SOIL MESOFAUNA AS BIOINDICATORS TO ASSESS ENVIRONMENTAL DISTURBANCE AT A PLATINUM MINE

JURIE J. WAHL
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Supervisor: Dr. M.S. Maboeta
Co-supervisor: Prof. P.D. Theron.

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DECLARATION

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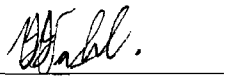
The study represents original work undertaken by the author and has not been previously submitted for degree purpose to any other university. Appropriate acknowledgements have been made in the text where the use of work conducted by other researchers has been included.



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SUMMARY

South Africa is rich in mineral resources and is one of the leading raw material exporters in the world, of which the more important are gold, diamonds and platinum. Mining is essential for economic development, but also has detrimental environmental consequences, namely in the form of chemical waste products (including a range of heavy metals) which are contained in the effluent being dumped as tailing dam material. It is well known that such tailings may contain metals such as Cu, Zn, Mn, Ni, Al, Pb, Fe and Cd, constituting a range of potential environmental hazards. The aim of this study was to investigate the utilization of soil mesofauna in the assessment of environmental disturbance at different distances away from a tailings dam by comparing the species data with the soil metal analysis. It was also deemed necessary to determine which species or functional groups were influenced most by the metals found in the soil. Six random soil samples (replicates) were collected at seven sites on and away from the tailings dam and mesofauna was extracted. Sampling was done four times over a period of one year during the following months: August 2005, December 2005, March 2006 and May 2006. Both the soil and the mesofauna were physically and chemically analysed. Statistical analysis indicated that some metal concentrations decreased when moving further away from the tailings dam. These specific metals (Cu, Cr and Ni), which are consistent with platinum tailings material, apparently had the greatest influence on the soil mesofauna sampled. Only a few mite species dominated the two sites on the tailings dam, representing the prostigmatic-, cryptostigmatic- and the mesostigmatic taxa. Prostigmatic species were present in the most disturbed areas and may be a good candidate for further bioindication studies. A metal pollution gradient exists at the sites that were sampled and species richness generally increased towards the more natural environment. Seasonal variation was evident in the soil data, as well as in the species data.

Keywords: *mesofauna, metals, inorganic tailings, community structure, bioindicators.*

OPSOMMING

Suid-Afrika is ryk aan minerale en is ook een van die topuitvoerders daarvan, veral met verwysing na goud, diamante en platinum. Alhoewel mynbou noodsaaklik is vir ekonomiese groei en ontwikkeling, het dit 'n negatiewe uitwerking op die omgewing. Die hoofrede daarvoor lê in die groot hoeveelhede chemiese afvalmateriaal (wat ook swaar-metale bevat), wat as platinummynslik gestort word. Dit is algemeen bekend dat metale voorkom in mynslik, bv. Cu, Zn, Mn, Ni, Al, Pb, Fe en Cd en dus 'n potensiële omgewingsgevaar inhou. Die doel met hierdie studie was om ondersoek in te stel na die gebruik van grondmesofauna in die bepaling van omgewingsversteuring by verskillende afstande vanaf die slikdam, deur die spesiedata te vergelyk met die chemiese analise van grondmonsters. Dit was ook noodsaaklik om te bepaal watter van die spesies, en dus ook funksionele groepe, die meeste deur die metale in die grond beinvloed word. Ses herhalings grondmonsters is by elk van die sewe persele geneem vanaf bo-op die slikdam tot by die laaste perseel wat 1350m vanaf die eerste perseel geleë is. Vier stelle opnames is oor 'n eenjaar-periode geneem tydens die volgende maande: Augustus 2005, Desember 2005, Maart 2006 en Mei 2006. Die mesofauna is hierna uit die grond geëkstraheer. Beide die grond en die mesofauna is fisies en chemies geanaliseer. Statistiese analises het aangedui dat sekere metale wat in die grond voorkom, 'n afname in konsentrasie toon vanaf die slikdam na die verste perseel. Hierdie metale, nl. Ba, Mn en Pb, wat met platinummynslik geassosieer word, het blykbaar die grootste invloed op die organismes. Slegs 'n paar spesies was dominant op die slikdam en is verteenwoordigend van die prostigmatiese-, cryptostigmatiese- en mesostigmatiese taksons. Prostigmatiese spesies was teenwoordig in die mees versteurde persele en sal daarom moontlik goeie kandidate wees vir verdere bio-indikator studies. 'n Besoedelingsgradient is merkbaar vanaf die slikdam tot en met die verste perseel. Spesierykheid het toegeneem vanaf die slikdam tot by die laaste perseel. Seisoenale verskille was merkbaar in die gronddata en ook in die spesiedata.

