CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Main conclusions

The main conclusions from this study with reference to the main objectives (Section 1.2) are as follows:

Objective: To determine Pb and Cd accumulation, toxicity levels and yield of pasture grass under treated sewage application.

1. The study found that star grass is a high accumulator of both Pb and Cd. In this study, it accumulated 8 times the recommended level of 40 mg/kg Pb (United Kingdom Statutory Instrument No. 1412, 1995) and 18 times the recommended level of 1 mg/kg Cd (United Kingdom Statutory Instrument No. 1412, 1995) under conditions of high levels of added inorganic metals combined with repeated applications of treated sewage in the soil. Therefore growing star grass in a sandy soil for pasture under conditions of high levels of Pb and Cd application is not advisable.

2. Using models produced in this study, the toxicity levels of Pb and Cd in grass were established to be 53.7 mg/kg and 3.2 mg/kg, respectively. These levels corresponded to soil bio-available concentrations of Pb and Cd of 186.2 mg/kg and 8.3 mg/kg, respectively. The toxicity levels in grass are higher than the levels recommended in pasture grass. By absorbing more than the recommended limits of Pb and Cd at the threshold toxicity levels without showing visible signs of toxicity, star grass poses a risk to animals if bio-available soil metal levels are not regularly measured. This risk arises because animals may be grazed on star grass with Pb and Cd levels higher than recommended (if the grass or soil is not tested), since the point at which toxicity starts coincides with the highest level of productivity/yield.

3. Co-presence of Pb and Cd did not significantly affect uptake of Pb. It however caused a 260% increase in the rate of uptake of Cd by star grass subjected to high metal doses of mixed inorganic Pb and Cd compared to high doses of single inorganic Cd combined with treated sewage application. It is postulated that this effect of Pb on Cd also occurred under field conditions, leading to high uptake of Cd. Therefore besides reducing Cd levels, reduction of Pb levels in treated sewage may reduce uptake of Cd by star grass.

4. The study established that there was some correlation between yield of star grass and bio-available metal concentration. Though not statistically significant, the regression models of $\log_{10}$ (*above-ground tissue*) versus $\log_{10}$ (*soil bio-available metal concentration*) were sufficient to derive toxicity levels of Pb and Cd in grass.

Objective: To determine Pb and Cd accumulation in pasture grass under effluent and sewage sludge mixture application.

5. Using the models produced in this study, the critical bio-available levels of Pb and Cd at which metal uptake by star grass would not exceed recommended levels of 40 mg/kg Pb and 1 mg/kg Cd, were estimated to be 115.2 mg/kg and 0.20 mg/kg, respectively. The models:

$\log_{10}$ (*above-ground grass tissue Pb concentration*) = 0.3949 $\log_{10}$ (*bio-available soil Pb concentration*) + 0.788

and

$\log_{10}$ (*above-ground grass tissue Cd concentration*) = 0.363 $\log_{10}$ (*bio-available soil Cd concentration*) + 0.2987,

produced for predicting metal content in grass based on bio-available metal content in soils, are considered to be representative of the situation where grazing animals continue to graze on pasture thereby causing new re-growths. Though still to be field tested, these models could form a basis for estimating accumulation of Pb and Cd in grass on the basis of bio-available soil concentrations, at least as indicators of potential hazard to be validated by detailed tests on plant tissue.

This study recommends the management of bio-available Pb and Cd below 115.2 mg/kg and 0.20 mg/kg, respectively, in order to avoid accumulating critical pasture levels of 40 mg/kg Pb and 1 mg/kg Cd in star grass. This would ensure that pasture is safe for animal consumption.

6. Under conditions of repeated applications of treated sewage the recommended maximum total concentration of Cd of 1 mg/kg (sewage sludge directive limit for use of sewage sludge in agriculture (EEC, 1986) may be too high for a sandy soil. Uptake of Cd beyond

the recommended 1 mg/kg in mixed kikuyu and star grass pasture occurred despite the soil having an average total soil Cd concentration of 0.65 mg/kg, a value lower than the recommended 1 mg/kg. Absorption of 1.70 mg/kg by star grass against a soil bio-available concentration of 0.63 mg/kg under field conditions pointed to a similar conclusion.

