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THE RESIDUAL EFFECTS OF BIOSOLIDS

Part 1: Soil sampling

Report for the

Water Corporation

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Introduction

The long-term environmental impacts of land application of dewatered biosolids (DWB) to broadacre agriculture in WA have yet to be established. The development of guidelines for biosolids use has been limited by the lack of social experience with biosolids in Australia and limited local research data (Water Corporation 1997).

Current application rates for the use of biosolids in Western Australian (WA) agriculture have been based on data from elsewhere. These include the 1995 Guidelines for Sewage Systems – Biosolids Management, by the Water Technology Committee of the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), biosolids research data from the Eastern States and the 1996 Guidelines for the Use and Disposal of Biosolids Products produced by the New South Wales Environmental Protection Authority (Rawlinson 1997).

Biosolids application rates are determined by calculating the crop nitrogen requirement (the nitrogen limited biosolids application rate – NLBAR) and the maximum allowable soil contaminant concentration (contaminant limited biosolids application rate – CLBAR) for a particular site. More recently, crop phosphorus requirements have also been taken into consideration (the phosphorus limited biosolids application rate - PLBAR) when determining biosolids application rates. However, soil-monitoring needs to be conducted in WA to verify if the application rates calculated and applied are suitable for local conditions. For example, the mineralisation rates for nitrogen and phosphorus need verifying to ensure that crops are obtaining sufficient amounts of nutrients for optimum plant growth, whilst levels of contamination are kept to a minimum.

This report examines soil data collected in the second year after the application of DWB (rates of 17 dry t/ha and 24 dry t/ha) compared with a standard district fertiliser practice and an unfertilised bush site, on farming land near Perth. The main aim of the study was to investigate the residual concentrations of nutrients and other elements remaining in the soil 10 months after biosolids application to a wheat crop. These preliminary data will enable more informed decisions to be made as to biosolids application in WA using local soil and environmental conditions.

Methods and Materials

This section outlines the methodology used to establish the 1997 biosolids trial site and details of the subsequent soil sampling conducted early in 1998.

Source of Biosolids

Biosolids used in this trial were processed at the Beenyup Waste Water Treatment Plant (WWTP). Wastewater sludges at Beenyup WWTP undergo primary and secondary treatment, anaerobic digestion and are dewatered using a filter belt press to produce biosolids which range in solid content from 18-20% (dry solids). The biosolids were classified as 'Restricted Use 2B', consistent with NSW EPA (1996) grading in regards to the contaminant and stabilisation properties (Water Corporation 1997).

The composition and typical properties of DWB from Beenyup WWTP as used for the wheat application trial are given in Table 1. Also included for comparison are ranges for the major constituents of hopper samples collected from this WWTP between 7/4/97-22/4/97. Generally all values sampled were within the ranges expected, but highlight the variability experienced between sampling dates.

Levels of organic pesticides were below 0.5 mg/kg and were not considered further in this study.

Trial site

The biosolids trial site at the Muresk Institute of Agriculture is located in the Avon Valley, one of the closest broadacre farming areas to Perth. The Avon Valley, 100km east of Perth is a mixed farming area with a large, reliable demand for commercial fertiliser. Approximately 50% of farms are cropped annually, with wheat, lupins, barley, oats and field peas being the major crops grown. Annual pastures are usually subterranean clover (*Trifolium subterranean*) or medic (*Medicago* spp.) based with sheep being the dominant grazing animal. The annual rainfall is 450 mm per annum, with 70 % of rainfall falling over a five-month growing period (May to September).

The key soil type on which the trial was conducted was a York soil landscape unit, being a Rocky red brown loamy sand/ sandy loam soil type which comprises a large percent of the Avon Valley (Lantzke 1993). The native vegetation before clearing for agriculture consisted predominantly of York gum (*Eucalyptus loxophleba*) and Jam (*Acacia acuminata*) woodland. This site was acceptable within the National Guidelines in terms of environmental standards. The soil was of moderate permeability and depth, had less than a 15 % slope and was over 100m from any watercourse. The site was not located within ground and surface catchments used for drinking water. Existing contour grade banks were considered adequate to help prevent any off site movement.

Table 1 Chemical analysis of dewatered biosolids (DWB) used in the study

Constituent	Unit	Value
Total dry solids (DS)	%	(16.1-16.8)
pH		(7.9)
Nitrogen (Total Kjeldahl N)	%	**4.4** (1.3-3.8)
Phosphorus (Total P)	%	**1.9** (2.2-2.5)
Arsenic (As)	mg/kg	**2.9** (2.4-4.3)
Cadmium (Cd)	mg/kg	**2.7** (1.9-2.3)
Calcium (Ca)	%	*2.3-9.4*
Chromium (Cr)	mg/kg	**40** (68-83)
Copper (Cu)	mg/kg	**1,080** (1,300-1,500)
Lead (Pb)	mg/kg	**70** (66-89)
Magnesium (Mg)	%	*0.2-1.0*
Manganese (Mn)	mg/kg	*100-1,500*
Mercury (Hg)	mg/kg	**2.8** (1.7-11)
Molybdenum (Mo)	mg/kg	**9.2** (11-13)
Nickel (Ni)	mg/kg	**22** (25-32)
Potassium (K)	%	*0.1-0.24*
Selenium (Se)	mg/kg	**2.2** (4.3-9.0)
Silver (Ag)	mg/kg	*6-240*
Sodium (Na)	%	*0.1-0.24*
Sulphur (Total)	%	(not given-1.2)
Zinc (Zn)	mg/kg	**730** (650-780)

All constituents expressed as a dry weight basis
Figures in bold sourced from the 1997 review of the site by L.V. Rawlinson and Associates as used by Priestley in 1997.
Figures (in brackets) are ranges for the major constituents of Beenyup WWTP hopper samples collected between 7/4/97-22/4/97.
Figures in *italics* sourced from Water Corporation (1997) data.

The Muresk trial site was sampled in January 1997 by L.V. Rawlinson & Associates to assess the potential effects of applying biosolids and to determine the background concentrations of heavy metals and pesticides. Soil samples were collected over a range of depths where possible. Surface samples (0-15 cm) were analysed for electrical conductivity (EC) (1:5), total Kjeldahl nitrogen (TKN), total phosphorus, exchangeable phosphate (Bray 1), organic pesticides, pH (1:5) $CaCl_2$ and heavy metal concentrations (see Appendix). Determination of the CLBAR requires that soil from the application site be analysed for existing levels of contaminants (Water Corporation 1997).

Agronomic Trial 1997

The total trial site covered an area of 12 hectares (ha) and was replicated four times using three treatments, each approximately one ha in size. Two rates of biosolids (17 dry t/ha and 24 dry t/ha) were applied, which were compared with a control (standard district fertiliser practice of Urea @ 80 kg/ha plus Agstar @ 75 kg/ha. Further management details can be found in the Appendix. The higher of the biosolids rates was applied to determine any agronomic yield improvements.

The germination, growth and yield of wheat (*Triticum aestivum*) was monitored by Priestley throughout the 1997 season. There were no significant variations in germination rates between the various treatments with crop development being very similar. Biosolids treatments grew more rapidly until August, then differences became minimal. The number of seeds produced in an ear and the number of seeds produced by an individual plant were significantly ($P<0.05$) greater in the biosolids treatments compared with the control and also between the two rates of biosolids. Grain protein levels were slightly higher where biosolids had been applied. However, at harvest there were no differences in the final yields of wheat between any treatments (trial average=1.86 t/ha), suggesting that the rates of biosolids applied were suitable to obtain comparable agronomic yields. However, it was thought that the dry finish to the season could have masked the potential yield of this crop (Priestley 1998).

Table 2 gives an indication of the total loadings of elements applied to the Muresk trial site using the values in Table 1 as a guide. It should be noted that subsequent hopper cake samples (April 1997) were lower in total N and higher in total P than the data used and highlights the variability of biosolids with time, from a given WWTP.

Composite soil samples to a depth of 0-15 cm (15 cores using a 100mm auger) were collected at tillering and flowering and analysed by CSBP for phosphorus, nitrate, ammonium, potassium, sulfur, iron, organic carbon, pH and EC. The soil nutrient analysis showed higher levels ($P<0.05$) in the amounts of nitrate, ammonium, phosphorus and sulfur at various sampling times in the biosolids treatments compared with the standard fertiliser control (Priestley 1998). However, as there were no difference in wheat yield between the treatments, other environmental factors may have been limiting final yields. The extra N and P supplied at the higher biosolids rate did not result in an agronomic yield increase compared to the control. As highlighted elsewhere (Osborne 1995), the fertiliser value of biosolids are difficult to determine in short-term field studies where the effect of climate impact significantly.

Table 2 Loading rates of nutrients and other elements supplied for each treatment (kg/ha)

Nutrients & Elements	Concentration in DWB (Dry Solids) ***	DWB @ 17dry t/ha	DWB @ 24dry t/ha	Control (Agstar & Urea)****
		kg/ha	kg/ha	kg/ha
N (TKN)	4.4%	748	1056	
N Available*	6800 mg/kg	115	163	48
P Total	1.9%	323	456	
PAvailable**	3990 mg/kg	68	96	10
K	*0.2* %	34	48	
As	2.9 mg/kg	0.05	0.07	
Ca	*5.8* %	986	1,392	
Cd	2.7 mg/kg	0.05	0.06	
Cr	40 mg/kg	0.68	0.96	
Cu	1,080 mg/kg	18.4	25.9	
Hg	2.8 mg/kg	0.05	0.07	
Mg	*0.6* %	102	144	
Mo	9.2 mg/kg	0.16	0.22	
Na	*0.2* %	34	48	
Ni	22 mg/kg	0.38	0.53	
Pb	70 mg/kg	1.19	1.68	
S	1.0 %	170	240	9
Se	2.2 mg/kg	0.04	0.05	
Zn	730 mg/kg	12.4	17.5	0.03

*N available calculated by Rawlinson (1997) to be 6,800 mg/kg N given: 6 mg/kg nitrate, 5 mg/kg nitrite, 3,700 mg/kg ammonium and 40,400 mg/kg organic N, assuming in year one that the nitrogen mineralisation rate is 15% & volatilisation of ammonium is 20%.