Sleutelwoorde: *mesofauna, metale, mynslik, gemeenskapstruktuur, bio-indikatore*

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CHAPTER 1

1. Introduction

1.1 Mining

Mining has been around for longer than most people realize. When mines are mentioned, most people paint a mental picture of a shaft of a few hundred meters deep accompanied by tailing dams on which raw mining waste is deposited. In reality, mining existed in ancient times because hundreds of years BC people used silver, gold and precious stones as currency to fulfill basic needs (Bible, 1995). Since then, technology is the only aspect that has undergone major changes.

In the last few decades, man has extensively exploited the earth for developmental purposes. Development includes activities such as urbanization, agriculture and industry, all which provides for the need of mankind, a species with an ever growing population. South Africa is no exception since it is rich in mineral resources and is one of the leading raw material exporters in the world, e.g. gold, diamonds and platinum. The country produces 62% of the world's platinum and holds 75% of global reserves, making it the largest producer of platinum in the world (Chamber of Mines South Africa, 2003), most of which are deposited in the North-West Province (Mbendi Information Services, 2005). South Africa currently has four integrated primary platinum producers, namely Amplats, Impala Platinum, Lonmin Platinum and Northam Platinum (Jones, 2005). These mines produce the six platinum group elements (PGEs), namely rutherium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir) and platinum (Pt), which are in great demand in chemical, electrical, glass, electronic, and automotive industries (Xiao and Laplante, 2004).

1.2 Dangers of mining

Mining is essential for economic development, but on the other hand it does have some detrimental impacts, mainly in the form of chemical waste products (including a range of heavy metals) which is contained in the effluent being dumped as tailings dam material. In the case of platinum mines, large amounts of inorganic tailings are produced (up to one million tons of tailings material per month), consisting mainly of sand (75%) and silt (20%) with the remaining 5% of the particles represented by a clay fraction (Maboeta *et al.*, 2006).

In a previous study it was found that these tailings dam facilities (TDF) may contain high levels of metals such as Cu, Ni, and Cr (Maboeta *et al.*, in press), constituting a range of potential environmental hazards. Because these metals are not easily degraded, they may persist in the mining area for hundreds of years after closing the facility (Dai *et al.*, 2003). This further leads to socio-ethical problems since subsequent generations may be negatively affected resulting from the potential health hazards of such persistents. Besides these problems, mining has also contributed to a total of 25% of natural ecosystem loss in South Africa (DEAT, 1999). Despite all this, these activities have not and might not cease or diminish, but have amplified to a great extent which is noticeable in many of South Africa's mining cities. This has lead to greater concern for the environment in the mining area, even though pollution resulting from mining activities is considered as acceptable risks with regard to economic growth. For this reason a design for mine closure, which involves extensive planning during mining operations to create a more sustainable environment in the post mining area, was implemented during the 80's and 90's to minimize the impacts on the environment. A concept for the sustainable use of the mining area was also added to the closure design. According to Robertson and Shaw (1999) planning for closure involves four key objectives, namely protecting public health and safety; alleviating or eliminating environmental damage; achieving a productive use of the land, or to returning it to its original condition or an acceptable alternative; and providing sustainability of social and economic benefits resulting from the mine development and operations.

The negative effects these sources of wealth had on the human population, became progressively evident over the past few decades. Following the Industrial Revolution, contamination of the environment by heavy metals increased dramatically causing numerous major outbreaks of chronic illnesses in humans (Yu, 2001), as well as soil pollution (Lukkari *et al.*, 2005). Although some of these metals are trace elements, which are also necessary for sustaining soil biota, higher concentrations may become directly toxic to organisms (Niklinska *et al.*, 2006). Despite the fact that some of these metals, such as Zn and Cu are trace elements essential for proper body functions, *in vitro* analysis shows that metals have negative effects on the immunity of certain animals and provide a ranking in the following order: Hg > Cu > Cd > Co > Cr > Mn > Zn > Se (Peakall, 1992; