DEFRA

WQ0206: AGRONOMIC BENEFITS AND ENVIRONMENTAL IMPACTS OF SPREADING ORGANIC MATERIALS TO LAND

APPENDIX C: DATA SUMMARIES AND REVIEW OF DATA

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APPENDIX C: DATA SUMMARIES AND REVIEW OF DATA

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1. INTRODUCTION

This section of the report (Appendix C) gives a summary analysis of the spread of data found in the data collation stage of the assessment.

Data was collated (where available) for the following parameters:

- pH
- % DM (Dry Matter)
- % Moisture content
- Total N
- Mineral nitrogen
- Extractable (available) N
- Total NH_3 (ammonium)
- Total NO_3 (nitrate) (water soluble)
- Total P (phosphate)
- Extractable (available) P or phosphate
- Total K (potassium)
- Extractable (available) K (potassium)
- Total S (sulphur)
- Extractable (available) S (sulphur)
- Total Mg (magnesium)
- Extractable (available) Mg (magnesium)
- Organic matter (or loss on ignition (LOI))
- Organic carbon % DM
- Zn (zinc)
- Cu (copper)
- Ni (nickel)
- Pb (lead)
- Cd (cadmium)
- Cr (chromium)
- Hg (mercury)

The extent of available organic waste characterisation data typically depended on the initial testing objective. Data was collected from over 4500 sets of analysis, and these were then sorted into generic categories which are discussed in this section.

Much of the testing has been undertaken to meet the analysis requirements for notification of paragraph 7 exemptions from Environmental Permitting. The parameters measured and the methods used are commonly not consistent and gaps are apparent for certain waste types and parameters. These gaps are most common for the more complex characteristics, which are expensive to analyse such as: biodegradability; bioavailability; leachability; toxicity; nitrogen mineralisation rate; organic pollutants and microbial pathogen content.

Data was reported in a huge range of units, making comparison between different waste streams a difficult process.

In the assessment of materials benefits and impacts, the average concentration of each waste stream is considered. However, as demonstrated in this Appendix, there is large variability within waste types.

2. DATA SUMMARIES

The data was collated both on a dry weight and wet weight ('as received') basis. The data collection exercise resulted in over 4600 records, containing over 90 000 separate measurements for all parameters. This data was then used for the subsequent risk assessments.

For some parameters (e.g. total nitrogen) data was available for almost all material and treatment types, and for most a large dataset was generated. For other parameters however, the dataset was relatively sparse.

Data summaries are reproduced in this appendix. Data is presented in the form of box-and-whisker plots as shown in Figure 2.1.

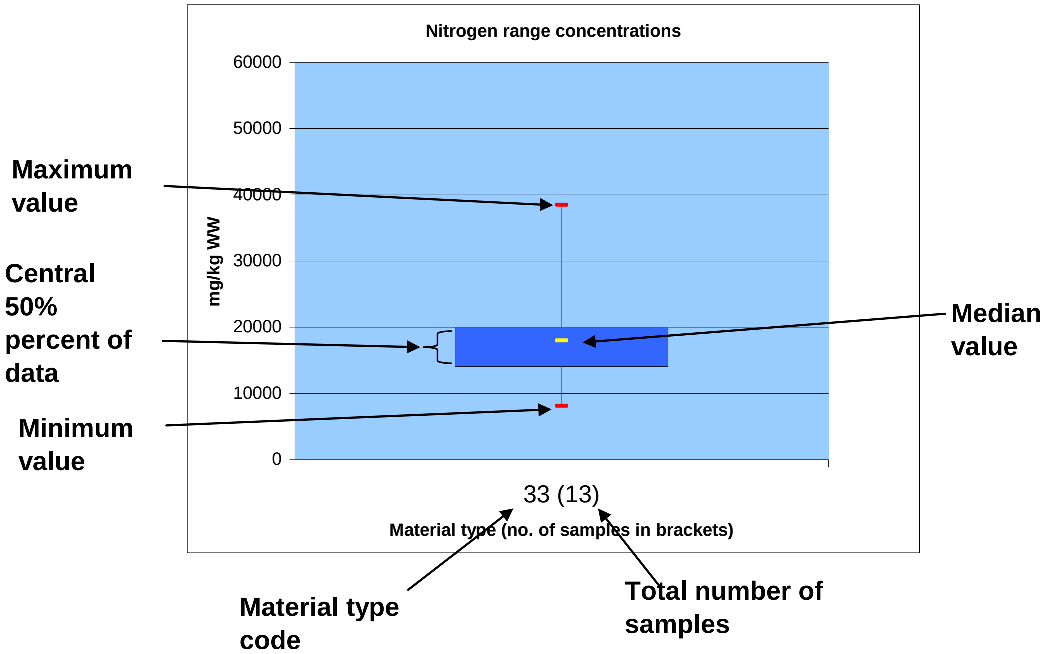

Figure 2.1 Example box and whisker type plot of nitrogen concentrations for composted separately collected municipal solid waste

The material type code is given on the x axis, and total wet weight concentration of nitrogen on the y axis. On the x axis, the total number of datapoints in the database are given in brackets. The dark blue box in each column represents the middle 50% of all measurements, and the yellow line the median value. The vertical lines capped by the horizontal red lines represent the total spread of the data.

These box and whisker plots allow rapid comparison of data. Where data was not available for a particular material or treatment type, it has been excluded from the plot for the sake of clarity. The scale on the y axis (concentration) has been chosen to best reflect the concentrations of most of the samples, and therefore for materials with very high maximum values these are not displayed. The list of waste type codes for which data has been collected are given in Table 2.2, and treatment type codes in Table 2.1. Each material for which data was collected was assigned a code on the basis of waste and treatment type. This allows comparison of waste characteristics by the input waste type, and also the treatment process to which it is subjected to. This appendix summarises the data collected for these waste and treatment types and highlights the major differences and similarities between them.

Table 2.1 Treatment type codes used in risk assessment

Treatment Code	Treatment
U	Untreated
D	Mesophilic AD
T	Thermophilic AD
C	Composting
P	Pasteurisation
M	Mechanical dewatered
H	Heat dried
A	Autoclaved
L	Lime stabilisation
Q	Liquid fraction
N	Not specified
W	waste class not specified (WRc inputed data)
G	Waste class and Treatment Class not specified A Godley inputed data)
LS	liquid storage for three months

Table 2.2 Waste type codes used in risk assessment

Waste Class	Description	Waste Class	Description
10	Manures	44	Vegetable Washings
11	Cattle Slurry	45	Vegetable Production Waste (Peelings, Choppings)
12	Pig Slurry	46	Sugar Processing
13	Cattle Manure	47	Wastes From Baking And Confectionary
14	Pig Manure	48	Beverage Production
15	Sheep Manure	49	Fish Farm Waste (Faeces And Uneaten Food)
16	Poultry Manure	40.1	Dairy Production Waste
17	Horse Manure	40.2	Catering Waste
18	Livestock Slurry	40.3	Kitchen Waste
19	Manures (General)	40.4	ABPR Waste
20	Sewage Sludge	40.5	Foodwaste (General)
21	Screenings	50	Biowaste (Mixed Organic Wastes)
23	Sludges From Biological Treatment Of Industrial Waste	51	Bio Waste Municipal
24	Activated Sludge	52	Biodegradable Kitchen And Canteen Wastes
25	Biological Aerated Filters	53	BMW
26	Sewage Sludge (General)	54	MBT Residues
30	Greenwaste	50.6	Green Waste And COM
31	Plant Tissue Waste	50.7	MSW And Manure
32	Garden And Park Waste	55	Manure And Biobin Material
33	Separately Collected Fraction MSW (Curb Side Collections)	70	Others
34	CA Site Greenwaste	71	De-Inking Sludges From Paper Recycling
35	Grass Cuttings	72	Wastes From Processing Sheep Fleeces
36	Source Segregated Green Waste	73	Dredgings
37	Wood	74	Construction And Demolition Wastes (Soil)
38	Greenwaste (General)	75	Chipboard
40	Foodwaste	76	MDF
41	Sludges From Washing And Cleaning For Food Preperation	77	Cardboard
42	Gut Content	78	Sludges From Treatment Of Drinking Water
43	Blood	N	Not Specified

3. COMPARISON OF WASTE CHARACTERISTICS

Data was collected on a dry weight and a wet weight basis (where data on dry matter was available). Data is by convention compared on a dry weight basis (i.e. not including the moisture content of the material), and such a comparison is shown in this section. It offers a useful summary of the data, but for a true comparison of the material as they are applied to land, the data must be studued on a wet weight basis, and this is shown in Section 4.

3.1 <u>Material type</u>

3.1.1 Nitrogen range concentrations

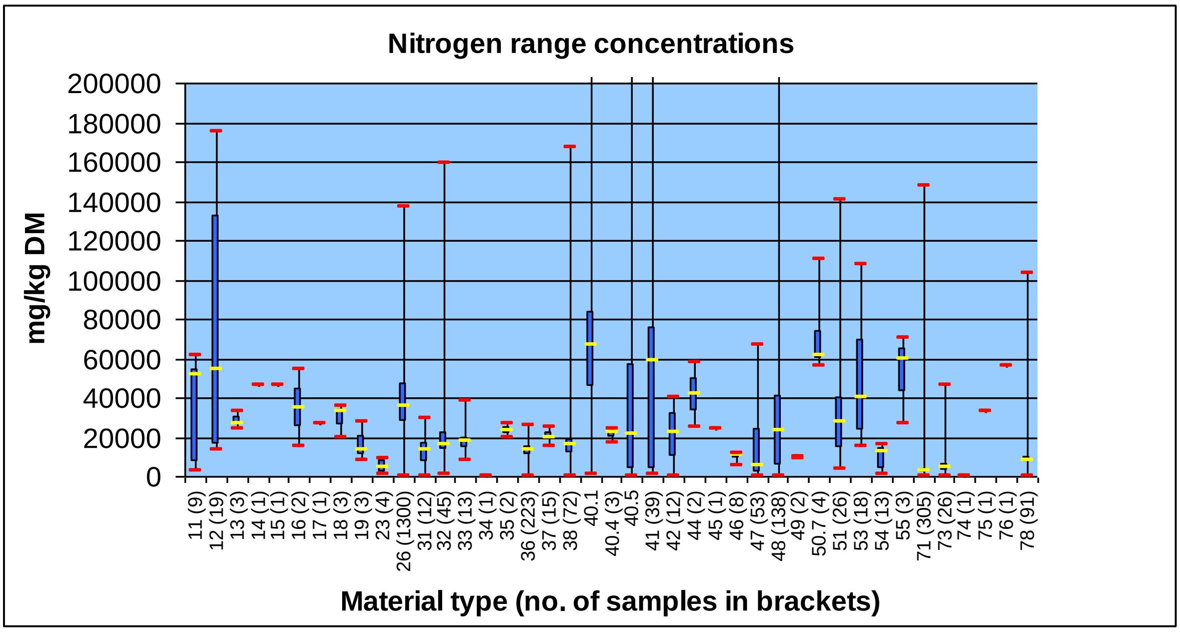

Figure 3.1 Nitrogen range concentrations by material type

Nitrogen was the parameter for which the most substantial dataset was available, with over 3000 measurements recorded. As discussed in Appendix A, this is generally because nitrogen content of the material is the most common justification for applying waste to land. Figure 3.1 shows the range of nitrogen concentrations for different waste types. This plot incorporates all waste treatment types.

The striking point about the plot is the range of values reported, which span several orders of magnitude for most waste types where a large number of data points have been collected. The long tail on the upper quartile for e.g. waste code 38 (greenwastes) shows that whilst the middle 50% of the data collected spans a relatively small range of values (11900 mg/kg to 18900 mg/kg) a few values collected skew the whole set of data. (max 167000 mg/kg). Whilst care has been taken to exclude erroneous data, where this data is as reported the results have been included in the assessment to show the breadth of results reported.

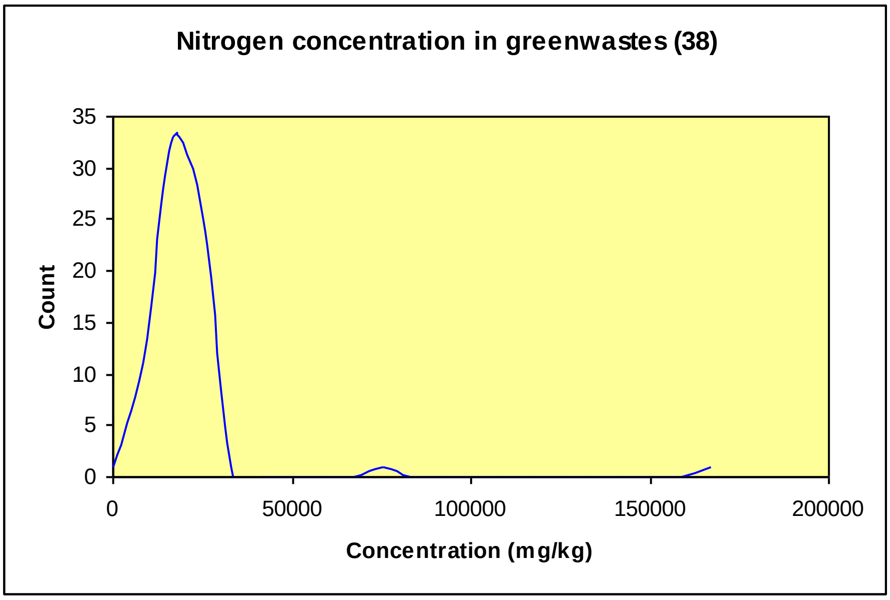

Figure 3.2 Nitrogen range concentrations for green wastes (code 38)

Figure 3.2 shows the distribution of results for greenwastes, and shows that the vast majority of results are less than 35 000 mg/kg (95th percentile is 22 000 mg/kg.

Dairy production wastes had the highest average nitrogen concentration by dry weight, but again the variability was very high. This may reflect the large number of different types of waste that may be included in this category, such as off specification milk, wash down waters, lairage waste and waste from manufacture of yoghurt and cheese.

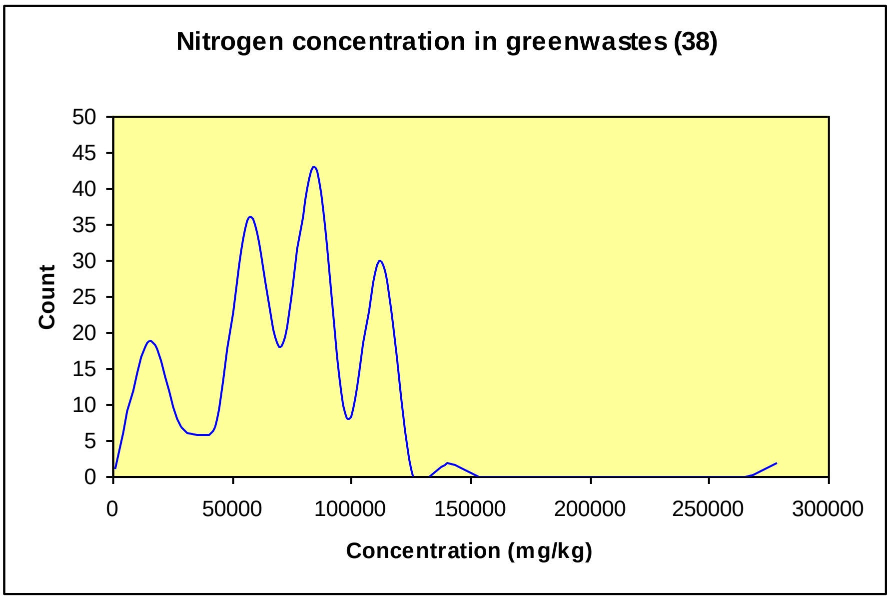

Figure 3.3 Nitrogen range concentrations for dairy wastes (code 40.1)

Wastes with low total nitrogen content include MBT residues, de-inking sludges from paper recycling, MBT residues and wastes from baking and confectionary. Even for these wastes there was a high degree of variability, which again may reflect the broad number of sources of analysis, or the various types of materials that are included in these categories.

3.1.2 Available nitrogen range concentrations

There was not a large amount of data available nitrogen. Figure 3.4 summarises the results obtained.

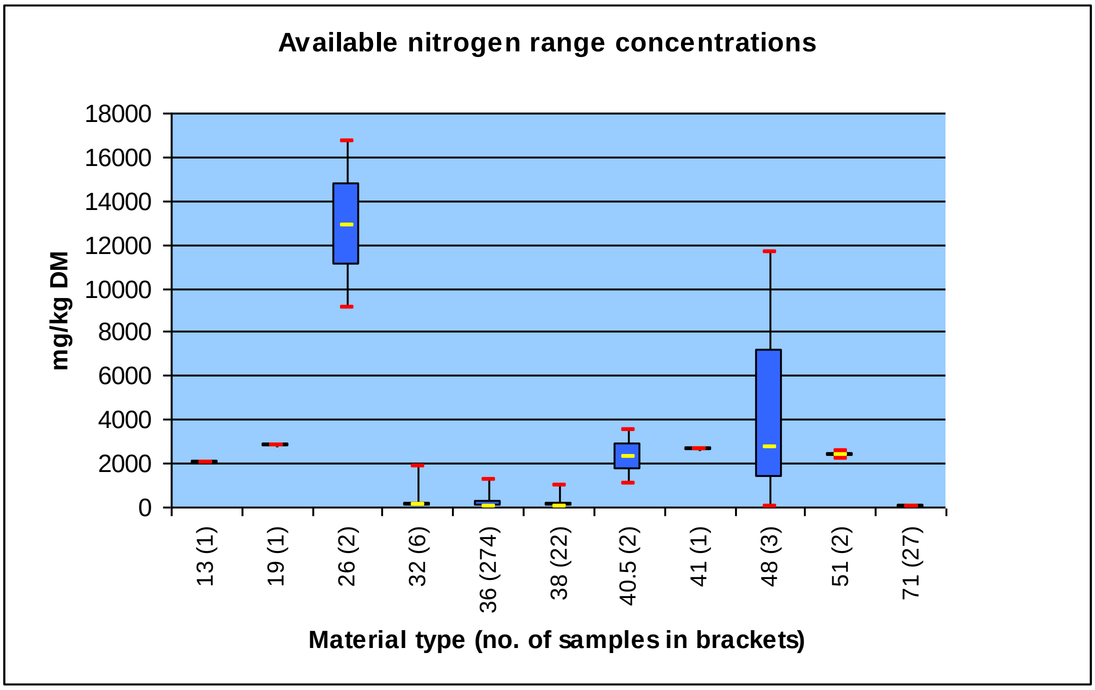

Figure 3.4 Available nitrogen range concentrations by material type

The results do highlight that sewage sludge (material code 26) has a high available nitrogen content compared with other waste materials, although a low number of data points were collected.

3.1.3 Phosphorus range concentrations

The phosphorus range concentrations are shown in Figure 3.5. Materials with high phosphorus content include pig and cattle slurry (12 and 18) and sewage sludge (26).

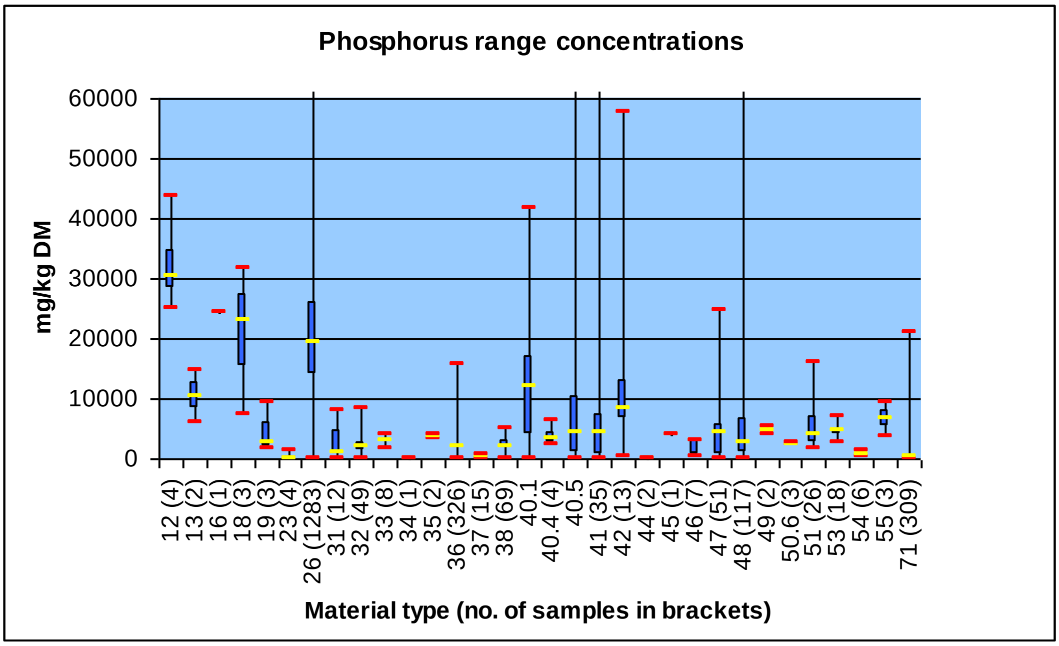

Figure 3.5 Phosphorus range concentrations by material type

For the central 50% of sewage sludges, the range of phosphorus concentrations are reasonably small (14000 mg/kg to 26000 mg/kg) considering the size of the dataset (1300). The spread of data for sewage sludge is shown in Figure 3.6.

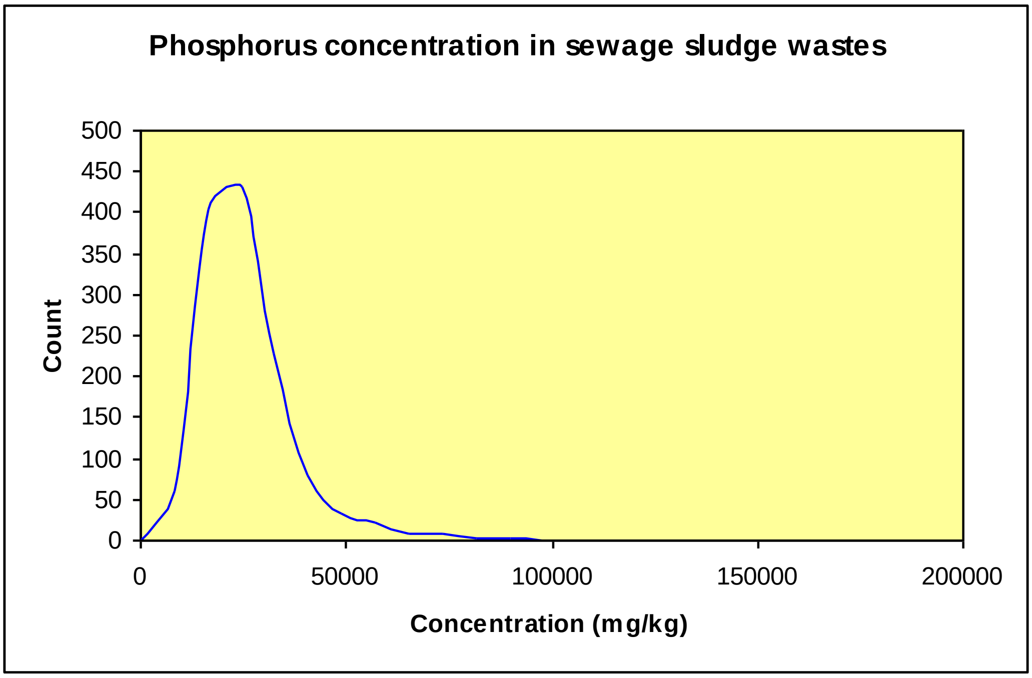

Figure 3.6 Phosphorus range concentrations for sewage sludge

3.1.4 Phosphorus range concentrations

As with available nitrogen, we were not able to collect a substantial amount of data for available phosphorus. A summary of the data that was collected is shown in Figure 3.7.

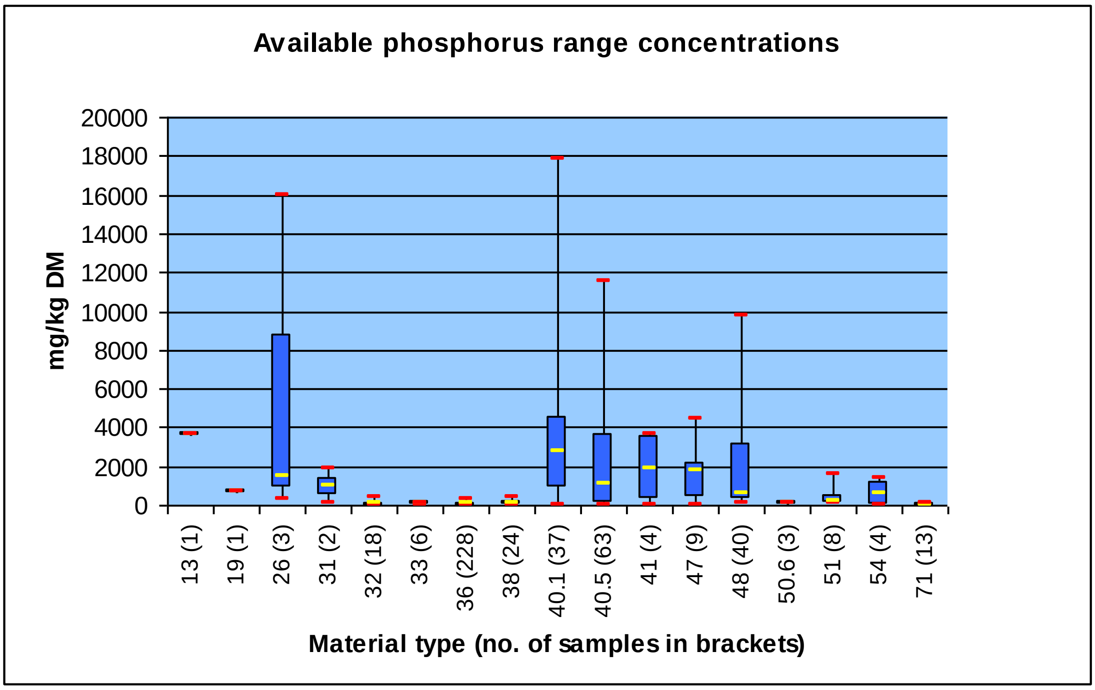

Figure 3.7 Available phosphorus range concentrations by material type

3.1.5 Potassium range concentrations

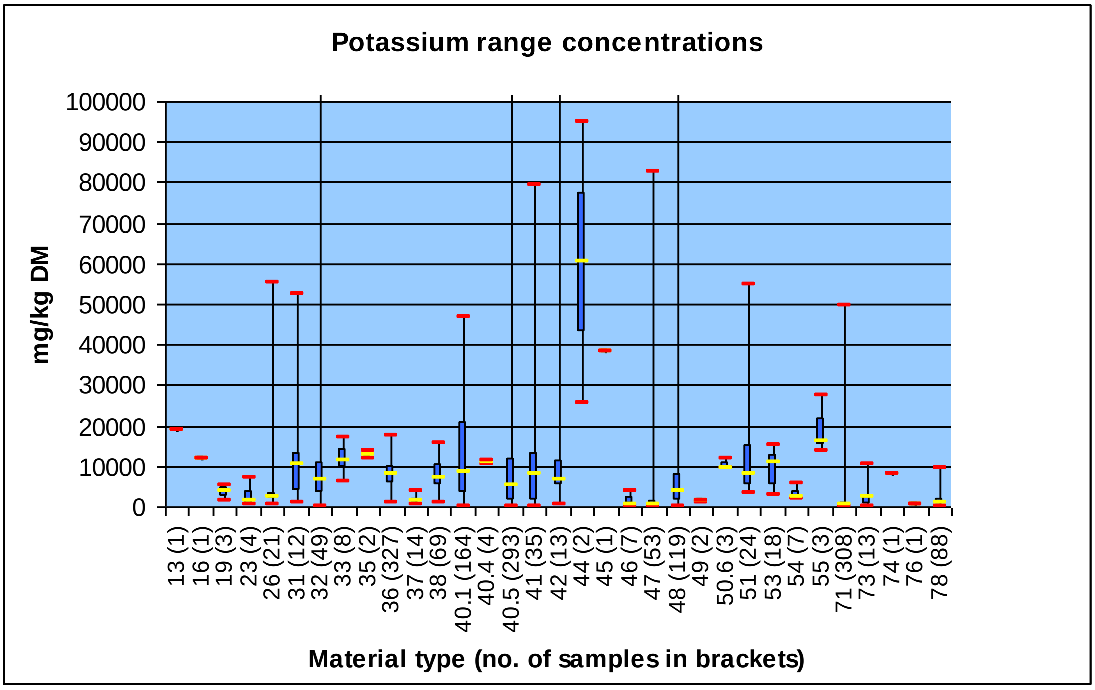

Figure 3.8 Potassium range concentrations by material type

The potassium range concentrations are shown in Figure 3.8. It shows as would be expected that greenwastes have a much higher concentration of potassium than sewage sludge. De-inking sludges from paper recycling have a very low potassium concentration, as do sludges from treatment of drinking water.

3.1.6 Available potassium range concentrations

The available potassium range concentrations give a similar situation scenario as the total potassium concentrations. Sewage sludge and manures have a very low potassium concentration (albeit based on a small sample number) as do de-inking sludges and sludges from treatment of drinking water. Green wastes have a much higher available potassium concentration, with a relatively small range of values, suggesting that the available potassium in greenwastes do not vary a great deal. Dairy production wastes have a much larger range of available potassium concentrations. As previously stated this may be due to the large number of waste types in this category.

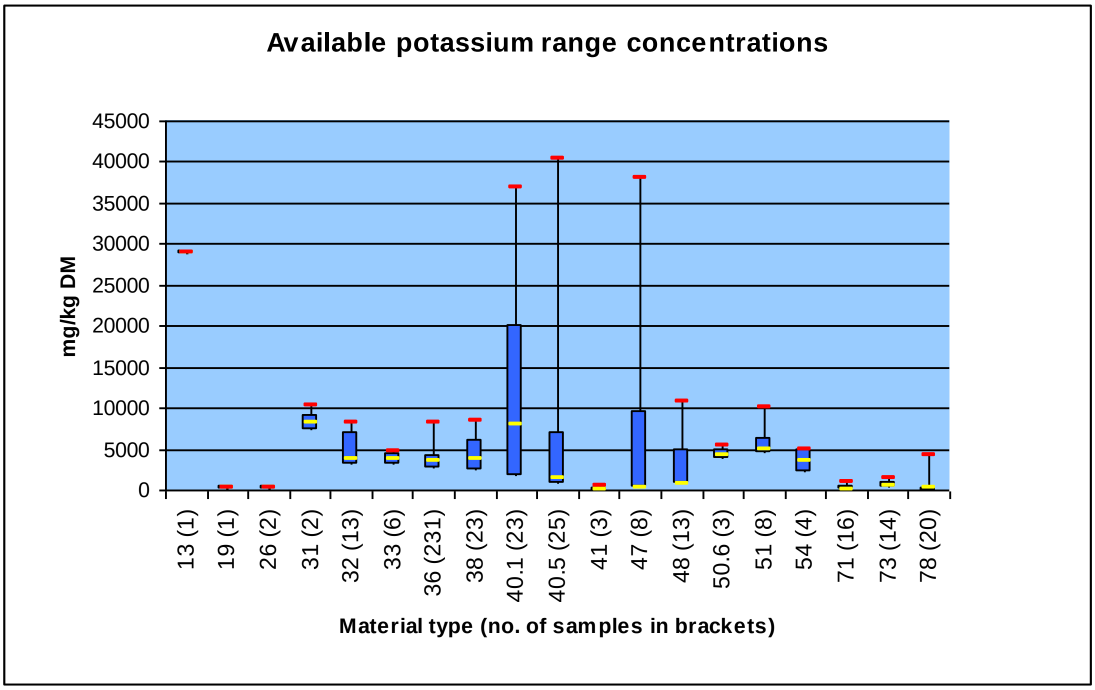

Figure 3.9 Available potassium range concentrations by material type

3.1.7 Metals

The concentrations of metals found in the various material types are given in plots 3.10 – 3.16. Biodegradable municipal waste (BMW) and MBT residues generally have a high metal concentration, and a high variability, reflecting the large variation of waste inputs for these waste streams. Interestingly, the study found that metal concentrations in MBT residues and BMW were comparable or lower than those of sewage sludge (with the exception of nickel and cadmium). MBT residues are not currently permitted to be spread to land under paragraph 7 exemptions, and metal concentration is one of the major concerns with applying MBT residues to land.

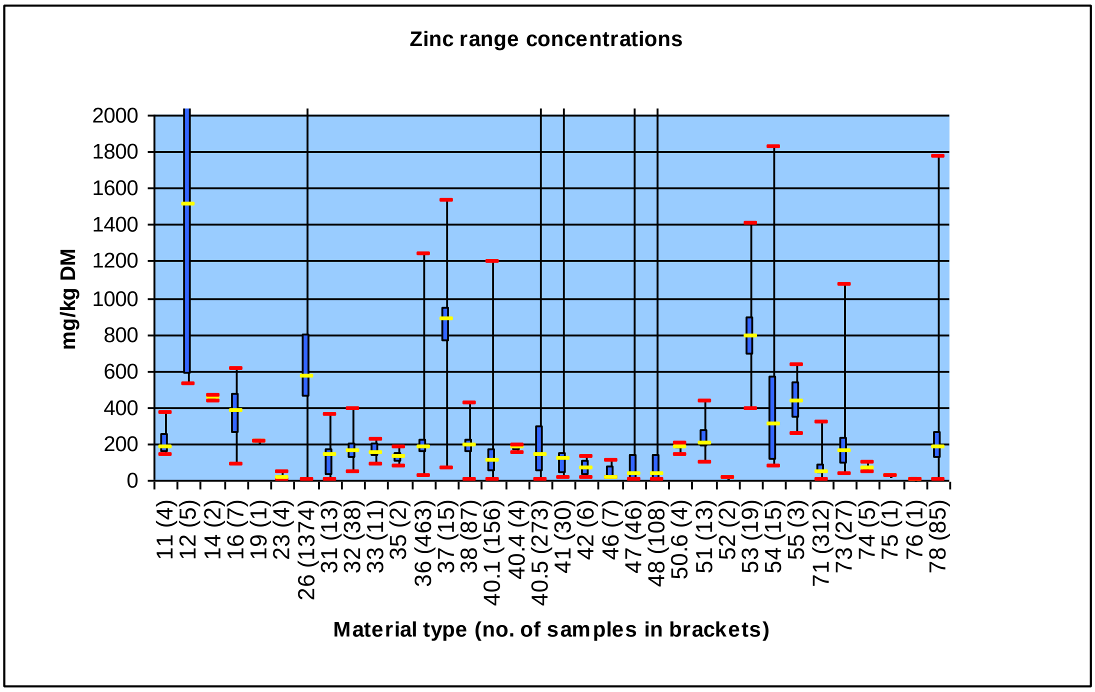

Figure 3.10 Zinc range concentrations by material type

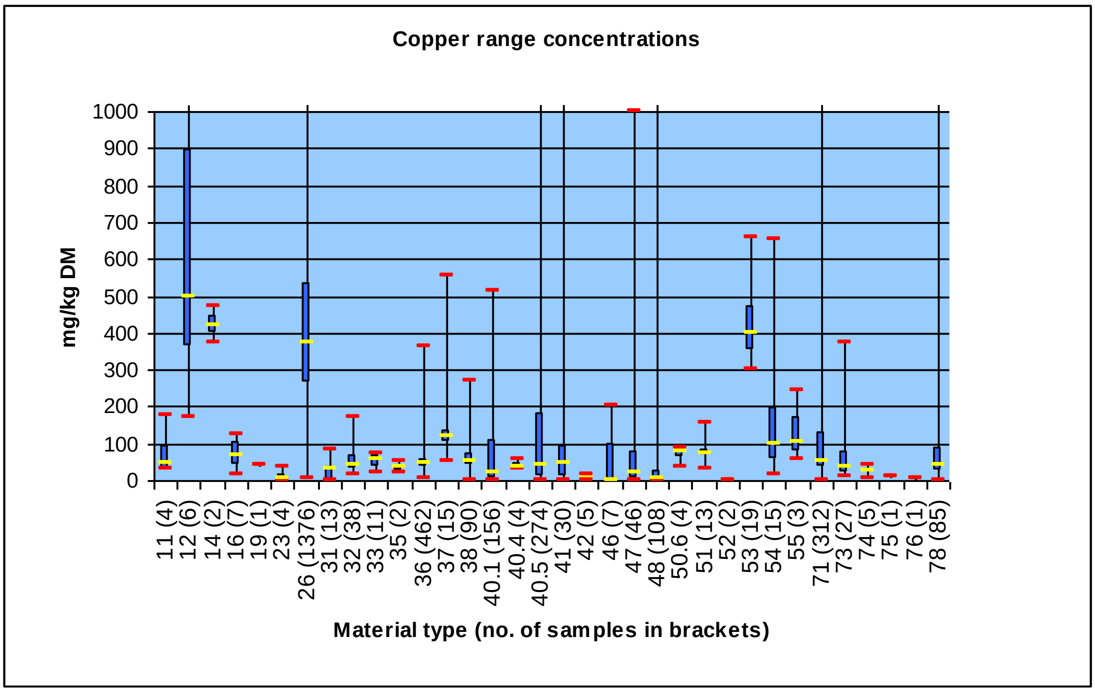

Figure 3.11 Copper range concentrations by material type

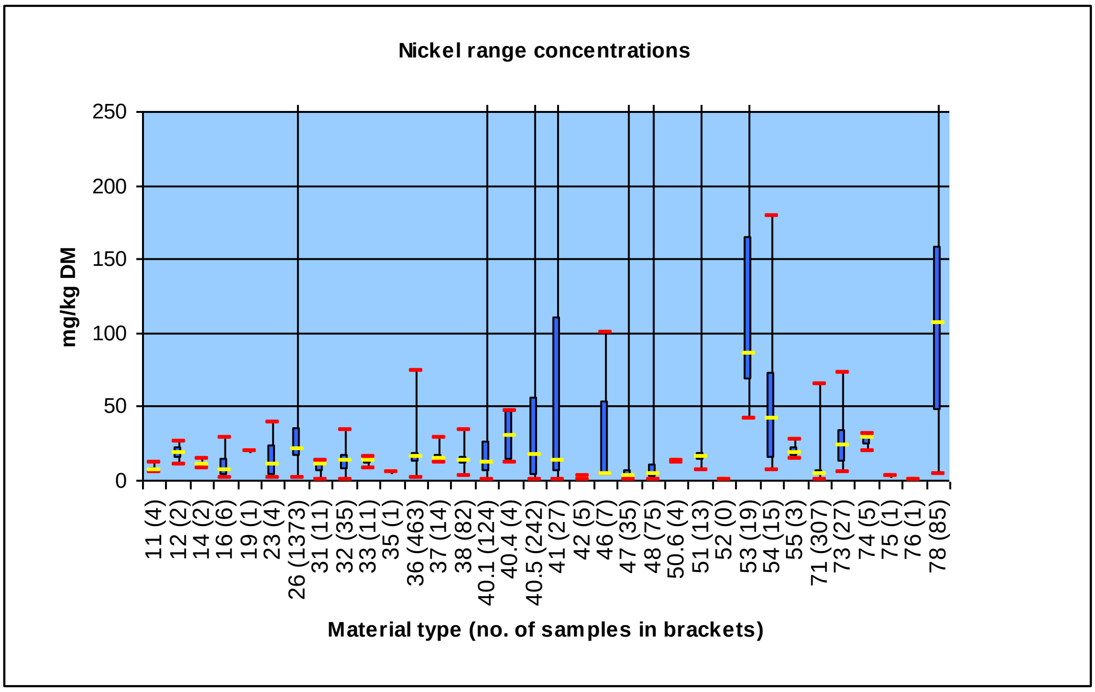

Figure 3.12 Nickel range concentrations by material type

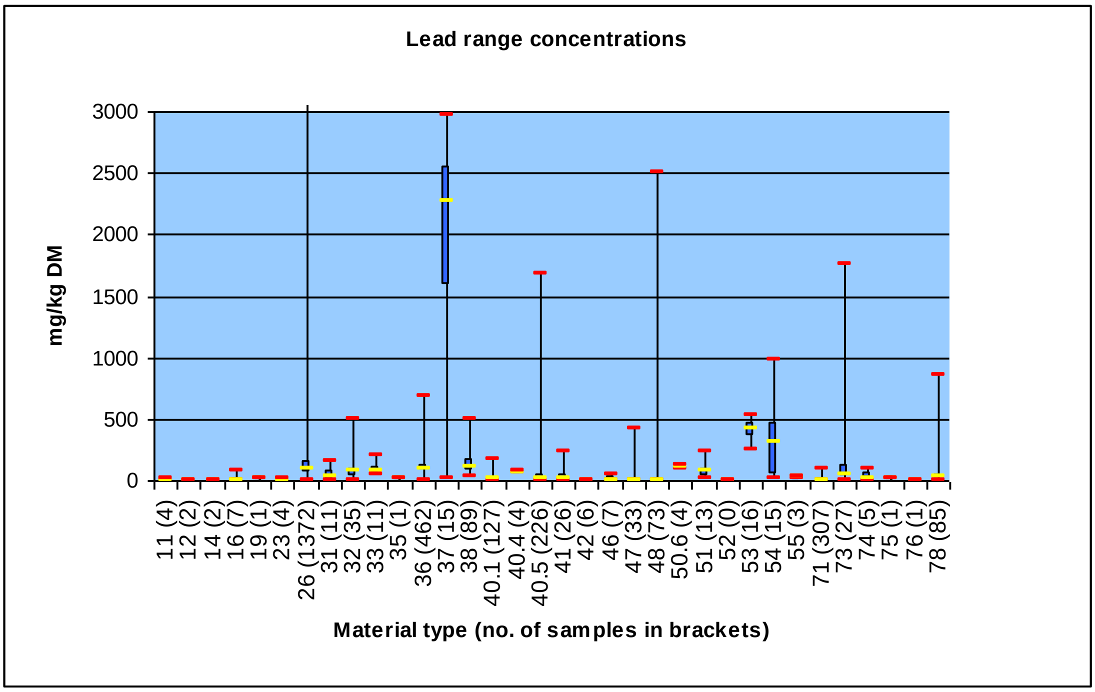

Figure 3.13 Lead range concentrations by material type

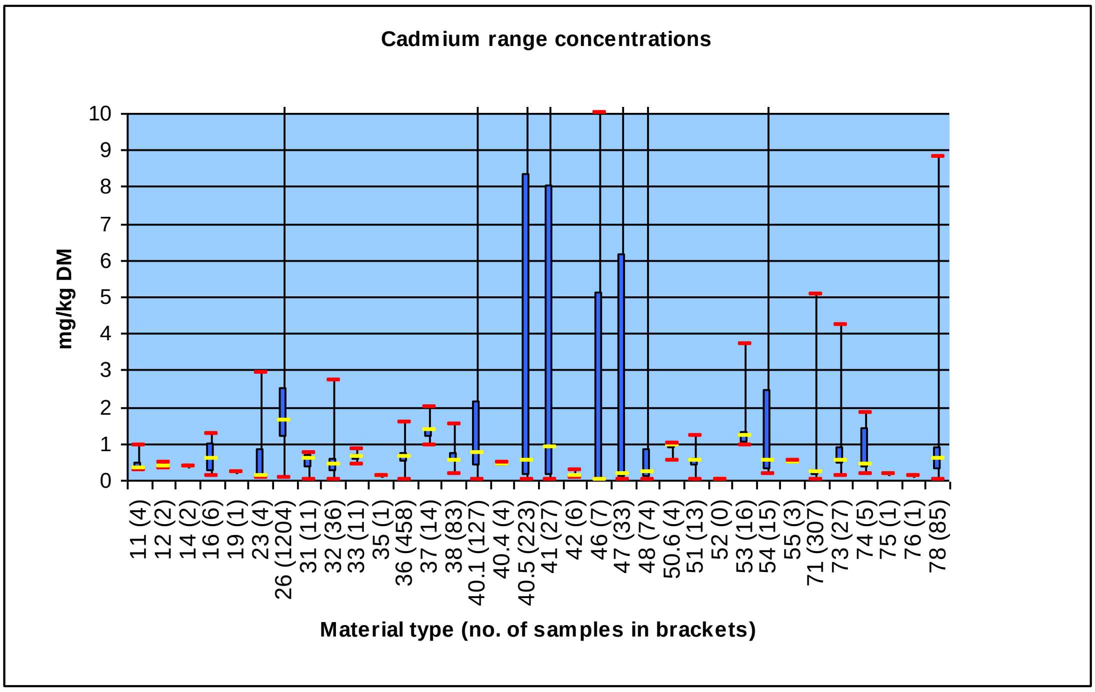

Figure 3.14 Cadmium range concentrations by material type

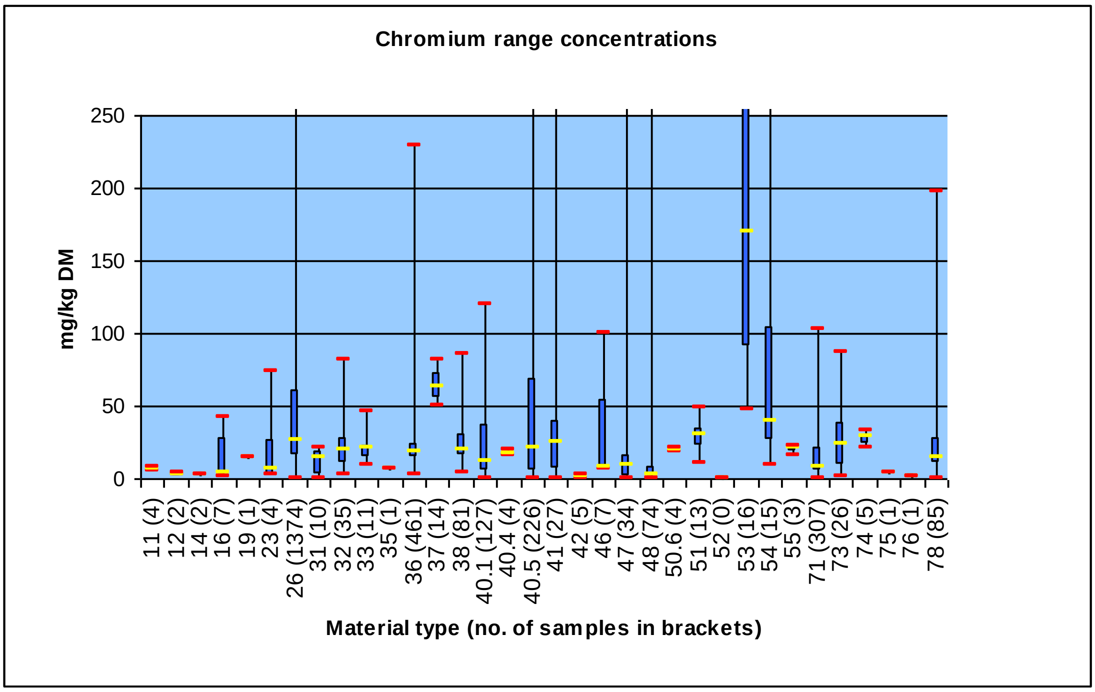

Figure 3.15 Chromium range concentrations by material type

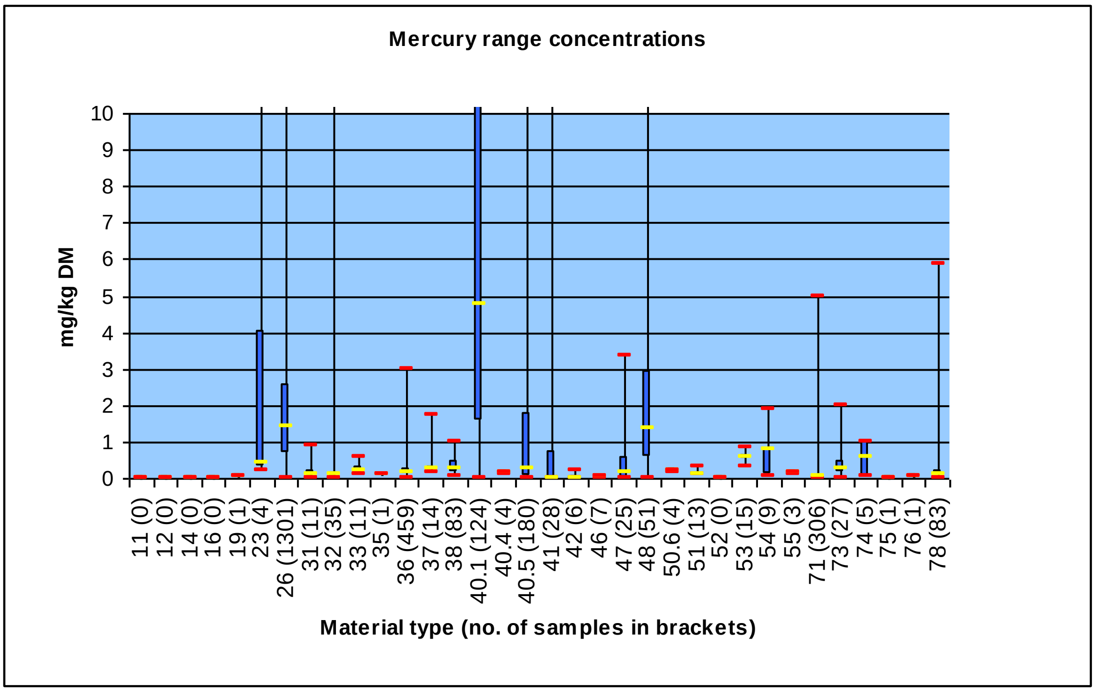

Figure 3.16 Mercury range concentrations by material type

3.2 Discussion on range concentrations

The data summaries show that for many parameters there is a large variability of values within a particular waste input type. This reflects the diverse range of data used in the assessment, as well as variations on material and treatment type.

For example, for greenwaste, where we have gathered a substantial amount of data, it can be clearly seen in the plot below that there is large variability within this single waste stream, as shown in Figure 3.14.

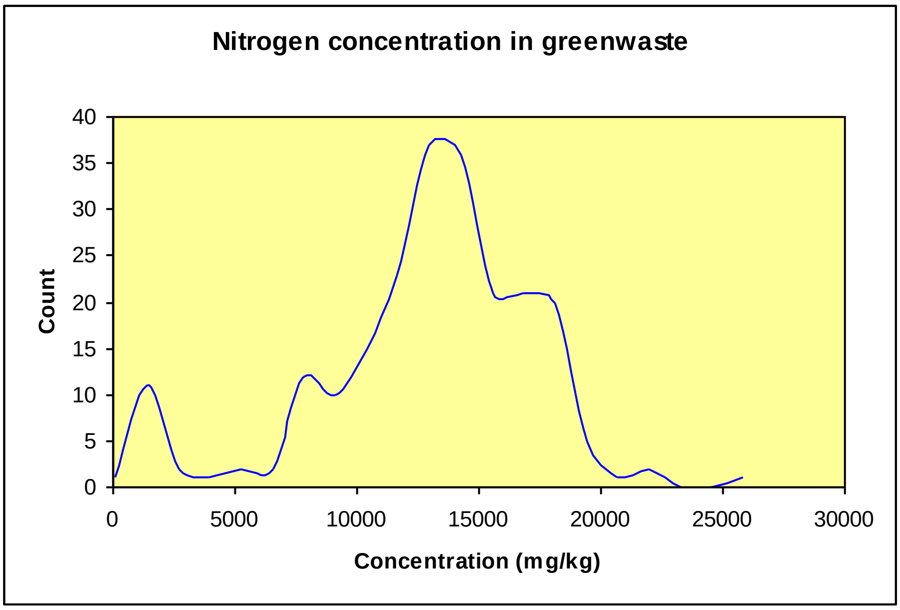

Figure 3.17 Distribution of nitrogen range concentrations for material source segregated greenwaste (material code: 36)

All data collected on greenwaste was on material that had been aerobically composted.

3.2.1 Sewage sludge by treatment type

Sewage sludge was the material where we collected the strongest dataset, and is therefore worth considering separately. The plots below show data collected for sewage sludge by treatment type, and therefore gives a useful comparison on treatment methods.

Data was collected on the following treatment types for sewage sludge.

Table 3 Treatment types for sewage sludge

Treatment class	Treatment
C	Composting
DM	Mesophilic AC with mechanical dewatering
D	Mesophilic AD
H	Heat dried
L	Lime stabilisation
LS	Liquid storage for three months
M	Mechanical dewatered
R	Anaerobic digestion (type unspecified)
TM	Thermophilic AD with mechanical dewatering
T	Thermophilic AD
U	Untreated

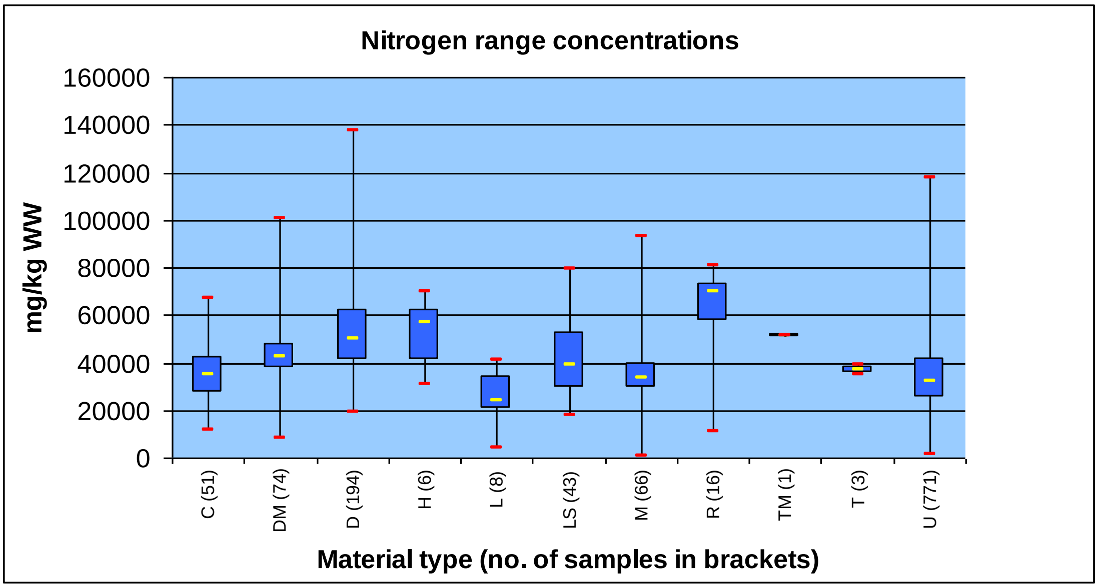

Figure 3.18 Nitrogen range concentrations in sewage sludge for different treatment types

Figure 3.18 shows the range of concentrations for sewage sludges by various treatment types on a wet weight (as applied) basis. The total nitrogen value does not appear to vary a great deal between treatment types, as most of the ranges over lap. It can be seen however that where mechanical dewatering has taken place the total nitrogen concentration is lower. This is because a large proportion of the total nitrogen will be in the liquid phase. Where the sewage sludge has been composted or was untreated the average nitrogen concentration was lower, but there is overlap in the ranges.

Unfortunately there was no data collected on available nitrogen and therefore a comparison for this parameter between treatment types cannot be made.

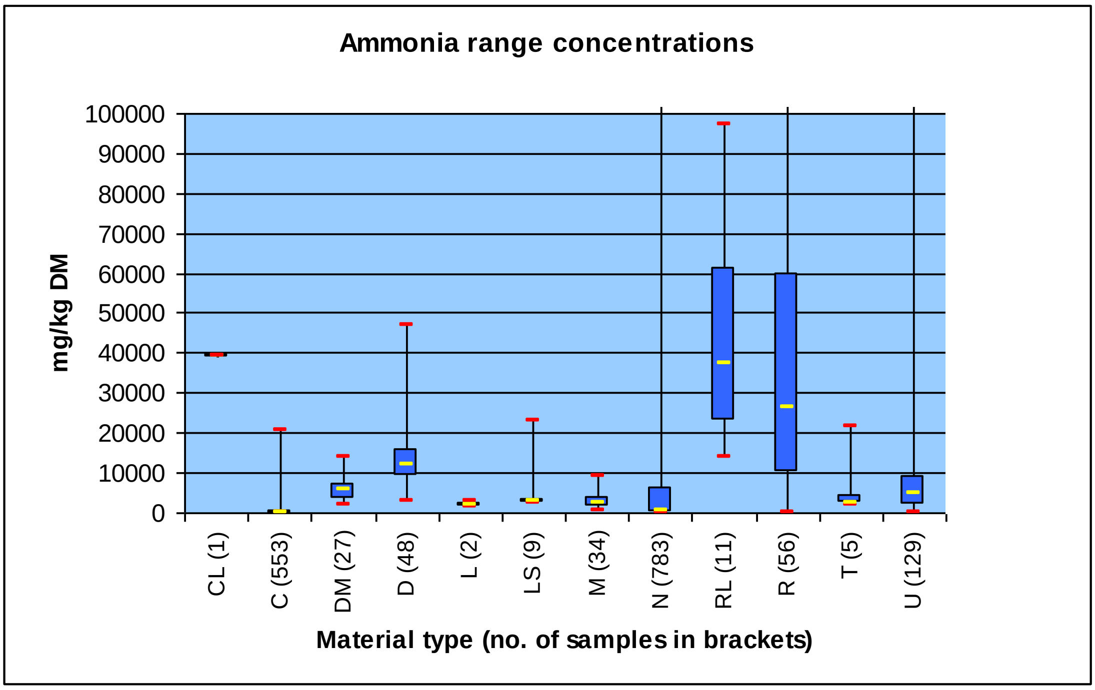

Figure 3.19 Nitrogen range concentrations in sewage sludge for different treatment types

The above plot shows the range data for ammonia concentrations for different treatment types. The range for anaerobic digestates (R) is extremely large reflecting the different materials that are being digested.

Figure 3.20 shows ammonia concentrations for anaerobic digestates by input material type. Anaerobic digestates generally contain little or no NO_2, and there for ammonia can be considered a surrogate for total mineral (easily available) nitrogen. The data shows that ammonia concentrations are higher in digested sewage sludge than in digested cattle slurry. Highest nitrogen concentrations were found in digested municipal solid waste (51).

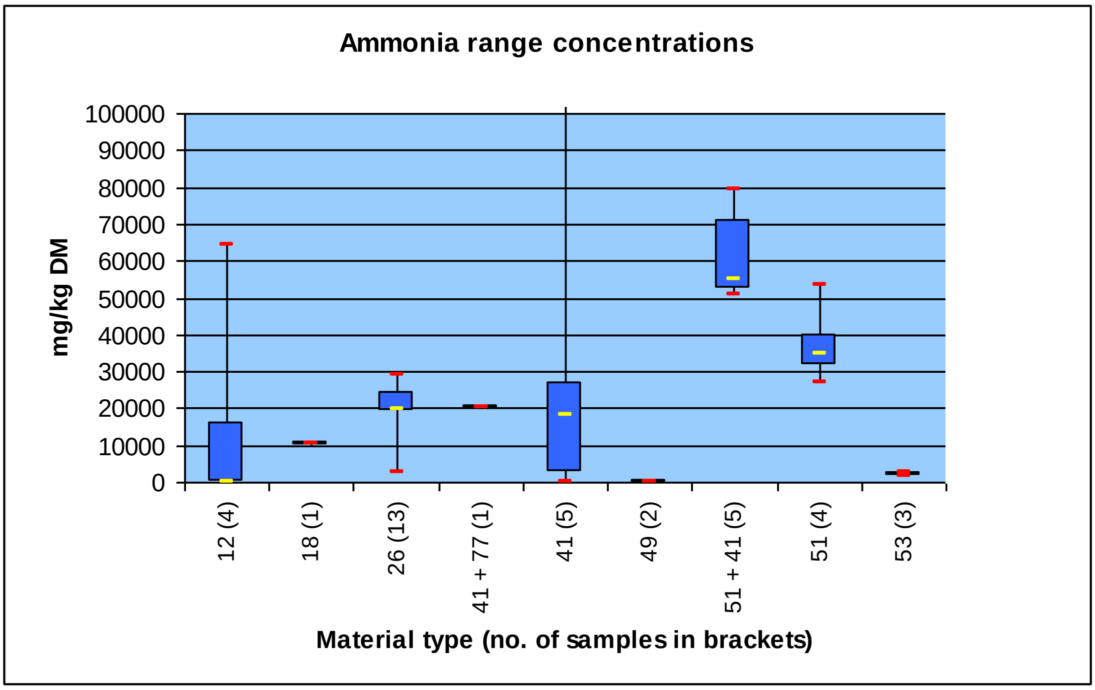

Figure 3.20 Ammonia range concentrations in sewage sludge for different treatment types

Figure 3.21 compares nitrogen concentrations for different input materials. High nitrogen concentrations were found for composted manure and municipal waste was much lower.

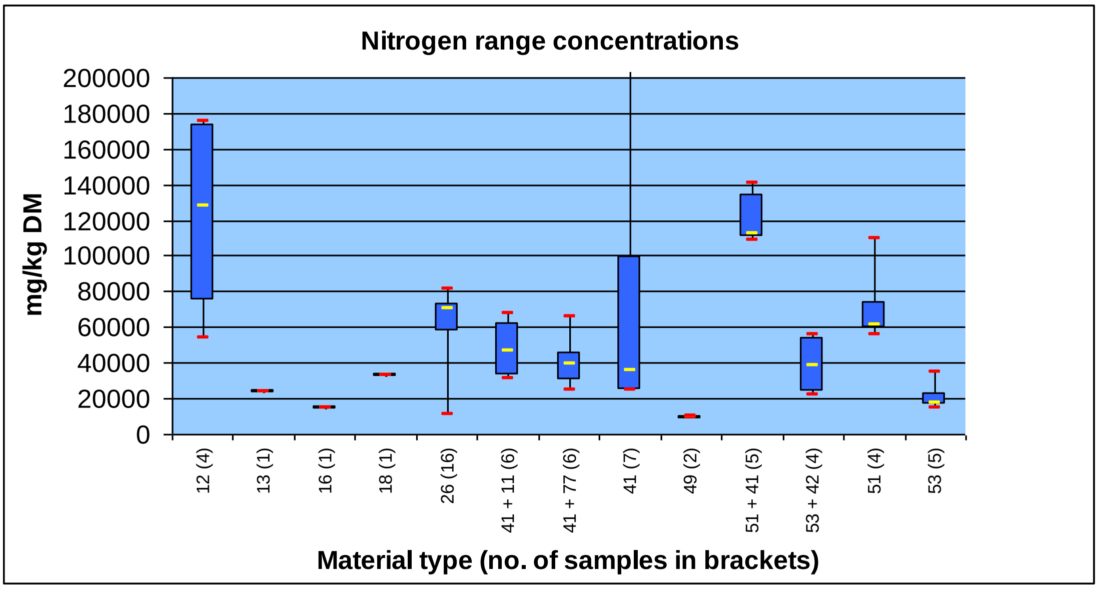

Figure 3.21 Nitrogen range concentrations for composted materials

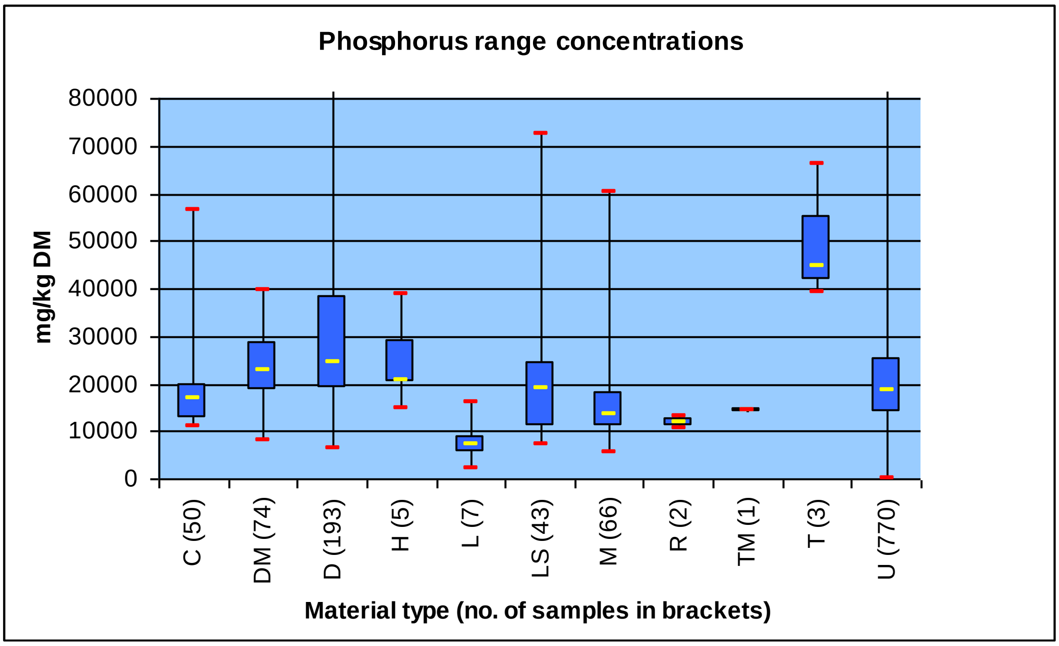

Figure 3.22 Phosphorus range concentrations in sewage sludge for different treatment types

It should be noted that much of the data on sewage sludge was collected prior to implementation of the Water Framework Directive. Therefore data collected on sewage sludge more recently may well have higher concentrations of phosphorus as the requirements of the WFD to reduce P concentrations in STW effluents.

Concentrations of metals in the sewage sludge did not vary significantly between treatment type.

3.3 By treatment type

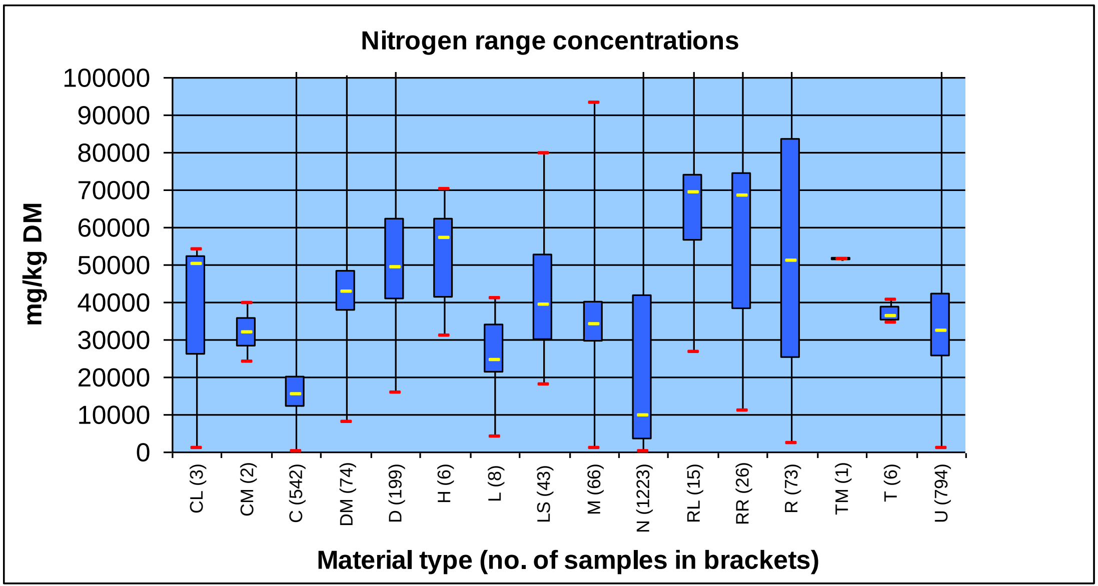

Figure 3.23 Nitrogen range concentrations for different treatment types

The range for composted materials (C) was found to be one of the least variable of any treatment type. This suggests that nitrogen concentration does not vary when input waste type changes. Anaerobic digestates (R) were much more variable spanning a much larger range, despite the fact that there was much less data available for this treatment type. Despite the variability seen for anaerobic digestates, it can still clearly be seen that on average composts have a lower nitrogen concentration that for anaerobic digestates. No significant difference was seen for the different types of anaerobic digestates (thermophillic or mesophillic).

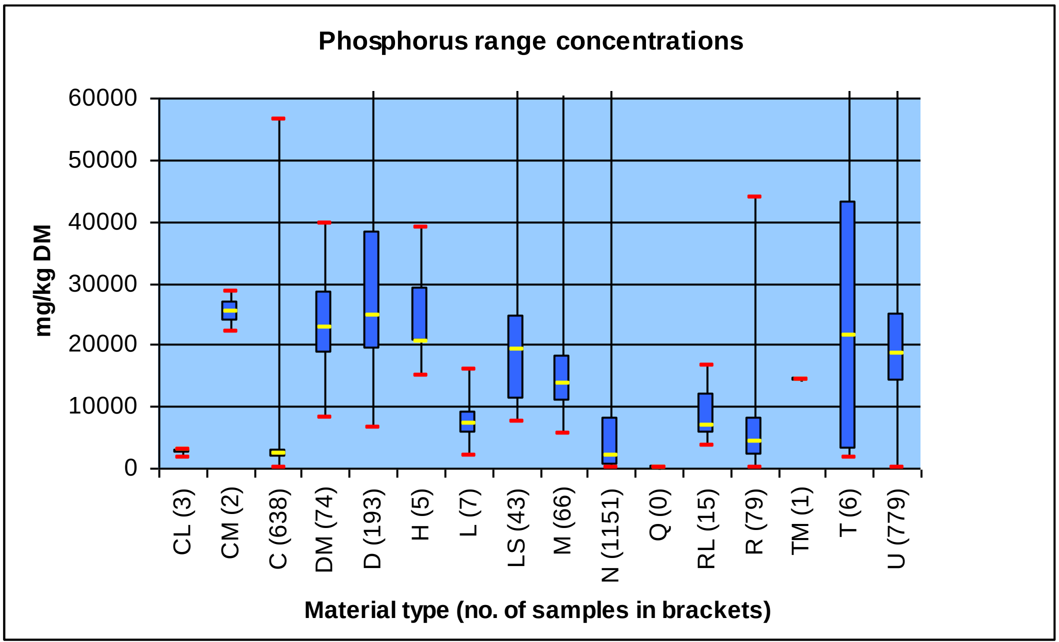

Figure 3.24 Phosphorus range concentrations for different treatment types

As with nitrogen concentrations, compost (C) phosphorus concentrations were much lower than most other treatment types.

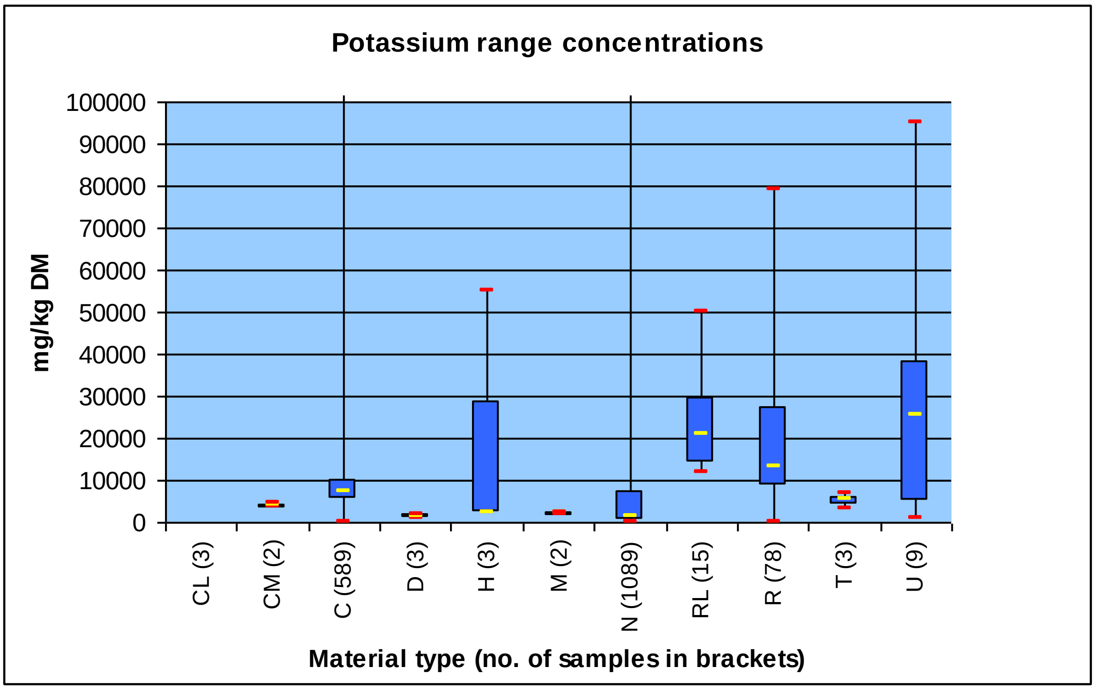

Figure 3.25 Potassium range concentrations for different treatment types

3.4 Metals

There is less difference in the concentrations of metals for treatment types than for waste types. This is because metals concentrations are not changed in the process(other than being concentrated after loss of some organic material and moisture). Therefore treatment type is not good for predicting the concentration of metals in a substance.