**P available based on an estimated 20% mineralisation rate of total P in year one.

*** Determined from Table 1.

**** Agstar values calculated using CSBP data (1999 Fertiliser Price list) 15.4% N, 13% P, 11.5% S and 0.04% Zn. Urea calculated using 46% N.

Soil Sampling 1998

Composite soil samples to a depth of 0-15 cm (12 cores using a 150 mm auger) were collected prior to the break of the season in March, 1998. Samples were taken for the three treatments and four replicates from the 1997 trial as previously.

In addition, a bush site 200m west of the trial site was also sampled. The native vegetation on this site was predominantly Jam woodland with an understorey consisting mostly of annual-grasses. This site was included to give an estimate as to soil nutrient levels prior to agricultural activities.

Soil nutrient levels were analysed through CSBP and heavy metal concentrations by the Australian Environmental Laboratories (AEL). Only one replicate for the bush site was included in the AEL soil analysis, so these data can only be used as a guide. Samples were also taken from a depth of 15-30 cm and stored.

Livestock (sheep) had grazed the wheat stubble throughout the hot/dry summer period.

Data was analysed using GENSTAT statistical software for which details can be found in the Appendix.

Results and Discussion

Monitoring programs are necessary to avoid degradation of soil and water resources as a result of biosolids application. Monitoring needs to be site specific and needs to target properties that may cause concern (Hardie and Hird 1998). A summary of the 1998 soil parameters in the 0-15 cm soil fraction for all treatments is given in Table 3 and should identify major changes in soil nutrients with time as a result of biosolids application. Where available, 1997 soil data collected prior to the trial being conducted are also included. Full details for all soil analysis are given in the Appendix.

Biosolids application compared with standard fertiliser practice

Major plant nutrients; N, P & K

There were no significant differences in soil concentrations of the three major plant nutrients (N, P or K) where biosolids had been applied 10 months previously compared with the standard fertiliser practice.

Table 3 Summary of 1998 soil data for all treatment areas

(all measurements in mg/kg unless specified)

Nutrient	Treatment				
	DWB@ 17 dry t/ha	DWB@ 24 dry t/ha	Control	Bush	1997 (prior to trial)
Aluminium (exch)	<5	<5	<5	<5	
Ammonium	8	12	6	6	
Arsenic	<0.5	<0.5	<0.5*	0.5	<0.5
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium (exch)	800	765	720	1600	700
Chromium	11	8	16	25	9
EC (dS/m)	0.07	0.08	0.05	0.06	0.06
EC (1:5) (μS/cm)	95	100	65	70	
Copper	8	8	6*	19	6
Iron	604	402	615	454	
Lead	<5	<6*	<5*	11	5
Magnesium(exch)	44	43	36	62	
Mercury	0.05	0.05	0.05	0.05	<0.2
Molybdenum	<5	<5	<5	<5	<0.5
Nickel	<5	<5	<6*	14	3
TKN (Total Kjeldahl Nitrogen)	848	942	1022	1300	700
Nitrate	17	15	8	6	
Organic Carbon %	1.3	1.3	1.4	2.0	
pH CaCl2	5.0	5.1	4.8	5.6	4.8
pH 1.5 Water (av)	5.6	5.8	5.6	6.1	
Phosphorus ($NaHCO_3$)	43	48	36	7	
Phosphorus (Total)	229	260	278	170	120
Phosphorus (Bray)	9	10	8	<5	20
Potassium	136	158	210	152	
Potassium(exch)	74	81	116	91	
Selenium	<1	<1	1	<1	<0.5
Sodium(exch)	33	33	36	32	
Sulphur	13	13	6	4	
Zinc	12	8	11	14	6

*Metals may have been below the level of chemical detection such that the average may be less than stated due to non exact values eg. < X

(exch) = exchangeable ions (mg/kg)

Figures in *italics* analysed by AEL, all others by CSBP

Higher concentrations of nitrogen (TKN) would have been expected in the biosolids treatment in the 1998 sampling compared with the control given the relative total N loadings and requires further investigation (Table 3). Levels of nitrate and ammonium appeared higher where biosolids had been applied, but were not significant ($P<0.05$)*. The NLBAR currently used in WA (which assumes a N mineralisation rate of 20% and ammonium volatilisation of 50% in year one) warrants further investigation to identify whether agronomic nitrogen needs are being met, or other factors are limiting plant growth. The availability of N from soil and biosolids have been demonstrated to vary significantly from year to year (Osborne 1995) and this needs to be taken into account. Trials from NSW Agriculture have suggested that higher rates of biosolids could be used to maximise crop response without contaminating the environment (Osborne, Parkin, Michalk and Grieve 1995; Rawlinson 1997). It has been suggested that rates of DWB higher than 14.4 dry t/ha @ 2.4 % TKN were needed to obtain a yield response in one particular study (Bamforth 1996). *(Nitrate levels were higher in the biosolids at $P<0.07$).

Although total P loadings were higher in the biosolids treatments compared with the control following application (Table 2), this was not evident 10 months later from the soil analysis (Table 3), with the control appearing higher. Compared with the 1997 soil analysis, the total P had been enriched by all treatments. Not all P applied from biosolids application is available immediately for plant growth, with mineralisation rates of around 20 % currently estimated for year one. The amount of plant available P (Bray P) was approximately 50% less than that measured prior to the trial, with little difference between treatments. Plant available P measured by $NaHCO_3$ gave much higher P levels than by the Bray P test, highlighting a variation in the test used to estimate plant available P.

The fate and effectiveness of P needs further investigation, as higher concentrations of total P in the biosolids treatments would have been expected. The mineralisation rate for P needs validating to ensure P is not limiting plant growth. The concentrations of residual P and available P needs examining further given the low P status and high P sorption capacity (phosphorus retention index-PRI) of many WA soils. For example, the effect of iron in the soil on P sorption may need to be examined further as there appeared to be a negative correlation between levels of available P ($NaHCO_3$) and Fe from the soil samples (Table 3).

Levels of K appeared much lower in the biosolids treatments compared with the control. This was consistent also for two sampling times throughout 1997 (Priestley 1998). A large variation in K was observed across the trial site. For example, in the control sites between replicates, ranges of between 100 mg/kg-325 mg/kg total K were analysed. This variability needs to be reduced across the site to examine the effects of K more accurately. The amount of K applied in biosolids @ 17 dry t/ha (Table 2) is similar to that recommended by CSBP (1988) for annual maintenance levels of 10-30 kg/ha of K.

Given that there were no significance differences in wheat yields in 1997, a similar rate of nutrient removal would have been expected across all treatments. As a guide, the amounts of nutrients removed in one tonne of wheat grain are given in Table 4. The average wheat yield on the Muresk site was 1.86 t/ha, so removal rates need to be multiplied by this factor. (In calculating the NLBAR, usually 100 kg/ha of N are assumed to be required for wheat annually, but this amount can vary depending on the type of crop). Grain harvest would have removed N:P:K in the approximate proportions of 37:6:11 kg/ha. Both biosolids treatments should have supplied an excess of these nutrients. Levels of N and P are higher in the 1998 soil test compared to 1997 as expected. However, it is not clear why there are little differences in these nutrients between the biosolids treatments as compared with the control, which supplied much lower rates of these essential nutrients (and did not include any K).

Table 4 Nutrients removed in 1 tonne wheat grain (average WA values)

Nutrient	Amount (kg)
N	18-24
P	2.5-3.5
K	5-7
Ca	0.2-0.4
Mg	1.0-1.5
S	2-3
Mn	0.02-0.04
Cu	0.002-0.004
Zn	0.020-0.030
Mo	0.0001-0.0002

Source: (CSBP 1988)

The effects of sheep grazing the wheat stubble over the dry summer period on nutrient recycling and distribution is not known.

Interactions between these essential nutrients on plant growth would be expected to be minimal throughout 1998. The results of a study to investigate pasture establishment during 1998 are being analysed.

Other plant nutrients

The concentrations of sulfur (S) were significantly higher ($P<0.05$) at both rates of biosolids application compared to the control. This would be expected given the high proportion of total S in biosolids compared to the control fertiliser. The control treatment (Agstar @11.5% S) should have provided adequate S for crop growth and therefore S should not have been limiting plant growth. The residual effect of S on plant growth and the soil may warrant investigation.

Ca and Mg are usually found in adequate amounts in most WA soils. There were no differences in the levels of Ca and Mg for any of the treatments even though biosolids application would have resulted in high loadings of these nutrients.

Trace elements and heavy metals

There were no significant differences in the concentrations of any of the trace elements, Zn, Cu, Mo, Se and Fe between the control and biosolids treatments. Soil sampling was unable to detect any significant soil changes in these elements at the biosolids loadings applied, with Zn concentrations appearing to increase in all treatments. Minimal changes in the soil were evident suggesting that these nutrients did not appear to pose a problem to the environment at the biosolids rates used in this trial.

The heavy metals Pb, Ni, As & Cd were at low limits of chemical detection, with differences between the biosolids and control site insignificant or negligible. Concentrations of Cr appeared to be higher in the control compared with the biosolids treatments. Levels of heavy metals at the highest rate of biosolids application were well below the NSW EPA (1995) guidelines for heavy metals (Table 5). Research by New South Wales (NSW) Agriculture has shown that application rates for most biosolids on a range of soil types are limited primarily by the agronomic nitrogen requirements of the crop rather than the contamination level in the biosolids. Using historical data from Perth's Beenyup WWTP, Rawlinson (1997) calculated for this site, the NLBAR for wheat would be 12 dry t/ha, whereas the CLBAR would be much higher at 67 dry t/ha.

Heavier rates of biosolids (or repeat applications) should be able to be applied to agriculture in WA without causing heavy metal contamination (given that the existing soil contaminant level is not high). Data presented in Table 5 would support this. However, it is widely recommended that at high rates of application, levels of metals such as Cd, Zn and Cu in grain and in pasture may need to be monitored. (Cadmium is also present in small amounts in superphosphate and therefore some soils with a previous high usage of superphosphate may have higher than average Cd levels).

Plant uptake of heavy metals could be examined further where higher rates or repeat applications are used. Whatmuff (1995) has shown in NSW that where soil pH was < 5.8 $CaCl_2$ and soil Cd was >1 mg/kg, the MPC (Maximum Permissible Concentrations) of Cd may be exceeded in plant tissue. Metal uptake was shown to be negatively correlated with soil pH, which is particularly relevant in WA where many soils are acidic. The concentration of heavy metals in biosolids from the Beenyup WWTP are low compared with elsewhere due to low industry input and this needs to be taken into consideration when comparing with other biosolids amended sites.

Table 5 NSW EPA (1995) maximum allowable soil contaminant and total metal concentrations detected following biosolids application @ 24 dry t/ha.

Metal	Soil Quality Guidelines (μg/g)	Biosolids @ 24 dry t/ha (μg/g)
As	20	<0.5
Cd	1	<0.5
Cr	100	8
Cu	100	8
Hg	1	0.05
Ni	60	<5
Pb	150	<6
Se	5	1
Zn	200	8

Electrical conductivity and pH

Statistical interpretation for soil pH and electrical conductivity (EC) were inconclusive for the analysis conducted, although biosolids applied at 24 dry t/ha may have increased the soil pH and EC. Biosolids applications are restricted in saline areas > 2 dS/m (measured by exchangeable EC) as excess salts may further restrict plant growth (Hardie *et al.* 1998). The EC of the Muresk site at 0.06 dS/m was not a limiting factor influencing application rates. Sites with a soil pH ($CaCl_2$) <5.5 are generally regarded as limiting for biosolids application due to soil acidity problems. Many soils in WA experience problems with soil acidity and need lime amendment. Lime amended biosolids could be investigated on these soils.

Bush site

Of interest were the concentrations of nutrients on land that had not been subjected to cropping, cultivation and general farming practice. The bush site contained higher levels of the elements Ca, Cr, Cu, Pb, Mg, Ni, and Zn compared with the agricultural sites. In particular, the concentrations of Ca and Cu were significantly higher ($P<0.05$) in the bush site. As would be expected the soil pH (1.5 water) had decreased slightly as a result of farming practice. The levels of P were significantly higher where biosolids had been applied compared with the bush site, but the % of organic carbon was less. It appears that farming practices may have removed significant quantities of Ca and Cu from the soil over time. These data also highlights the low levels of P in virgin soils prior to repeat applications of fertilisers containing P.

Conclusions

Residual concentrations of nutrients and other elements remaining in the soil 10 months after the initial biosolids application were small and did not appear to be a risk to the environment at this site using biosolids rates up to 24 dry t/ha. Plant growth in subsequent years after biosolids application needs to be determined to assess the benefit of residual concentrations of nutrients. The large variability in soil parameters across this site needs to be eliminated to obtain specific data on more subtle soil changes.

Further investigation as to the biosolids application rate based on the NLBAR and PLBAR could be conducted to determine N and P loading levels required to obtain agronomic yield responses, whilst preventing environmental problems due to nutrients available in excess of plant growth. Levels of plant available P ($NaHCO_3$) and available N (nitrate and ammonium) in particular appeared higher in the biosolids treatments, but these differences were not significant and may have been masked by the large site variability.

Biosolids increased the amounts of sulphur in the soil. The effects of high rates of S in the soil on plant growth and other nutrients may need to be examined further. Factors limiting plant growth following biosolids application needs to be determined to identify other plant nutrients and soil amendments that may be required for increased productivity. Soil pH may need to be examined as to its effect on nutrient availability and managed appropriately.

Heavy metal contamination was not shown to be a problem on this site. Much higher rates of biosolids would need to be applied before the CLBAR was reached. The existing guidelines concerning contaminant loadings appear to be adequate in preventing excessive heavy metal contamination. Monitoring should be site specific and target soil properties that may be causing any concern.

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Appendix

Appendix 1 Additional management details relating to the 1997 Trial

Date	Activity	Comments
26 April	Pre-emergent weed control	Sprayseed @ 1.5 L/ha
16 May	Pre-emergent weed control	Roundup @ 0.85 L/ha
18-23 May	Biosolids applied prior to the break of the season using a rear-discharge manure spreader	Sourced from a bunded, impervious stockpile adjacent to the site.
18-23 May	Plots cultivated within 36 hours using a scarifier and trailing rotary harrows	Control plots also cultivated
26 May	Agstar applied to the control plots	@ 75kg/ha
26 May	Wheat (*Triticum aestivum* var. Aroona) direct drilled	@ 75 kg/ha using a 7.46m Combine
16 June	Urea applied to the control plots	@ 80 kg/ha
7-15 July	Post emergent weed control:	Achieve @ 380 ml/ha, Bromoxynil MCPA @ 1.1 L/ha & Eclipse @ 5 gm/ha
2 Dec	Wheat crop harvested using a plot harvester with a comb of 1.8 m	Five cuts of 25 m in length were used to calculate final wheat yields from each replicate.
	Previous paddock history	1996: wheat (Stiletto) yielding 1.43t/ha 1991-1995:subterranean clover/grass pasture.

Appendix 2 Laboratory analysis for 1998 soil samples

Complete Summary table of soil test results for Biosolids treatments
March 1998

Key : c = CSBP analysis, h = Heavy metal analysis

units measured		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	ds/m	mS/cm	mg/kg	mg/kg
Sections	**Treatment**	Aluminium h	Ammonium c	Arsenic h	Cadmium h	Calcium h	Chromium h	Conductivity c	Electrical Conductivity h	Copper h	Iron c
1	**17t/ha**	<5	11	<0.5	<0.5	900	12	0.104	140	9	1096
			10					0.101			1136
	24t/ha	<5	9	<0.5	<0.5	930	9	0.097	140	8	462
			12					0.105			428
	Control	<5	5	0.8	<0.5	680	13	0.054	70	5	863
			8					0.054			943
2	**17t/ha**	<5	5	<0.5	<0.5	670	10	0.052	60	6	467
			6					0.044			439
	24t/ha	<5	9	<0.5	<0.5	650	7	0.06	80	7	370
			7					0.053			390
	Control	<5	8	0.5	<0.5	740	8	0.07	70	<5	516
			7					0.046			490
3	**17t/ha**	<5	10	<0.5	<0.5	860	7	0.08	100	8	348
			10					0.078			376
	24t/ha	<5	20	<0.5	<0.5	660	9	0.106	100	8	326
			17					0.073			450
	Control	<5	5	<0.5	<0.5	740	8	0.037	50	5	498
			6					0.046			438
4	**17t/ha**	<5	7	<0.5	<0.5	770	15	0.06	80	9	478
			6					0.064			489
	24t/ha	<5	10	<0.5	<0.5	820	9	0.058	80	9	308
			10					0.066			378
	Control	<5	5	<0.5	<0.5	720	35	0.053	70	11	580
			5					0.054			591
5	**Bush**	<5	8	0.5	<0.5	1600	25	0.0537	70	19	420
			4					0.0562			487

units measured		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
Sections	**Treatment**	Lead h	Magnesium h	Mercury h	Molybdenum h	Nickel h	T. Kjeldahl Nitrogen h	Nitrate c	Organic Carbon % c	pH (CaCl2) c	pH (1.5 Water) c
1	**17t/ha**	<5	77	<0.05	<5	<5	1100	23	1.34	5.18	5.71
								26	1.29	5.18	5.73
	24t/ha	<5	39	<0.05	<5	<5	1100	22	1.39	5.18	5.75
								22	1.28	5.28	5.87
	Control	<5	42	<0.05	<5	<5	990	8	1.23	4.81	5.59
								8	1.17	4.69	5.59
2	**17t/ha**	<5	21	<0.05	<5	<5	990	9	1.11	4.71	5.66
								7	1.16	4.71	5.51
	24t/ha	<5	38	<0.05	<5	<5	880	11	1.01	5.1	5.76
								7	1.91	4.88	5.55
	Control	<5	22	<0.05	<5	<5	1100	8	1.59	4.8	5.63
								8	1.4	4.91	5.53
3	**17t/ha**	<5	37	<0.05	<5	<5	300	24	1.28	5.11	5.75
								22	1.37	5.09	5.76
	24t/ha	5	54	<0.05	<5	<5	790	20	1.13	5.4	5.99
								11	0.97	5.04	5.72
	Control	5	8	<0.05	<5	<5	1000	9	1.46	4.89	5.63
								10	1.3	4.64	5.43
4	**17t/ha**	<5	42	<0.05	<5	<5	1000	12	1.42	5.4	5.51
								10	1.46	4.82	5.49
	24t/ha	8	42	<0.05	<5	<5	1000	11	1.2	4.81	5.53
								13	1.27	5.01	5.73
	Control	5	73	<0.05	<5	7	1000	7	1.41	4.75	5.68
								7	1.35	4.78	5.68
5	**Bush**	11	62	<0.05	<5	14	1300	5	2.01	5.98	6.56
								7	1.91	5.23	5.93

units measured			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Sections	**Treatment**	pH (1.5 Water) h	Phosphorus c	Total Phosphorus h	Bray Phosphorus h	Potassium c	Potassium h	Selenium h	Sodium h	Sulphur c	Zinc h
1	**17t/ha**	5.8	62	340	11	134	76	<1	36	21.2	12
			63			135				17.8	
	24t/ha	5.9	59	320	11	219	130	<1	32	12.9	8
			58			267				14.2	
	Control	5.6	40	250	8	200	120	<1	42	5.2	8
			40			189				5.9	
2	**17t/ha**	5.4	28	230	6	138	75	<1	32	10.9	9
			29			116				8.1	
	24t/ha	5.6	43	250	10	115	58	<1	35	14.3	7
			39			118				4.5	
	Control	5.5	40	260	10	240	110	<1	32	8.4	12
			37			178				7.6	
3	**17t/ha**	5.7	44	65	11	100	45	<1	35	14.4	18
			44			106				15	
	24t/ha	5.7	70	230	11	177	60	<1	34	18.6	6
			43			115				16.4	
	Control	5.4	27	280	6	133	54	3	32	4.8	11
			31			100				5.2	
4	**17t/ha**	5.5	33	280	8	164	100	<1	30	9.9	7
			38			197				9.9	
	24t/ha	5.6	33	240	10	107	75	<1	31	11.7	9
			41			143				15.2	
	Control	5.6	32	320	8	311	180	1	36	4.9	13
			37			325				5.6	
5	**Bush**	6	8	170	<5	146	91	<1	32	3.8	14
			6			158				4.5	

Australian Environmental Laboratories

LABORATORY REPORT COVERSHEET

DATE:	22 April 1998
TO:	Muresk Institute of Agriculture
	NORTHAM WA 6401
ATTENTION:	Ms Deborah Pritchard
YOUR REFERENCE:	Quote 980310A
OUR REFERENCE:	38968
SAMPLES RECEIVED:	26/3/98
SAMPLES/QUANTITY:	13 Soils

The above samples were received intact and analysed according to your accompanying chain of custody form which is returned with this report for your reference.
Unless otherwise stated, solid samples are reported on a dry weight basis and liquid samples as received.
Mercury and Selenium were analysed by Analabs, Welshpool, report No.WM034378.

Steven Edmett
STEVEN EDMETT
Manager Client Liaison

PETER BAMFORD
Manager Laboratory Services

This report must not be reproduced except in full.

(Analabs Pty. Ltd.) ACN 004 591 664
52 Murray Road Welshpool Western Australia 6106 Australia
Telephone: (08) 9458 7278 Facsimile: (08) 9451 3505

Australian Environmental Laboratories

CLIENT: Muresk Institute of Agriculture **OUR REFERENCE:** 38968
PROJECT: Quote 980310A

LABORATORY REPORT

Your Reference Our Reference Type of sample	1A 38968-1 Soil	1B 38968-2 Soil	1C 38968-3 Soil	2A 38968-4 Soil	2B 38968-5 Soil
pH (1:5)	5.9	5.8	5.6	5.4	5.6
Electrical Conductivity @ 25°C 1:5 soil:water	140	140	70	60	80
Total Phosphorus, P	320	340	250	230	250
Bray Phosphorus	11	11	8	6	10
Total Kjeldahl Nitrogen	1100	1100	990	990	880
Sodium, Na (Exchangeable)	32	36	42	32	35
Potassium, K (Exchangeable)	130	76	120	75	58
Calcium, Ca (Exchangeable)	930	900	680	670	650
Magnesium, Mg (Exchangeable)	39	77	42	21	38
Aluminium, Al (Exchangeable)	<5	<5	<5	<5	<5

Your Reference Our Reference Type of sample	2C 38968-6 Soil	3A 38968-7 Soil	3B 38968-8 Soil	3C 38968-9 Soil	4A 38968-10 Soil
pH (1:5)	5.5	5.7	5.7	5.4	5.6
Electrical Conductivity @ 25°C 1:5 soil:water	70	100	100	50	80
Total Phosphorus, P	260	65	230	280	240
Bray Phosphorus	10	11	11	6	10
Total Kjeldahl Nitrogen	1100	300	790	1000	1000
Sodium, Na (Exchangeable)	32	35	34	32	31
Potassium, K (Exchangeable)	110	45	60	54	75
Calcium, Ca (Exchangeable)	740	860	660	740	820
Magnesium, Mg (Exchangeable)	22	37	54	8	42
Aluminium, Al (Exchangeable)	<5	<5	<5	<5	<5

Australian
Environmental
Laboratories

CLIENT: Muresk Institute of Agriculture
PROJECT: Quote 980310A

OUR REFERENCE: 38968

LABORATORY REPORT

Your Reference Our Reference Type of sample	4B 38968-11 Soil	4C 38968-12 Soil	BUS + 1 38968-13 Soil
pH (1:5)	5.5	5.6	6.0
Electrical Conductivity @ 25°C 1:5 soil:water	80	70	70
Total Phosphorus, P	280	320	170
Bray Phosphorus	8	8	<5
Total Kjeldahl Nitrogen	1000	1000	1300
Sodium, Na (Exchangeable)	30	36	32
Potassium, K (Exchangeable)	100	180	91
Calcium, Ca (Exchangeable)	770	720	1600
Magnesium, Mg (Exchangeable)	42	73	62
Aluminium, Al (Exchangeable)	<5	<5	<5

Australian Environmental Laboratories

CLIENT: Muresk Institute of Agriculture **OUR REFERENCE:** 38968
PROJECT: Quote 980310A

LABORATORY REPORT

Your Reference Our Reference Type of sample	1A 38968-1 Soil	1B 38968-2 Soil	1C 38968-3 Soil	2A 38968-4 Soil	2B 38968-5 Soil
Arsenic, As	<0.5	<0.5	0.8	<0.5	<0.5
Cadmium,Cd	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium, Cr	9	12	13	10	7
Copper, Cu	8	9	5	6	7
Mercury, Hg	<0.05	<0.05	<0.05	<0.05	<0.05
Lead, Pb	<5	<5	<5	<5	<5
Nickel, Ni	<5	<5	<5	<5	<5
Zinc, Zn	8	12	8	9	7
Molybdenum, Mo	<5	<5	<5	<5	<5
Selenium, Se	<1	<1	<1	<1	<1

Your Reference Our Reference Type of sample	2C 38968-6 Soil	3A 38968-7 Soil	3B 38968-8 Soil	3C 38968-9 Soil	4A 38968-10 Soil
Arsenic, As	0.5	<0.5	<0.5	<0.5	<0.5
Cadmium,Cd	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium, Cr	8	7	9	8	9
Copper, Cu	<5	8	8	5	9
Mercury, Hg	<0.05	<0.05	<0.05	<0.05	<0.05
Lead, Pb	<5	<5	5	5	<5
Nickel, Ni	<5	<5	<5	<5	<5
Zinc, Zn	12	18	6	11	9
Molybdenum, Mo	<5	<5	<5	<5	<5
Selenium, Se	<1	<1	<1	3	<1

Your Reference Our Reference Type of sample	4B 38968-11 Soil	4C 38968-12 Soil	BUS + 1 38968-13 Soil
Arsenic, As	<0.5	<0.5	0.5
Cadmium,Cd	<0.5	<0.5	<0.5
Chromium, Cr	15	35	25
Copper, Cu	9	11	19
Mercury, Hg	<0.05	<0.05	<0.05
Lead, Pb	8	5	11
Nickel, Ni	<5	7	14
Zinc, Zn	7	13	14
Molybdenum, Mo	<5	<5	<5
Selenium, Se	<1	1	<1

Australian Environmental Laboratories

CLIENT: Muresk Institute of Agriculture **OUR REFERENCE:** 38968
PROJECT: Quote 980310A

LABORATORY REPORT

TEST PARAMETERS	UNITS	LOR	METHOD
pH (1:5)	pH Units	0.1	PEI-300
Electrical Conductivity @ 25°C 1:5 soil:water	µS/cm	5	PEI-032
Total Phosphorus, P	mg/kg	5	PEI-066
Bray Phosphorus	mg/kg	5	Unassigned
Total Kjeldahl Nitrogen	mg/kg	20	PEI-012
Sodium, Na (Exchangeable)	mg/kg	1	PEM-001
Potassium, K (Exchangeable)	mg/kg	5	PEM-001
Calcium, Ca (Exchangeable)	mg/kg	5	PEM-002
Magnesium, Mg (Exchangeable)	mg/kg	1	PEM-002
Aluminium, Al (Exchangeable)	mg/kg	5	PEM-001
Metals in Soil			
Arsenic, As	mg/kg	0.5	PEM-004
Cadmium,Cd	mg/kg	0.5	PEM-001
Chromium, Cr	mg/kg	5	PEM-002
Copper, Cu	mg/kg	5	PEM-001
Mercury, Hg	mg/kg	0.05	PEM-005
Lead, Pb	mg/kg	5	PEM-001
Nickel, Ni	mg/kg	5	PEM-001
Zinc, Zn	mg/kg	5	PEM-001
Molybdenum, Mo	mg/kg	5	PEM-001
Selenium, Se	mg/kg	1	PEM-004

NOTES:
LOR= Limit of Reporting.
Metals in soil digestion method_PEP-025.
pH and conductivity are reported on the 1:5 extract basis with all other results reported on the air dried sample basis.

