CHAPTER 1

General Introduction

1.1 Introduction

The disposal of sewage sludge (or biosolids) is a many faceted problem facing most, if not all, local authorities worldwide. The challenges are generally related to treatment and disposal options of the treated material depending on its nutrient, pathogen, heavy metal, or organic pollutant content. In 2001 the Water Research Commission (WRC) initiated a research program that included the following projects:

- **K5/1209**: An evaluation of dedicated land disposal practices for sewage sludge
- **K5/1210**: Laboratory and field scale evaluation of agricultural use of sewage sludge
- **K5/1240**: A technical and financial review of sludge treatment technologies
- **K5/1283**: A detailed metal content survey of South African sewage sludge and an evaluation of analytical methods for metal determination
- **K5/1339**: Survey and methodology for analysing organic pollutants in South African sewage sludge

As part of the K5/1210 project it was decided to investigate the influence of pH on heavy metal mobility in soil that had received metal containing sludges for prolonged periods under the climatic conditions experienced on the South African Highveld. Finding soils that adhered to the requirements mentioned above proved challenging and in the end it was decided to sample two different sacrificial biosolids disposal soils. Sacrificial disposal of biosolids can take many different forms but the end result is often a soil that is enriched with organic matter, heavy metals, acidity, and nutrients such as phosphorus and nitrogen. Very little management, if any, is practiced on these soils and sludge that has been disposed of on these soils is mostly ploughed into the soils when dry. Sludge metal content as well as its land application is variable and no records exist regarding the total tonnage or volume disposed of on the soils. This

aspect poses a problem regarding research on these soils due to unknown metal loading rates.

For a preliminary greenhouse trial bulk samples were collected of the two soils. Soil 1 originally was a dystrophic pale-yellow gravely sandy loam soil from Rooiwal, north of Pretoria, that originated on coarse-grained granite and Soil 2 was a dystrophic red sandy clay loam that originated on dolomite from Hartebeestfontein, southeast of Pretoria. Both of the sampled soils had undergone significant changes in physical and chemical characteristics due to the prolonged disposal of biosolids. During the preliminary pot trial, where large quantities of lime were added to the soils, it was found that the soils had high pH buffer capacities due to low pH and high organic matter content. After a six months aerobic incubation and regular wetting and drying of the soils it was found that the EDTA extractable metal fraction of the soils increased for many of the tested metals. This phenomenon was communicated to the steering committee of the project and discussed at a number of steering committee meetings. From the minutes of the final meeting of the steering committee for project K5/1210, held in Pretoria on 26 May 2003, it was clear that general feeling amongst the committee members was that the phenomenon was contrary to "a wealth of literature indicating the opposite". The minutes contained several suggestions for the "anomaly" and these include:

- "The soils might have been acidic enough to affect the extraction efficiency after liming."
- "The liming could have enhanced the mineralization of organic material."
- "The variability could be due to sampling variability as a result of a small sample size."
- "The sample might have had free lime left as it had been taken out after six months where the liming effect normally takes about two years."

Although the suggestions were not very clear, what was clear is that the phenomenon was considered to be a product of erroneous or inadequate trial set-up. Subsequent to the feedback from the steering committee the phenomenon and its far-reaching implications for the rehabilitation of sacrificial soils in South Africa were discussed at length with a number of colleagues from the University of Pretoria as well as other

academic and research institutions (locally and abroad). No one was able to provide an acceptable explanation for the increased metal extractability. Here it should be mentioned that high organic matter soils that are severely polluted with heavy metals are scarce in South Africa and little research has been conducted on the behaviour of the metals and organic matter in these soils. The initial results have subsequently been peer reviewed and published as a short communication (Van der Waals et al., 2005).

1.2 Critical Research Questions

In the light of the initial results as well as the situation as discussed above it was decided to conduct a number of dedicated trials to answer the questions that were implied in the minutes as well as the questions that arose in the mind of this worker. The questions that needed answering were:

1. What is the extent of the increased extractability of the metals with the complexing agent EDTA and how do these values compare to those of a neutral salt extractant such as NH_4NO_3?
2. What is the influence of incubation time on the reactivity of the added lime and the extractability of the metals?
3. Could the increased metal extraction be correlated with mineralising organic material?
4. What is the influence of increasing lime application rates on metal extractability and could the values be correlated with other soil characteristics such as extractable organic matter?
5. What is the influence of increased EDTA extractable metals on plant metal uptake and content, especially in the light of a number of studies that have shown correlations between the two?
6. What are the implications of the results obtained in the different trials for the management and rehabilitation of sacrificial disposal sites as well as agricultural fields where biosolids are used on a continual basis?

1.3 Broad Aim of the Study

The aim of this study is to answer the critical research questions posed regarding the phenomenon of increased EDTA metal extractability from sacrificial sewage disposal site soils after intensive liming under laboratory and glasshouse conditions.

1.4 Communication of Results of the Study

At the time of submission of this study several of its results have been communicated through different publications, conference presentations and formal and informal meetings with colleagues. The outputs include:

1.4.1 Publications in Peer Reviewed Journals

Van der Waals, J.H., Snyman, H.G. & Claassens A.S. 2005. Increase in metal extractability after liming of sacrificial sewage sludge disposal soils. *Water SA* 31(2) p. 271-273.
(Chapter 4 is a style-edited version of the above publication)

1.4.2 Submitted Manuscripts for Peer Review

Van der Waals, J.H. & Claassens, A.S. The influence of increasing lime rates on ammonium EDTA (NH_4-EDTA) extractable metals and organic matter from two acid long-term biosolids disposal soils. Submitted to *Water SA* March 2005.

1.4.3 Conference Presentations

a. Snyman, H.G., Van der Waals, J.H. & Van Niekerk, C. Aspects of the beneficial agricultural use of sewage sludge in South African soils. IWA Conference on Environmental Biotechnology: Advancement on Water and Wastewater Applications in the Tropics Kuala Lumpur, Malaysia, 9-10 December 2003.

b. Van der Waals, J.H., & Snyman, H.G. 2004. Selected chemical and physical soil properties of three sacrificial sewage sludge disposal sites. Water Institute of South Africa (WISA) Conference, Cape Town, 2-6 May 2004.

c. Van der Waals, J.H. & Claassens, A.S. 2005. Influence of increasing lime rates on ammonium EDTA (NH_4-EDTA) extractable metals and organic matter from two acid long-term biosolids disposal soils. Combined Congress (Soil Science Society of South Africa, South African Society of Crop Production, South African Weed Science Society, Southern African Society for Horticultural Sciences), Potchefstroom, 11-14 January 2005.

1.4.4 Awards

The presentation at the Combined Congress of the Soil Science Society of South Africa, South African Society of Crop Production, South African Weed Science Society, Southern African Society for Horticultural Sciences, Potchefstroom, 11-14 January 2005, was awarded with the "Best Paper" award by the Soil Science Society of South Africa.