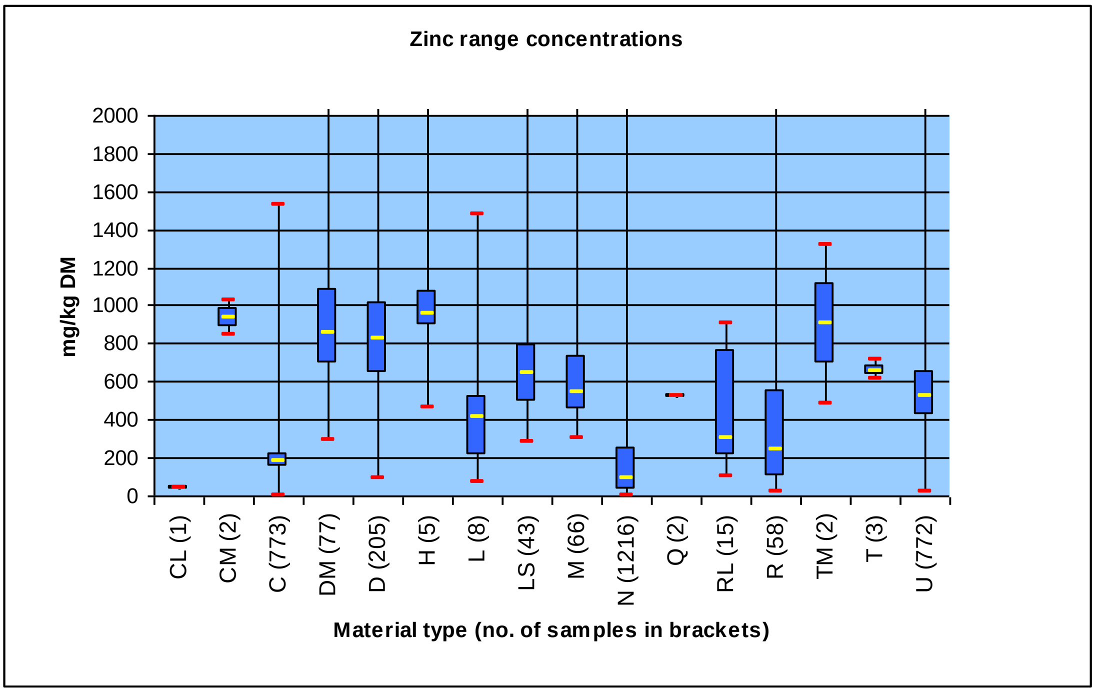

Figure 3.26 Zinc range concentrations for different treatment types

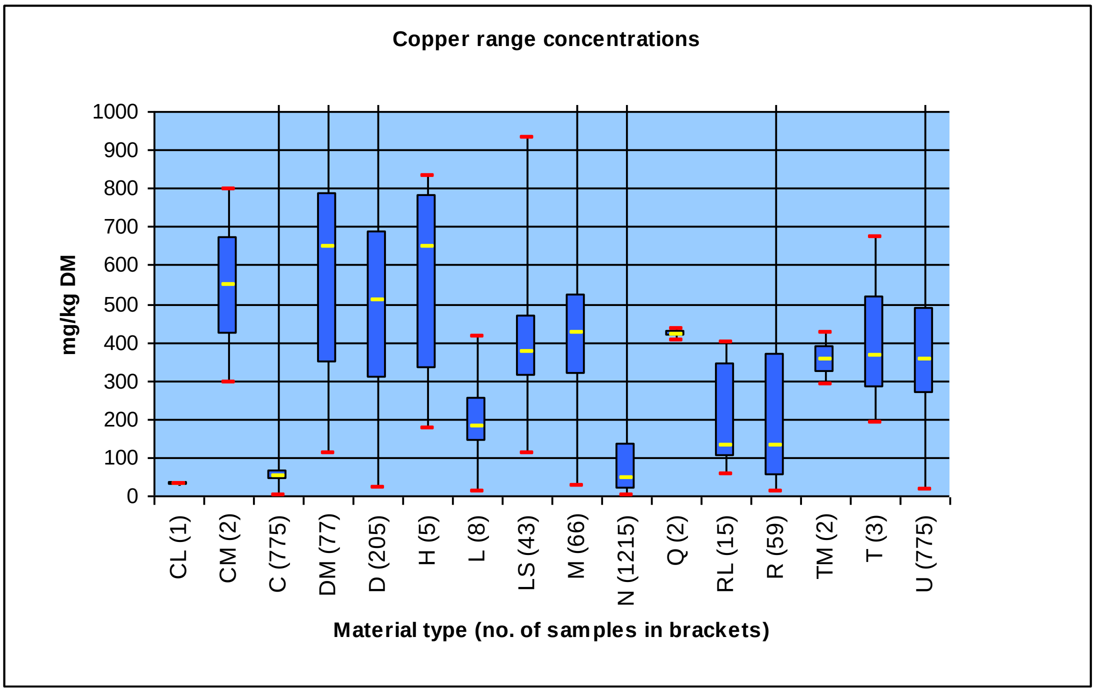

Figure 3.27 Copper range concentrations for different treatment types

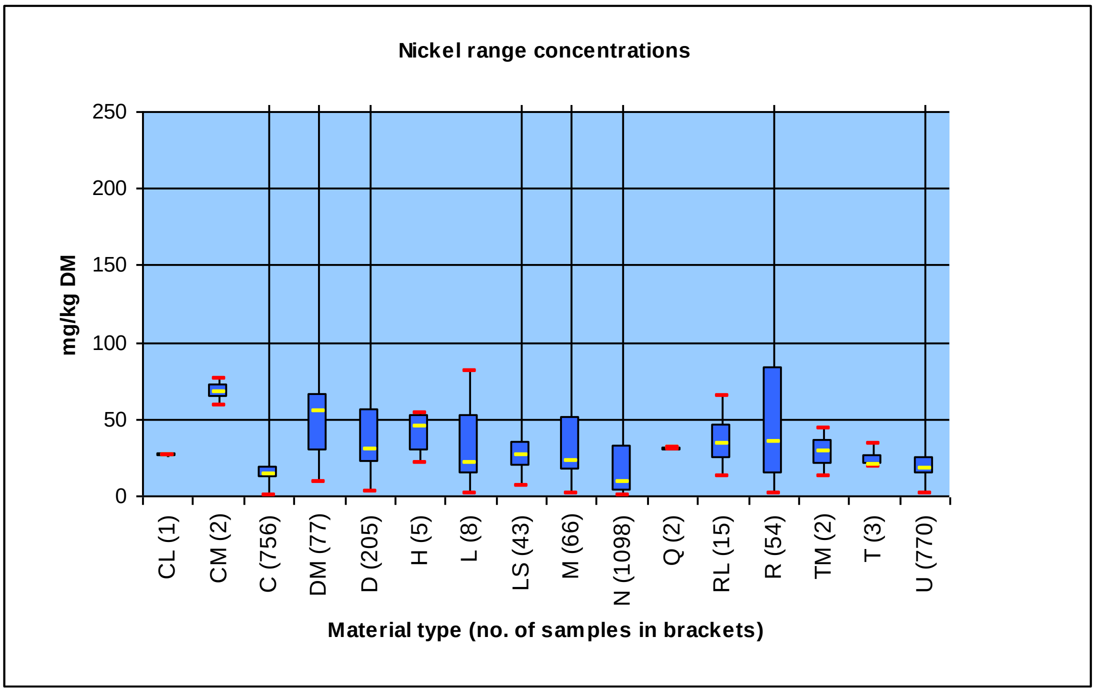

Figure 3.28 Nickel range concentrations for different treatment types

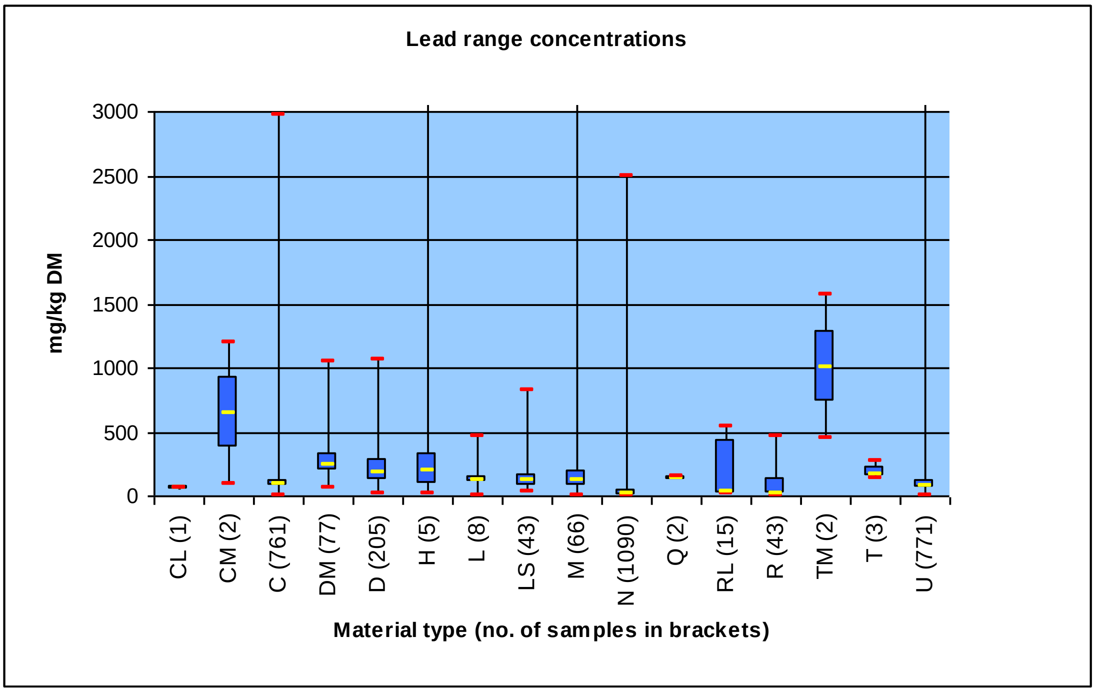

Figure 3.29 Lead range concentrations for different treatment types

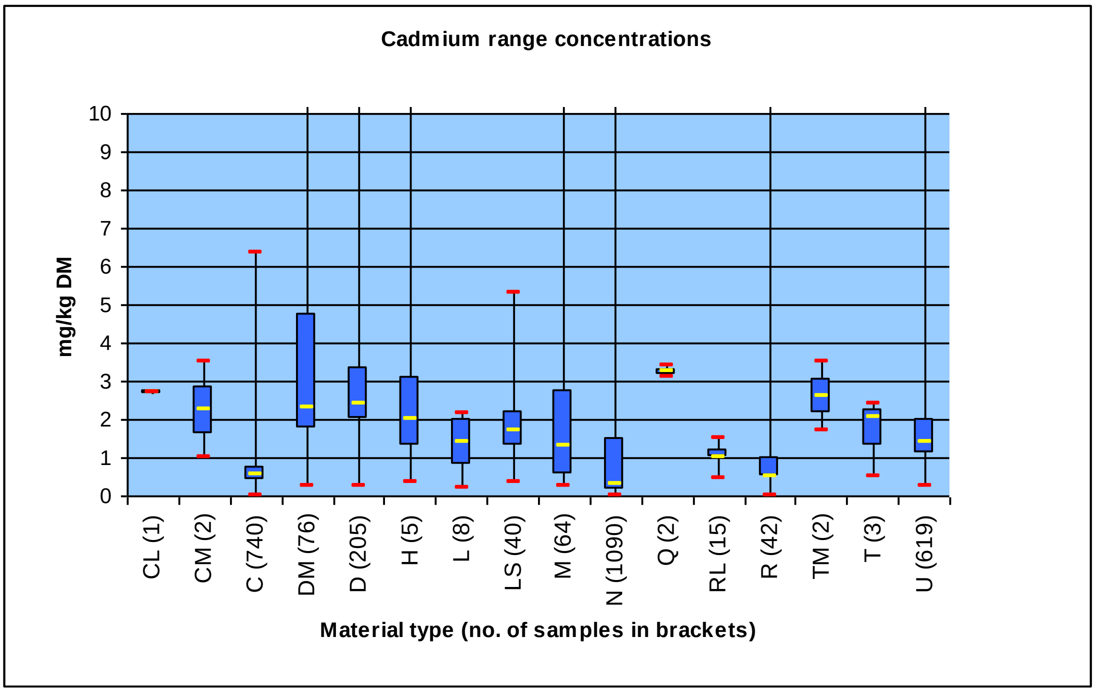

Figure 3.30 Cadmium range concentrations for different treatment types

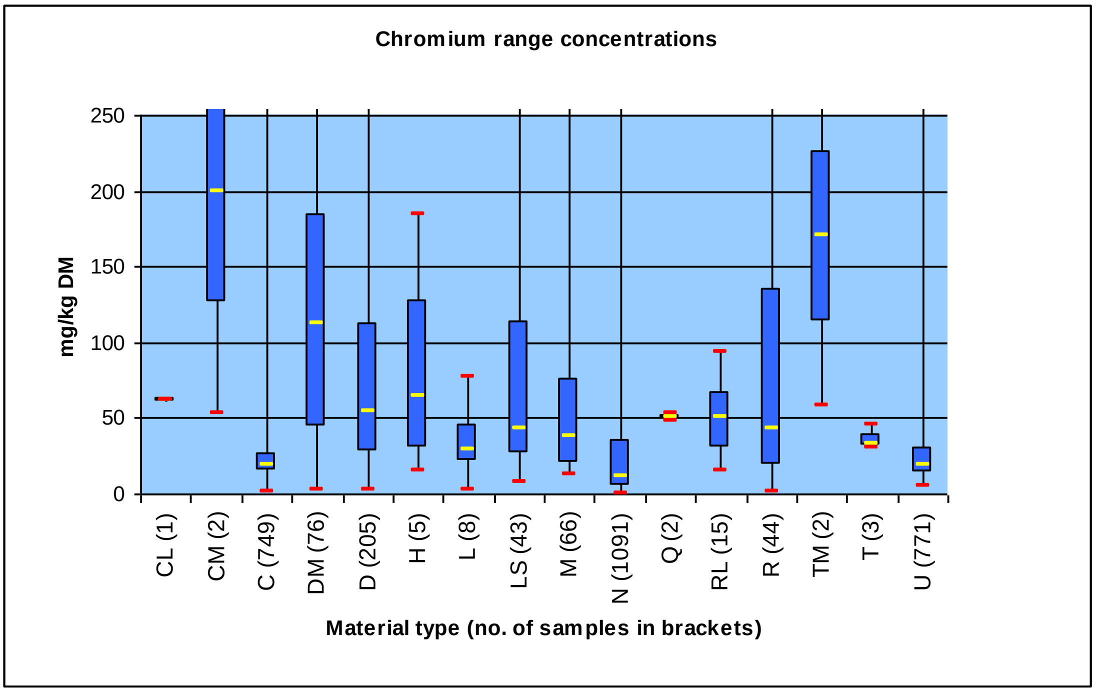

Figure 3.31 Chromium range concentrations for different treatment types

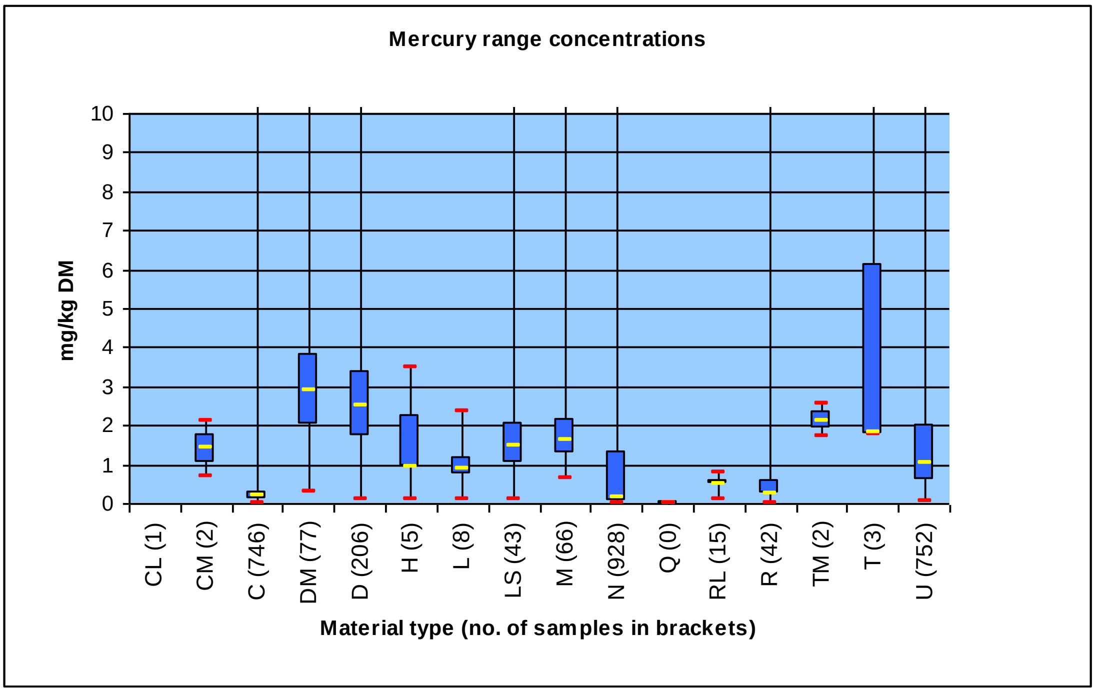

Figure 3.32 Mercury range concentrations for different treatment types

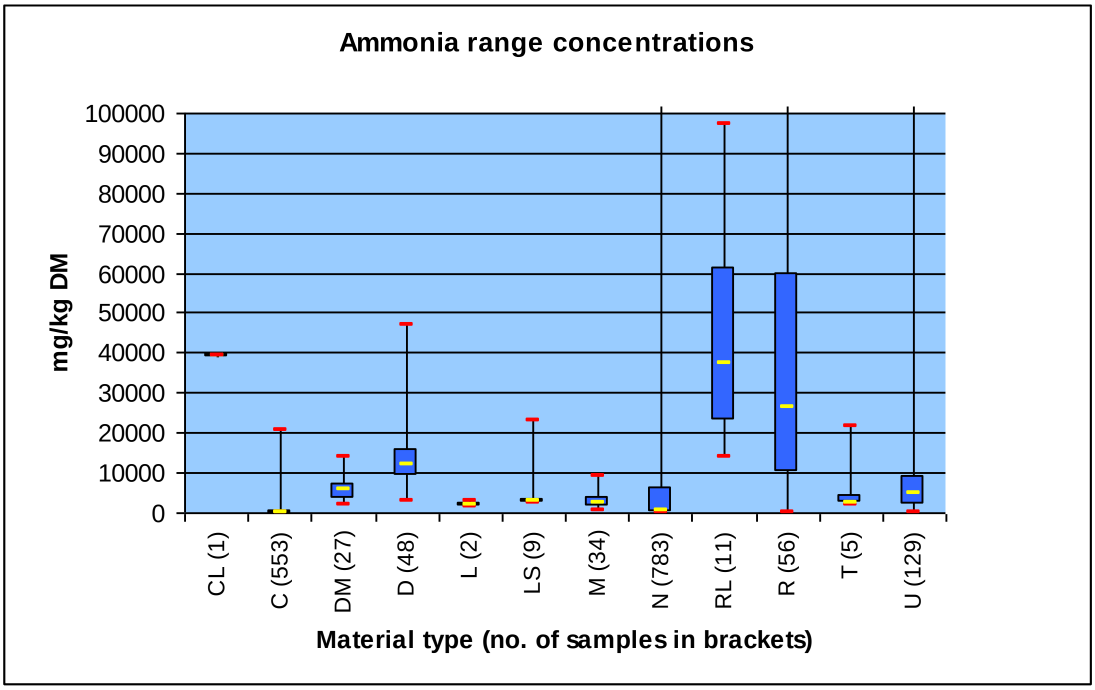

Figure 3.33 Nitrogen range concentrations in sewage sludge for different treatment types

The above plot shows the range data for ammonia concentrations for different treatment types. The range for anaerobic digestates (R) is extremely large reflecting the different materials that are being digested. The plot below shows ammonia concentrations for anaerobic digestates by input material type.

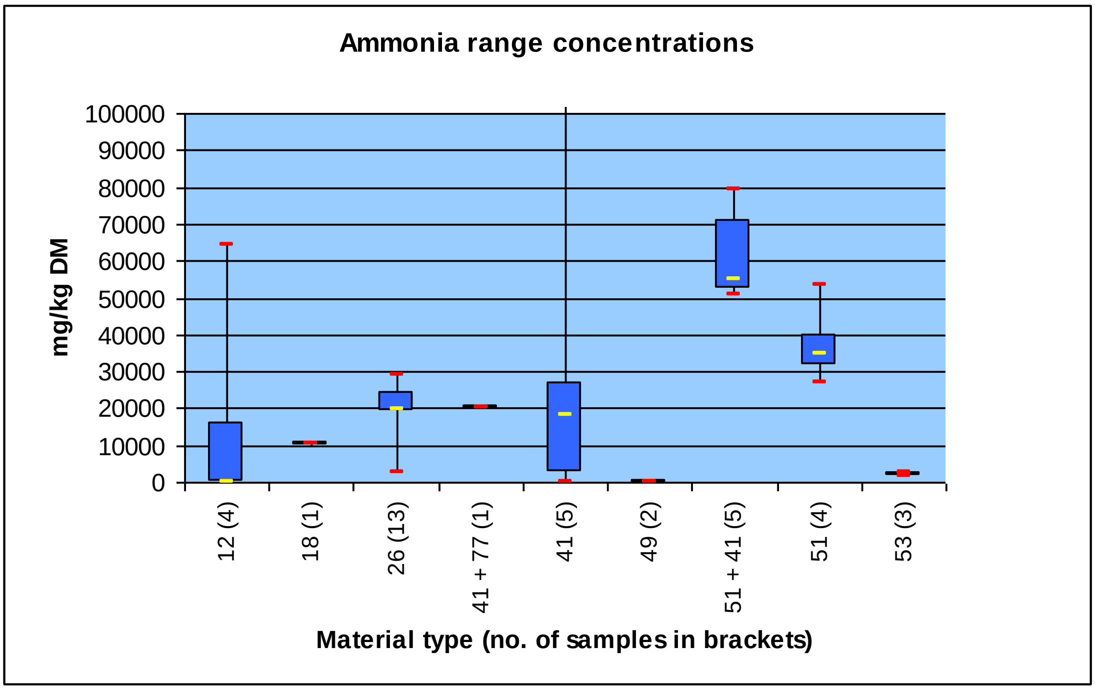