DING NAME: MURESK INSTITUTE OF AGRICULTURE
TAL ADDRESS: C/- POST OFFICE

TELEPHONE:
POSTCODE: 6401

PLES RECEIVED: 26/03/98
REPORT COMPLETED: 7/04/98

AL ID: DEB PRITCHARCH

MPLE ID	LAB NUMBER	TEXTURE	GRAVEL (%)	COLOUR	PHOSPHORUS (mg/Kg)	-NITROGEN mg/Kg- NITRATE	AMMONIUM	POTASSIUM (mg/Kg)	SULPHUR (mg/Kg)	ORGANIC CARBON %	IRON mg/Kg	CONDUCTIVITY dS/m	pH CaCl2	pH 1.5 Water
0-15	3Z146	1.5		BR	28	9	5	138	10.9	1.11	467	.0523	4.71	5.66
0-15	3Z147	1.5		BR	44	24	10	100	14.4	1.28	348	.0802	5.11	5.76
0-15	3Z148	1.5		BR	44	22	10	106	15.0	1.37	376	.0782	5.09	5.75
0-15	3Z149	1.5		BR	29	7	6	116	8.1	1.16	439	.0442	4.71	5.51
0-15	3Z150	1.5		BR	33	11	10	107	11.7	1.20	308	.0580	4.81	5.53
0-15	3Z151	1.5		BR	62	26	10	134	17.8	1.29	1136	.1011	5.18	5.73
0-15	3Z152	1.5		BR	40	8	5	200	5.2	1.23	863	.0536	4.81	5.59
0-15	3Z153	1.5	5	BR	32	7	5	311	4.9	1.41	580	.0527	4.75	5.68
0-15	3Z154	1.5	5	BR	27	10	6	133	5.2	1.30	438	.0460	4.89	5.63
0-15	3Z155	1.5	5	BR	59	22	9	219	12.9	1.39	462	.0974	5.18	5.75
0-15	3Z156	1.5	5	BR	58	22	12	267	14.2	1.28	428	.1046	5.28	5.87
0-15	3Z157	1.5	5	BR	40	8	8	240	8.4	1.59	516	.0702	4.80	5.63
0-15	3Z158	1.5	5	BR	43	11	9	115	14.3	1.01	370	.0604	5.10	5.76
0-15	3Z159	1.5	5	BR	41	13	10	143	15.2	1.27	378	.0661	5.01	5.73
0-15	3Z160	1.5	5	BR	37	8	7	178	7.6	1.40	490	.0464	4.91	5.53
0-15	3Z161	1.5	5	BR	37	7	5	325	5.6	1.35	591	.0536	4.78	5.68
0-15	3Z162	1.5	5	BR	70	20	20	177	18.6	1.13	426	.1061	5.40	5.99
0-15	3Z163	1.5	5	BR	40	8	8	189	5.9	1.17	943	.0538	4.69	5.59
0-15	3Z164	1.5	5	BR	63	23	11	135	21.2	1.34	1096	.1041	5.18	5.71
0-15	3Z165	1.5	5	BR	31	9	5	100	4.8	1.46	498	.0373	4.64	5.43
0-15	3Z166	1.5	5	BR	38	12	7	197	9.9	1.42	489	.0639	5.40	5.51
2	3Z167	1.5	5	BR	8	5	8	146	3.8	2.01	420	.0537	5.23	5.94

DING NAME: MURESK INSTITUTE OF AGRICULTURE
TAL ADDRESS: C/- POST OFFICE

TELEPHONE:
POSTCODE: 6401

PLES RECEIVED: 26/03/98
REPORT COMPLETED: 7/04/98

MPLE ID	LAB NUMBER	TEXTURE	GRAVEL (%)	COLOUR	PHOSPHORUS (mg/Kg)	-NITROGEN mg/Kg- NITRATE	AMMONIUM	POTASSIUM (mg/Kg)	SULPHUR (mg/Kg)	ORGANIC CARBON %	IRON mg/Kg	CONDUCTIVITY dS/m	pH CaCl2	pH 1.5 Water
AL ID: DEB PRITCHARCH														
0-15	3Z168	1.5	5	BR	43	11	17	115	16.4	.97	450	.0725	5.04	5.72
0-15	3Z169	1.5	5	BR	33	10	6	164	9.9	1.46	478	.0596	4.82	5.49
0-15	3Z170	1.5	5	BR	39	7	7	118	12.3	1.07	390	.0530	4.88	5.55
H 1	3Z171	1.5	5	BR	6	7	4	158	4.5	1.91	487	.0562	5.98	6.56

Appendix 3 Soil chemical data for 1997, prior to trial

Soil chemical data for Paddock 28, Muresk Institute of Agriculture

Analyte	Comp A	Comp B	mean	Comp A	Comp B	Comp A	Comp B	Comp A	Comp B
Depth(cm)	0-15	0-15	0-15	15-30	15-30	30-60	30-60	60-90	60-90
pH($CaCl_2$)	4.5	5.1	4.80	4.50	5.20	4.9	5.2	5.5	5.5
EC (1:5) (dS/m)	0.06	0.05	0.06	0.06	0.05	0.04	0.05	0.04	0.03
Bray P (mg/kg)	25	15	20.00						
Total P (mg/kg)	140	100	120						
TKN%	0.07	0.06	0.07						
exch Al (cmol(+)/kg)	0	0	0.0						
exch Mg (cmol(+)/kg	0.4	0.6	0.5						
exch Ca (cmol(+)/kg)	2.8	3.7	3.3						
exch K (cmol(+)/kg)	0.4	0.2	0.30						
exch Na (cmol(+)/kg)	0.9	0.4	0.7						
CEC (cmol(+)/kg)	4.4	4.9	4.7						
ESP	20.5	8.2	14.3						
exch Ca %	0.6	0.8	0.7						
As (mg/kg)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cd (mg/kg)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cr (mg/kg)	9.7	7.4	8.55	11	8.3	9.7	7.7	10	6.6
Cu (mg/kg)	6.7	4.8	5.75	7.1	5.2	7.5	6.6	7.9	6.8
Hg (mg/kg)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Mo (mg/kg)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ni (mg/kg)	3.8	2.3	3.05	3.4	2.6	4.2	2.6	3	3.3
Pb (mg/kg)	5.6	4.1	4.85	5.6	5.4	7.1	5.9	4.3	7.4
Se (mg/kg)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zn (mg/kg)	8.2	4.7	6.45	7.8	5.2	7.6	8.6	6.3	16
DDD (mg/kg)	<0.02	<0.02	<0.02						
DDE (mg/kg)	0.03	<0.02	0.03						
DDT (mg/kg)	<0.02	<0.02	<0.02						
Aldrin (mg/kg)	<0.02	<0.02	<0.02						
Dieldrin (mg/kg)	<0.02	<0.02	<0.02						
Chlordane (mg/kg)	<0.02	<0.02	<0.02						
Heptachlor (mg/kg)	<0.02	<0.02	<0.02						
HCB (mg/kg)	<0.02	<0.02	<0.02						
Lindane (mg/kg)	<0.02	<0.02	<0.02						
BHC (mg/kg)	<0.02	<0.02	<0.02						
PCB (mg/kg)	<0.2	<0.2	<0.2						

Appendix 4 Hopper cake analysis, April 1997

BEENYUP WWTP

WATER CORPORATION

Sample Date: 15/4/97

BATCH ID BYHPCK15Apr97

Description: hopper cake

CONTAMINANT GRADE: B

PATHOGEN GRADE: 2

CLASSIFICATION: 2B

NUTRIENT VALUE

moisture%:	83.2	
pH:	7.9	
TP:	22000	mg/kg
TKN:	38000	mg/kg
NH3:	8500	mg/kg
NO2:	5.1	mg/kg
NO3:	25	mg/kg
Total Sulphur %:	NR	
TOC %:	NR	

HEAVY METALS

Zn:	650	mg/kg
Cu:	1300	mg/kg
Cd:	1.9	mg/kg
total Cr:	75	mg/kg
Pb:	66	mg/kg
Hg:	4.7	mg/kg
Ni:	25	mg/kg
As:	4.3	mg/kg
Mo:	13	mg/kg
Se:	9.0	mg/kg

ORGANIC PESTICIDES

Aldrin:	<0.2	mg/kg
Dieldrin:	<0.2	mg/kg
Chlordane:	<0.2	mg/kg
Heptachlor:	<0.2	mg/kg
HCB:	<0.2	mg/kg
Lindane:	<0.2	mg/kg
DDT/DDD/DDE:	<0.2	mg/kg
PCB's:	<0.5	mg/kg

NOTE: PATHOGEN GRADE IS BASED ON >38% TS REDUCTION

RESULT ARE BASED ON A DRY WT BASIS UNLESS OTHERWISE STATED

NR: MEANS NOT REQUIRED

Authorised [signature]

Project Officer - Biosolids Management

WASTEWATER TREATMENT AND INDUSTRIAL WASTE BRANCH

04-Jul-97

BEENYUP WWTP

WATER CORPORATION

Sample Date: 7/4/97

BATCH ID BYHPCK7Apr97

Description: hopper cake

CONTAMINANT GRADE: B

PATHOGEN GRADE: 2

CLASSIFICATION: 2B

NUTRIENT VALUE

moisture%:	83.5	
pH:	7.9	
TP:	23000	mg/kg
TKN:	13000	mg/kg
NH3:	7300	mg/kg
NO2:	3.0	mg/kg
NO3:	39	mg/kg
Total Sulphur %:	1.2	
TOC %:	20.6	

HEAVY METALS

Zn:	780	mg/kg
Cu:	1500	mg/kg
Cd:	2.1	mg/kg
total Cr:	83	mg/kg
Pb:	89	mg/kg
Hg:	1.7	mg/kg
Ni:	32	mg/kg
As:	3.5	mg/kg
Mo:	11	mg/kg
Se:	4.3	mg/kg

ORGANIC PESTICIDES

Aldrin:	<0.2	mg/kg
Dieldrin:	<0.2	mg/kg
Chlordane:	<0.2	mg/kg
Heptachlor:	<0.2	mg/kg
HCB:	<0.2	mg/kg
Lindane:	<0.2	mg/kg
DDT/DDD/DDE:	<0.2	mg/kg
PCB's:	<0.5	mg/kg