7. The application of treated sewage at 17 times the recommended long-term concentration of 0.01 mg/l Cd caused star grass to accumulate Cd to levels beyond 1mg/kg, within a short period of 5 months. Therefore where concentrations of Cd in treated sewage are high, short-term accumulation of the metal in a sandy soil and star grass are important to consider.

Objective: To determine long-term Pb and Cd accumulation in soils subjected to treated sewage application.

8. Long-term accumulation of Pb and Cd occurred predominantly in the 0-20 cm depth of the sandy soil. The lower horizons of the irrigated soil had metal levels similar to background levels in non-contaminated soil. This pattern of accumulation of Pb and Cd suggests uncertainty in modelling soil-plant uptake since the depth from which the roots took up nutrients and Pb and Cd cannot be ascertained.

9. After 29 years of continuous disposal of treated sewage, with Pb concentrations of between 0.40 mg/l and 2.6 mg/l as determined in this study, total Pb was below the recommended level of 300 mg/kg for a soil. Pb accumulated in the sandy soil at an annual average of 5.7 mg/kg total concentration in the 0-10 cm depth and 0.3 mg/kg total concentration in the 10-20 cm depth of the soil. These concentrations in treated sewage caused a maximum accumulation in pasture grass of 40% of the recommended limit of 40 mg/kg in pasture. Therefore, the long-term accumulation of Pb from repeated application of Pb at less than 2.6 mg/l did not constitute a threat to the sandy soil, star grass and animals grazing on the pastures.

10. At a total soil concentration of 1.26 mg/kg in the 0-10 cm soil horizon and 0.75 mg/kg in the 10-20 cm horizon after 30 years of treated sewage disposal, total soil Cd in the top 10 cm was above the 1 mg/kg total Cd limit recommended for growing food crops. The annual accumulation rate of total Cd was 0.03 mg/kg in the top 10 cm and 0.01 mg/kg in the 10-20 cm layer. Since mixed kikuyu and star grass absorbed up to 1.2 mg/kg Cd at these soil levels, Cd poses a threat to the soil, star grass and animals grazing on the

pastures. The study recommends that under conditions of repeated applications of treated sewage with high levels of Cd, long-term limits of total Cd on sandy soils should be set lower than 1 mg/kg.

11. There was weak correlation between total Pb and Cd and the levels of the metals in mixed kikuyu and star grass, such that metal levels in grass could not be predicted on the basis of total soil metal concentrations.

Objective: To determine appropriate levels of Pb and Cd concentrations in sewage effluent and sludge mixture that would optimise yield of grass and minimise heavy metals in beef animals.

12. The study noted that although it was not possible to determine the actual appropriate levels under the conditions of the experiment where treated sewage had varying levels of metals when it was disposed onto pasturelands, the Pb level of 2.6 mg/l and below, did not present a hazard to star grass and animals. However, Cd presented a hazard at total soil concentrations lower than 1 mg/kg in the soil. The hazard, as measured by the concentration in the plant was evident after only 5 months of repeated application of treated sewage with a concentration 17 times the recommended rate.

8.2 Recommendations

The main findings of this study provide scope for further research in related areas suggested below:

1. There is a lack of knowledge on the depth from which grasses absorb metals. Given that the level of accumulation of Pb and Cd is related to soil depth and soil concentrations are inputs into soil-plant uptake models, a study to establish the depth of uptake would provide information on the depth to consider in relating metal content in grass and soil bio-available metal content.

2. Further research on uptake of the metals by re-growths of grass under the same conditions and multiple variable analysis of uptake could improve regression models established in this study. The models could consider incorporating pH or other chemicals species, especially where interaction of the metal under study with other chemical species is anticipated.

3. There is scope to carry out similar research on Pb and Cd hazard in other soil types, species of grass and other plants like agricultural crops, since these have not yet been studied locally.

4. A study in which accumulation of Pb and Cd in animal organs are investigated and related to those in grass and possibly soils would assist policy makers to draw up management practices and policies on risk assessment of Pb and Cd.