Figure 3.34 Ammonia range concentrations in sewage sludge for different treatment types

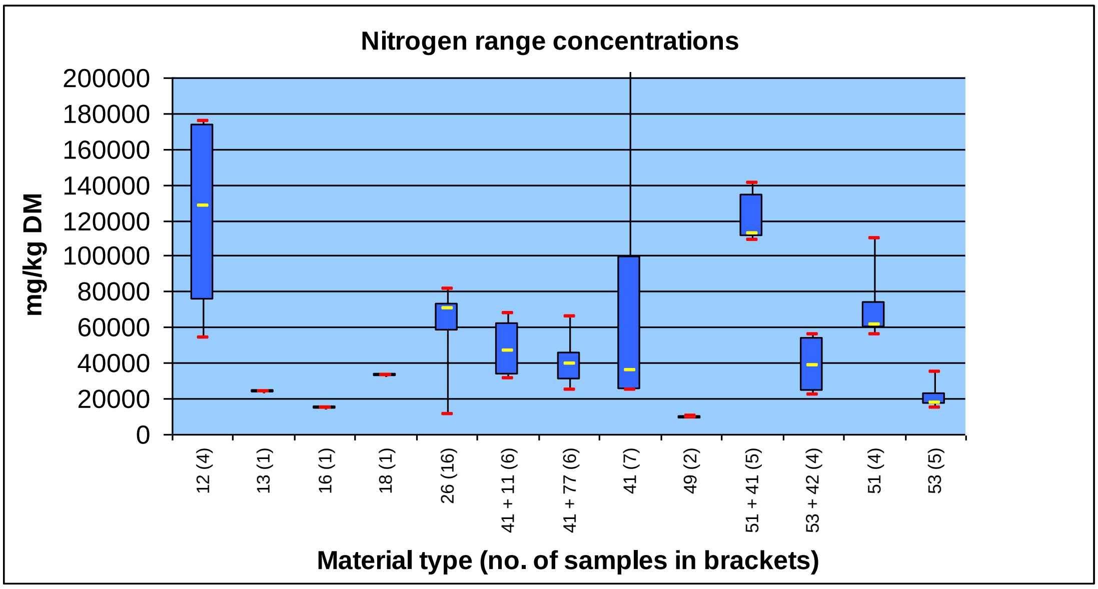

Figure 3.35 Nitrogen range concentrations in sewage sludge for different treatment types

4. CONCLUSIONS

A database has been collated from over 4500 sources on waste characterisation data. The data has been sorted in to generic categories, based on source of the waste and the treatment type.

The data has been summarised in a series of box and whisker type plots, showing the spread of the data, to give rapid comparison between the waste types. The main findings from this assessment of variability in waste composition is summarised below.

- For nutrient content treatment type was found to give a better indicator to concentration. For metal of the waste, the source of the material was found to give a better indicator.

- Sewage sludges were found to be comparatively very high in phosphorus, but varied considerably depending on source.

- Anaerobic digestates had a much higher available nitrogen concentration than composts, but were very variable depending on input waste type.

- Composted materials were generally found to be the least variable.

- Many parameters measured varied over many orders of magnitude for a given waste type