NOTE: PATHOGEN GRADE IS BASED ON >38% TS REDUCTION

RESULT ARE BASED ON A DRY WT BASIS UNLESS OTHERWISE STATED

NR: MEANS NOT REQUIRED

Authorised

Project Officer - Biosolids Management

WASTEWATER TREATMENT AND INDUSTRIAL WASTE BRANCH

04-Jul-97

BEENYUP WWTP

WATER CORPORATION

Sample Date: 22/4/97

BATCH ID BYHPCK22Apr97

Description: hopper cake

CONTAMINANT GRADE: B

PATHOGEN GRADE: 2

CLASSIFICATION: 2B

NUTRIENT VALUE

moisture%:	83.9	
pH:	7.9	
TP:	25000	mg/kg
TKN:	27000	mg/kg
NH3:	8200	mg/kg
NO2:	2.2	mg/kg
NO3:	7.8	mg/kg
Total Sulphur %:	NR	
TOC %:	NR	

HEAVY METALS

Zn:	740	mg/kg
Cu:	1400	mg/kg
Cd:	2.3	mg/kg
total Cr:	68	mg/kg
Pb:	85	mg/kg
Hg:	11	mg/kg
Ni:	30	mg/kg
As:	2.4	mg/kg
Mo:	13	mg/kg
Se:	6.3	mg/kg

ORGANIC PESTICIDES

Aldrin:	<0.2	mg/kg
Dieldrin:	<0.2	mg/kg
Chlordane:	<0.2	mg/kg
Heptachlor:	<0.2	mg/kg
HCB:	<0.2	mg/kg
Lindane:	<0.2	mg/kg
DDT/DDD/DDE:	<0.2	mg/kg
PCB's:	<0.5	mg/kg

NOTE: PATHOGEN GRADE IS BASED ON >38% TS REDUCTION

RESULT ARE BASED ON A DRY WT BASIS UNLESS OTHERWISE STATED

NR: MEANS NOT REQUIRED

Authorised *[signature]*

Project Officer - Biosolids Management

WASTEWATER TREATMENT AND INDUSTRIAL WASTE BRANCH

04-Jul-97

Australian Environmental Laboratories

CLIENT: Water Corporation
PROJECT NO: BT1477460G
PROJECT NAME: Beenyup WWTP

OUR REFERENCE: 32778

APPENDIX

METHODOLOGY

Abbreviation	Method	Reference methods
Metals - Soils	Low temperature nitric/hydrogen peroxide/hydrochloric acid digestion/AAS or ICP analysis.	AEL method PEI-100
Moisture content	Oven dry at 105°C to constant weight	AEL method PEI-600
OC and OP pesticides	Organochlorine and organophosphorus pesticides - solvent extraction/GC-ECD.	AEL method PEO-100
PCBs as Arochlor mixtures	Polychlorinated biphenyls - solvent extraction/GC-ECD.	AEL method PEO-100
pH	1:5 water extract, electrode	AEL method PEI-300
Nitrite Nitrogen	1:5 water extract, spectometry	APHA 4500 NO_2-B
Nitrate Nitrogen	1:5 water extract, spectometry	AEL method PEW 011
Ammoniacal Nitrogen	Steam distillation, titrimetric	AEL method PEW 010
Total Nitrogen, and Total Phosphorus	Kjeldahl digestion, autoanalyser	

Australian Environmental Laboratories

CLIENT: Water Corporation
PROJECT NO: BT1477460G
PROJECT NAME: Beenyup WWTP

OUR REFERENCE: 32778

REPORTING BASIS

All results for soils and sediments are reported on a dried (105°C) basis; for waters on an 'as received' basis.

QUALITY CONTROL

The following Quality Control Procedures are incorporated into all analytical procedures:

- Five percent of samples analysed are reagent/procedural blanks.
- Standards extending throughout the expected range of results are run at the beginning and during each set of analyses.
- Replicate samples are analysed every 20 samples.
- Recoveries are performed at least once in every 20 samples.
- Whenever available, control samples are run with each set of samples.
- Procedures outlined in APHA 1020, 19th Edition (1995) are followed when test results are interrogated for acceptance and rejection criteria.

SAMPLE STORAGE

Soil samples are refrigerated for 14 days after receival, then stored at ambient temperature for 3 months. Water samples are refrigerated on receival. After analysis is completed any remaining water samples are stored for 4 weeks. Unless otherwise requested, the samples are then disposed of appropriately.

Appendix 5 GENSTAT statistical analysis

Genstat 5 Release 3.2 (PC/Windows 95)

Genstat 5 Second Edition (for Windows)
Genstat 5 Procedure Library Release 3[3] (PL9)

Identifier	Minimum	Mean	Maximum	Values	Missing	
Sections	1.000	2.500	4.000	24	0	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Treatment				24	0	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Aluminium	5.000	5.000	5.000	24	12	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Ammonium	5.000	8.667	20.000	24	0	Skew

Identifier	Minimum	Mean	Maximum	Values	Missing	
Arsenic	0.500	0.5250	0.8000	24	12	Skew

Identifier	Minimum	Mean	Maximum	Values	Missing	
Cadmium	0.500	0.5000	0.5000	24	12	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Calcium	650.0	761.7	930.0	24	12	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Chromium	7.00	11.83	35.00	24	12	Skew

Identifier	Minimum	Mean	Maximum	Values	Missing	
Conductivity	0.037	0.06729	0.10600	24	0	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Electrical Conductivity	50.00	86.67	140.00	24	12	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Copper	5.000	7.500	11.000	24	12	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Iron	308.0	535.8	1136.0	24	0	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Lead	5.000	5.250	8.000	24	12	Skew

Identifier	Minimum	Mean	Maximum	Values	Missing	
Magnesium	8.00	41.25	77.00	24	12	
Mercury	0.05000	0.0500	0.0500	24	12	
Molybdenum	5.000	5.000	5.000	24	12	
Nickel	5.000	5.167	7.000	24	12	Skew
T.Kjeldahl Nitrogen	300.0	937.5	1100.0	24	12	Skew
Nitrate	7.00	13.13	26.00	24	0	
Organic Carbon %	0.970	1.312	1.910	24	0	
pH (CaCl)	4.640	4.965	5.400	24	0	
pH (1.5 water)CSBP	5.430	5.658	5.990	24	0	
pH (1.5 water)	5.400	5.608	5.900	24	12	
Phosphorus	27.00	42.12	70.00	24	0	
T.Phosphorus	65.0	255.4	340.0	24	12	
B.Phosphorus	6.000	9.167	11.000	24	12	
Potassium CSBP	100.0	167.8	325.0	24	0	
Potassium	45.00	90.25	180.00	24	12	

Identifier	Minimum	Mean	Maximum	Values	Missing	
Selenium	1.000	1.167	3.000	24	12	Skew

Identifier	Minimum	Mean	Maximum	Values	Missing
Sodium	30.00	33.92	42.00	24	12

Identifier	Minimum	Mean	Maximum	Values	Missing
Sulphur	4.50	10.94	21.20	24	0

Identifier	Minimum	Mean	Maximum	Values	Missing
Zinc	6.00	10.00	18.00	24	12

Variate: **Ammonium**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	74.333	24.778	1.50	
Sections.Treatmen stratum					
Treatmen	2	130.083	65.042	3.95	0.081
Residual	6	98.917	16.486	10.99	
Sections.Treatmen.*Units* stratum					
	12	18.000	1.500		
Total	23	321.333			

* MESSAGE: the following units have large residuals.

Sections 3.00 Treatmen 24t/ha 4.08 s.e. 2.03

***** Tables of means *****

Variate: Ammonium

Grand mean 8.67

Treatmen	Control	17t/ha	24t/ha
	6.12	8.13	11.75

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	4.968

***** Stratum standard errors and coefficients of variation *****

Variate: Ammonium

Stratum	d.f.	s.e.	cv%
Sections	3	2.032	23.4
Sections.Treatmen	6	2.871	33.1
Sections.Treatmen.*Units*	12	1.225	14.1

Bush = 6

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(16.486*(1/4+1))
11.10827502

Variate: **Calcium**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	68240.	22747.	2.52	
Sections.*Units* stratum					
Treatmen	2	25698.	12849.	1.42	0.312
Residual	6(12)	54133.	9022.		
Total	11(12)	101167.			

* MESSAGE: the following units have large residuals.

Sections 1.00	*units* 5	-115.	s.e. 47.
Sections 3.00	*units* 3	-97.	s.e. 47.

***** Tables of means *****

Variate: Calcium_

Grand mean 762.

Treatmen	Control	17t/ha	24t/ha
	720.	800.	765.

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	116.2

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: Calcium

Stratum	d.f.	s.e.	cv%
Sections	3	61.6	8.1
Sections.*Units*	6	95.0	12.5

Missing values: 12

Bush = 1600

LSD for Bush Plot Comparison =
$t_6^{0.5}$ Square Root (Residual m.s.x(1/4 +1))
2.447*SQRT(9022*(1/4+1))
259.86

Therefore, there is a **sig.difference** at 5% between the **bush area and all treatments.**

Variate: **Chromium**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	531.09	177.03	3.94	
Sections.*Units* stratum					
Treatmen	2	233.23	116.61	2.60	0.154
Residual	6(12)	269.33	44.89		
Total	11(12)	651.67			

* MESSAGE: the following units have large residuals.

Sections 4.00	*units* 3	-7.3	s.e. 3.3
Sections 4.00	*units* 5	11.2	s.e. 3.3

***** Tables of means *****

Variate: Chromium

Grand mean 11.8

Treatmen	Control	17t/ha	24t/ha
	16.0	11.0	8.5

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	8.20

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: Chromium

Stratum	d.f.	s.e.	cv%
Sections	3	5.43	45.9
Sections.*Units*	6	6.70	56.6

Missing values: 12

Bush = 25

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(44.89*(1/4+1))
18.33005544

Variate: **Conductivity**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	0.00353646	0.00117882	2.50	
Sections.Treatmen stratum					
Treatmen	2	0.00297508	0.00148754	3.16	0.116
Residual	6	0.00282692	0.00047115	5.61	
Sections.Treatmen.*Units* stratum	12	0.00100850	0.00008404		
Total	23	0.01034696			

* MESSAGE: the following units have large residuals.

