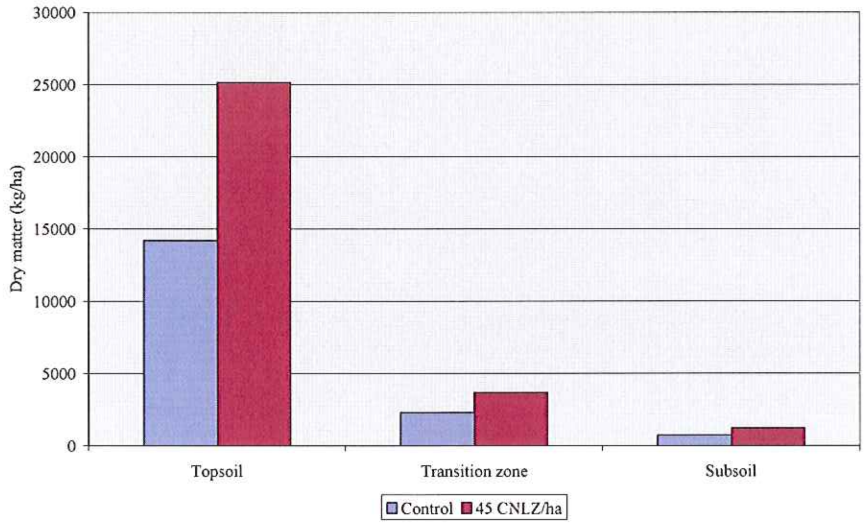

Figure 6. Excavated dry root mass of control and 45t/ha treatments from the dairy farm soil.

DISCUSSION

It should be noted that this study was conducted for a period of 7 months. Much of the data was collected during a severe drought and dry matter production data (both above and below ground) may have been detrimentally influenced.

Whilst both low (5t/ha) and high (45t/ha) CNLZ application rates have been used in the study discussions will focus on the application of 15 t/ha which seems to be a manageable application rate. (It would be good to provide a bit more details about the rationale.)

The use of the adapted sub-soiler on established pastures may have benefit in breaking compaction layers and enhancing root depth. In this study soil was packed down in an attempt to duplicate natural soil compaction. It is unlikely that this was achieved therefore it must be concluded that the dry matter (both above and below the soil) results obtained maybe be some what higher than may be achieved in a normal established pasture situation.

Application of 15 t/ha CNLZ to a poor pumice soil did not increase nitrate leachate, pasture dry matter production was 10,566 kg/ha (an increase of 264% over the control). After application of cow's urine leaching decreased 233% although overall the leachate values were low.

Application of 15 t/ha CNLZ to well a fertilised dairy soil did not increase nitrate leachate, pasture dry matter production was 12,774 kg/ha (an increase of 16% over the control). After application of cow's urine leaching decreased 48% although overall the leachate values were low.

It is difficult to explain the apparent discrepancy in the Hills Laboratory test result for the nitrogen content of the cow's urine. Test analysis shows that after application of the urine (application rate of nearly 5 kg/ha of N) leaching values showed over 20 and 10 kg/ha of nitrate + nitrate –N. These leaching values are higher than the urine test results and clearly question the validity of the Hills Labs test results.

Substantial increases in root dry matter were recorded. Placement of CNLZ below the surface may provide an option to increase the carbon content in NZ soils. On the pumice soil, total root dry matter increased from 14,361 kg/ha in the control to 22,246 kg/ha in the 45 t/ha treatment rate. An increase of 7,885 kg/ha or 55% was recorded. On the relatively fertile dairy farm soil a lessor response was expected. However, total root dry matter from went from 17,283 kg/ha in the control to 30,096 kg/ha in the 45 t/ha treatment rate; an increase of 12,813 kg/ha or 74%.

CONCLUSIONS

As a "proof of concept study" it has been demonstrated that the trapping of ammonium and other contaminant ions on zeolite from the RDC landfill leachate and composting this with bio-solids with the final product being used as an "in-ground" fertiliser is worthy of further consideration.

Modified James Engineering 5 tine subsoiler showing attached hopper and feeding tubes behind each tine

Appendix 1

Pasture growth on the pumice soil prior to first harvest

1)Control

2) 5 t CNLZ/ha

3) 15 tonne/ha of CNLZ

4) 30 tonne/ha of CNLZ

5) 45tonne/ha CNLZ

Appendix 2
Root growth in topsoil, transition zone and subsoil zones of pumice and dairy farm soil
1) Control

3) 45tonne/ha of CNLZ – showing mass of roots at CNLZ deposition zone and well established roots in base drainage grave

3) Control Dairy farm soil – virtually no root penetration into sandy subsoil

4) 45tonne/ha CNLZ – good penetration of roots down to drainage gravel