Sections 3.00	Treatmen 24t/ha	*units* 1	0.0165	s.e. 0.0065
Sections 3.00	Treatmen 24t/ha	*units* 2	-0.0165	s.e. 0.0065

***** Tables of means *****

Variate: Conductivity

Grand mean 0.0673

Treatmen	Control	17t/ha	24t/ha
	0.0518	0.0729	0.0773

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	0.02656

***** Stratum standard errors and coefficients of variation *****

Variate: Conductivity

Stratum	d.f.	s.e.	cv%
Sections	3	0.01402	20.8
Sections.Treatmen	6	0.01535	22.8
Sections.Treatmen.*Units*	12	0.00917	13.6

Bush = 0.0550

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(0.0005*(1/4+1))
0.05938388

Variate: **Copper**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	43.314	14.438	6.50	
Sections.*Units* stratum					
Treatmen	2	11.995	5.997	2.70	0.146
Residual	6(12)	13.333	2.222		
Total	11(12)	41.000			

* MESSAGE: the following units have large residuals.

Sections 4.00 *units* 5 2.33 s.e. 0.75

***** Tables of means *****

Variate: Copper

Grand mean 7.50

Treatmen	Control	17t/ha	24t/ha
	6.50	8.00	8.00

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	1.824

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: Copper

Stratum	d.f.	s.e.	cv%
Sections	3	1.551	20.7
Sections.*Units*	6	1.491	19.9

Missing values: 12
Bush = 19

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(2.222*(1/4+1))
4.078129412

There is a **sig. difference** between the **bush** and all treatments, **17t/ha, 24 t/ha and the control.**

Variate: **Electric**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	7729.8	2576.6	6.63	
Sections.*Units* stratum					
Treatmen	2	5730.7	2865.4	7.37	**0.024**
Residual	6(12)	2333.3	388.9		
Total	11(12)	9066.7			

* MESSAGE: the following units have large residuals.

Sections 1.00 *units* 5	-25.0	s.e. 9.9
Sections 2.00 *units* 5	21.7	s.e. 9.9

***** Tables of means *****

Variate: Electric

Grand mean 86.7

Treatmen	Control	17t/ha	24t/ha
	65.0	95.0	100.0

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	24.13

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: Electric

Stratum	d.f.	s.e.	cv%
Sections	3	20.72	23.9
Sections.*Units*	6	19.72	22.8

Missing values: 12

There is a significant between the ***control and 17 t/ha*** and the ***control and 24 24t/ha.***

Bush = 70
LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(388.9*(1/4+1))
53.95204955

Variate: **Iron**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	664823.	221608.	4.46	
Sections.Treatmen stratum					
Treatmen	2	259227.	129613.	2.61	0.153
Residual	6	297836.	49639.	33.17	
Sections.Treatmen.*Units* stratum					
	12	17959.	1497.		
Total	23	1239845.			

* MESSAGE: the following units have large residuals.

Sections 1.00	Treatmen 17t/ha		226.9	s.e. 111.4
Sections 1.00	Treatmen 24t/ha		-229.5	s.e. 111.4
Sections 3.00	Treatmen 24t/ha	*units* 1	-62.0	s.e. 27.4
Sections 3.00	Treatmen 24t/ha	*units* 2	62.0	s.e. 27.4

***** Tables of means *****

Variate: Iron

Grand mean 535.8

Treatmen	Control	17t/ha	24t/ha
	614.9	603.6	389.0

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	272.58

***** Stratum standard errors and coefficients of variation *****

Variate: Iron

Stratum	d.f.	s.e.	cv%
Sections	3	192.18	35.9
Sections.Treatmen	6	157.54	29.4
Sections.Treatmen.*Units*	12	38.69	7.2

Bush = 453.5

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(49639*(1/4+1))
609.5375819

```
Variate: Magnesium

Source of variation     d.f.(m.v.)       s.s.        m.s.     v.r.  F pr.

Sections stratum             3          3141.5      1047.2    2.38

Sections.*Units* stratum
Treatmen                     2           303.6       151.8    0.34  0.722
Residual                     6(12)      2645.3       440.9

Total                       11(12)      4370.3

* MESSAGE: the following units have large residuals.

Sections 1.00  *units* 1             21.3   s.e. 10.5
Sections 4.00  *units* 5             25.7   s.e. 10.5


***** Tables of means *****

Variate: Magnesium

Grand mean  41.2

 Treatmen  Control   17t/ha   24t/ha
              36.3     44.2     43.2


*** Least significant differences of means ***

Table              Treatmen
rep.                      8
d.f.                      6
l.s.d.                25.69

(Not adjusted for missing values)


***** Stratum standard errors and coefficients of variation *****

Variate: Magnesium

Stratum                     d.f.         s.e.        cv%

Sections                      3         13.21       32.0
Sections.*Units*              6         21.00       50.9

Missing values:  12
Bush = 62

LSD for Bush Plot Comparison =
 t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(440.9*(1/4+1))
57.44589833
```

Variate: **Nitrate**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	398.458	132.819	3.75	
Sections.Treatmen stratum					
Treatmen	2	316.000	158.000	4.46	**0.065**
Residual	6	212.667	35.444	6.92	
Sections.Treatmen.*Units* stratum	12	61.500	5.125		
Total	23	988.625			

* MESSAGE: the following units have large residuals.

Sections 3.00	Treatmen 24t/ha	*units* 1	4.50	s.e. 1.60
Sections 3.00	Treatmen 24t/ha	*units* 2	-4.50	s.e. 1.60

***** Tables of means *****

Variate: Nitrate

Grand mean 13.13

Treatmen	Control	17t/ha	24t/ha
	8.13	16.62	14.63

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	7.284

***** Stratum standard errors and coefficients of variation *****

Variate: Nitrate

Stratum	d.f.	s.e.	cv%
Sections	3	4.705	35.8
Sections.Treatmen	6	4.210	32.1
Sections.Treatmen.*Units*	12	2.264	17.2

Consider 7% instead of 5% and there would be a significant difference
Likely to be between the control and 17t/ha

Bush = 6

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(35.444*(1/4+1))
16.28772169

Variate: **T.Kjeldahl Nitrogen**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	482321.	160774.	4.21	
Sections.*Units* stratum					
Treatmen	2	122632.	61316.	1.61	0.276
Residual	6(12)	228934.	38156.		
Total	11(12)	531825.			

* MESSAGE: the following units have large residuals.

Sections 3.00	*units* 1	-307.	s.e. 98.
Sections 3.00	*units* 5	218.	s.e. 98.

***** Tables of means *****

Variate: T.Kjeldahl Nitrogen

Grand mean 938.

Treatmen	Control	17t/ha	24t/ha
	1022.	848.	942.

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	239.0

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: T.Kjeldahl Nitrogen

Stratum	d.f.	s.e.	cv%
Sections	3	163.7	17.5
Sections.*Units*	6	195.3	20.8

Missing values: 12
Bush = 1300

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(38156*(1/4+1))
534.4048561

Variate: **Organic Carbon %**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	0.05202	0.01734	0.33	
Sections.Treatmen stratum					
Treatmen	2	0.03607	0.01804	0.35	0.720
Residual	6	0.31226	0.05204	1.33	
Sections.Treatmen.*Units* stratum	12	0.46810	0.03901		
Total	23	0.86845			

* MESSAGE: the following units have large residuals.

Sections 2.00	Treatmen 24t/ha	*units* 1	-0.450	s.e. 0.140
Sections 2.00	Treatmen 24t/ha	*units* 2	0.450	s.e. 0.140

***** Tables of means *****

Variate: Organic Carbon %

Grand mean 1.313

Treatmen	Control	17t/ha	24t/ha
	1.364	1.304	1.270

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	0.2791

***** Stratum standard errors and coefficients of variation *****

Variate: Organic Carbon %

Stratum	d.f.	s.e.	cv%
Sections	3	0.0538	4.1
Sections.Treatmen	6	0.1613	12.3
Sections.Treatmen.*Units*	12	0.1975	15.0

Bush = 1.96

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(0.052*(1/4+1))
0.624104939
Therefore, there is a **sig.difference** at 5% between the **bush area and 17t/ha**
And the **bush and 24t/ha.**

Variate: **pH (CaCl)**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	0.15601	0.05200	1.08	
Sections.Treatmen stratum					
Treatmen	2	0.41166	0.20583	4.29	**0.070**
Residual	6	0.28777	0.04796	1.76	
Sections.Treatmen.*Units* stratum	12	0.32735	0.02728		
Total	23	1.18280			

* MESSAGE: the following units have large residuals.

Sections 4.00	Treatmen 17t/ha	*units* 1	0.290	s.e. 0.117
Sections 4.00	Treatmen 17t/ha	*units* 2	-0.290	s.e. 0.117

***** Tables of means *****

Variate: pH (CaCl)

Grand mean 4.965

Treatmen	Control	17t/ha	24t/ha
	4.784	5.025	5.088

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	0.2679

***** Stratum standard errors and coefficients of variation *****

Variate: pH (CaCl)

Stratum	d.f.	s.e.	cv%
Sections	3	0.0931	1.9
Sections.Treatmen	6	0.1549	3.1
Sections.Treatmen.*Units*	12	0.1652	3.3

Consider 7% instead of 5% there is likely to be a significant difference.
Bush = 5.605
LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(0.047*(1/4+1))
0.599140342

Therefore, there is a **sig.difference** at 5% between the **bush area and** the **control** and the **bush and 17t/ha.**

Variate: **pH (1.5 water)**
CSBP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	0.06632	0.02211	1.14	
Sections.Treatmen stratum					
Treatmen	2	0.08490	0.04245	2.19	0.193
Residual	6	0.11643	0.01941	1.90	
Sections.Treatmen.*Units* stratum	12	0.12240	0.01020		
Total	23	0.39005			

***** Tables of means *****

Variate: pH (1.5 water)

Grand mean 5.657

Treatmen	Control	17t/ha	24t/ha
	5.595	5.640	5.737

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	0.1704

***** Stratum standard errors and coefficients of variation *****

Variate: pH (1.5 water)

Stratum	d.f.	s.e.	cv%
Sections	3	0.0607	1.1
Sections.Treatmen	6	0.0985	1.7
Sections.Treatmen.*Units*	12	0.1010	1.8

Bush = 6.25
LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(0.019*(1/4+1))
0.381155107

Therefore, there is a **sig.difference** at 5% between the **bush area and all treatments.**

Variate: **pH (1.5 water)**

(Heavy Metal Analysis)

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	0.23156	0.07719	6.46	
Sections.*Units* stratum					
Treatmen	2	0.12328	0.06164	5.16	**0.050**
Residual	6(12)	0.07167	0.01194		
Total	11(12)	0.24917			

* MESSAGE: the following units have large residuals.

Sections 3.00	*units* 5	-0.117	s.e. 0.055
Sections 4.00	*units* 5	0.117	s.e. 0.055

***** Tables of means *****

Variate: pH (1.5 water)

Grand mean 5.608

Treatmen	Control	17t/ha	24t/ha
	5.525	5.600	5.700

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	0.1337

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: pH (1.5 water)

Stratum	d.f.	s.e.	cv%
Sections	3	0.1134	2.0
Sections.*Units*	6	0.1093	1.9

There is a significant difference between the **control and 24 t/ha.**
Missing values: 12
Bush = 6

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(0.01194*(1/4+1))
0.298944893
Therefore, there is a **sig.difference** at 5% between the **bush area and all treatments.**

Variate: **Phosphorus**
CSBP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	1281.13	427.04	2.97	
Sections.Treatmen stratum					
Treatmen	2	653.25	326.62	2.27	0.184
Residual	6	862.75	143.79	3.89	
Sections.Treatmen.*Units* stratum	12	443.50	36.96		
Total	23	3240.63			

* MESSAGE: the following units have large residuals.

Sections 3.00	Treatmen 24t/ha	*units* 1	13.5	s.e. 4.3
Sections 3.00	Treatmen 24t/ha	*units* 2	-13.5	s.e. 4.3

***** Tables of means *****

Variate: Phosphorus

Grand mean 42.1

Treatmen	Control	17t/ha	24t/ha
	35.5	42.6	48.2

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	14.67

***** Stratum standard errors and coefficients of variation *****

Variate: Phosphorus

Stratum	d.f.	s.e.	cv%
Sections	3	8.44	20.0
Sections.Treatmen	6	8.48	20.1
Sections.Treatmen.*Units*	12	6.08	14.4

Bush = 7

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(143.79*(1/4+1))
32.80600281

Therefore, there is a **sig.difference** at 5% between the **bush area and 17t/ha** and the **bush** and **24t/ha.**

Variate: **Total Phosphorus**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	42188.	14063.	2.95	
Sections.*Units* stratum					
Treatmen	2	9745.	4872.	1.02	0.415
Residual	6(12)	28571.	4762.		
Total	11(12)	54573.			

* MESSAGE: the following units have large residuals.

Sections 1.00	*units* 5	-75.	s.e. 35.
Sections 3.00	*units* 1	-100.	s.e. 35.

***** Tables of means *****

Variate: T.Phosphorus

Grand mean 255.

Treatmen	Control	17t/ha	24t/ha
	277.	229.	260.

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	84.4

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: T.Phosphorus

Stratum	d.f.	s.e.	cv%
Sections	3	48.4	19.0
Sections.*Units*	6	69.0	27.0

Missing values: 12
Bush = 170

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(4762*(1/4+1))
188.7920366

Variate: **Bray Phosphorus**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	7.323	2.441	0.63	
Sections.*Units* stratum					
Treatmen	2	25.299	12.649	3.25	0.110
Residual	6(12)	23.333	3.889		
Total	11(12)	39.667			

* MESSAGE: the following units have large residuals.

Sections 2.00	*units* 1	-2.50	s.e. 0.99
Sections 2.00	*units* 5	2.50	s.e. 0.99
Sections 3.00	*units* 5	-2.17	s.e. 0.99

***** Tables of means *****

Variate: B.Phosphorus

Grand mean 9.17

Treatmen	Control	17t/ha	24t/ha
	8.00	9.00	10.50

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	2.413

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: B.Phosphorus

Stratum	d.f.	s.e.	cv%
Sections	3	0.638	7.0
Sections.*Units*	6	1.972	21.5

Missing values: 12
Bush = <5

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(3.889*(1/4+1))
5.395204955
Therefore, there is a **sig.difference** at 5% between the **bush area and 24t/ha.**

Variate: **Potassium**
CSBP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	27158.1	9052.7	1.33	
Sections.Treatmen stratum					
Treatmen	2	22702.6	11351.3	1.67	0.265
Residual	6	40798.8	6799.8	11.40	
Sections.Treatmen.*Units* stratum	12	7156.5	596.4		
Total	23	97816.0			

***** Tables of means *****

Variate: Potassium

Grand mean 167.8

Treatmen	Control	17t/ha	24t/ha
	209.5	136.3	157.6

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	100.89

***** Stratum standard errors and coefficients of variation *****

Variate: Potassium

Stratum	d.f.	s.e.	cv%
Sections	3	38.84	23.1
Sections.Treatmen	6	58.31	34.8
Sections.Treatmen.*Units*	12	24.42	14.6

Bush = 152

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(6799.8*(1/4+1))
225.5989352

Variate: **Potassium**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	15598.7	5199.6	6.10	
Sections.*Units* stratum					
Treatmen	2	8135.3	4067.6	4.77	**0.058**
Residual	6(12)	5117.8	853.0		
Total	11(12)	16990.2			

* MESSAGE: the following units have large residuals.

Sections 1.00	*units* 3	30.8	s.e. 14.6
Sections 4.00	*units* 3	-33.8	s.e. 14.6
Sections 4.00	*units* 5	35.9	s.e. 14.6

***** Tables of means *****

Variate: Potassium

Grand mean 90.2

Treatmen	Control	17t/ha	24t/ha
	116.0	74.0	80.8

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	35.73

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: Potassium

Stratum	d.f.	s.e.	cv%
Sections	3	29.44	32.6
Sections.*Units*	6	29.21	32.4

Missing values: 12
Consider 6% instead of 5% and there would be a signicant difference
Likely to be between the treatments and the control but not between
treatments.

Bush = 91
LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(853*(1/4+1))
79.9030747

Variate: **Sodium**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	65.74	21.91	1.97	
Sections.*Units* stratum					
Treatmen	2	30.29	15.15	1.36	0.326
Residual	6(12)	66.83	11.14		
Total	11(12)	114.92			

* MESSAGE: the following units have large residuals.

Sections 1.00	*units* 3	-3.75	s.e. 1.67
Sections 1.00	*units* 5	3.75	s.e. 1.67

***** Tables of means *****

Variate: Sodium

Grand mean 33.92

Treatmen	Control	17t/ha	24t/ha
	35.50	33.25	33.00

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	4.083

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: Sodium

Stratum	d.f.	s.e.	cv%
Sections	3	1.911	5.6
Sections.*Units*	6	3.337	9.8

Missing values: 12
Bush = 32

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(11.14*(1/4+1))
9.131278132

Variate: **Sulphur**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	70.298	23.433	1.01	
Sections.Treatmen stratum					
Treatmen	2	299.023	149.512	6.43	**0.032**
Residual	6	139.557	23.259	4.09	
Sections.Treatmen.*Units* stratum					
	12	68.180	5.682		
Total	23	577.058			

* MESSAGE: the following units have large residuals.

Sections 2.00	Treatmen 24t/ha	*units* 1	4.90	s.e. 1.69
Sections 2.00	Treatmen 24t/ha	*units* 2	-4.90	s.e. 1.69

***** Tables of means *****

Variate: Sulphur

Grand mean 10.94

Treatmen	Control	17t/ha	24t/ha
	5.95	13.40	13.48

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	5.900

***** Stratum standard errors and coefficients of variation *****

Variate: Sulphur

Stratum	d.f.	s.e.	cv%
Sections	3	1.976	18.1
Sections.Treatmen	6	3.410	31.2
Sections.Treatmen.*Units*	12	2.384	21.8

There is a significant difference between the **control and 17t/ha** and the **control and 24t/ha.**

Bush = 4.15
LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(23.259*(1/4+1))
13.19424351

Variate: **Zinc**

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Sections stratum	3	22.64	7.55	0.59	
Sections.*Units* stratum					
Treatmen	2	75.90	37.95	2.97	0.127
Residual	6(12)	76.67	12.78		
Total	11(12)	126.00			

* MESSAGE: the following units have large residuals.

Sections 3.00	*units* 1	4.84	s.e. 1.79
Sections 4.00	*units* 1	-4.17	s.e. 1.79

***** Tables of means *****

Variate: Zinc

Grand mean 10.00

Treatmen	Control	17t/ha	24t/ha
	11.00	11.50	7.50

*** Least significant differences of means ***

Table	Treatmen
rep.	8
d.f.	6
l.s.d.	4.373

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: Zinc

Stratum	d.f.	s.e.	cv%
Sections	3	1.121	11.2
Sections.*Units*	6	3.575	35.7

Missing values: 12
Bush = 14

LSD for Bush Plot Comparison =
t60.5 x Square Root (Residual m.s. (1/4 +1))
2.447*SQRT(12.78*(1/4+1))
9.780350136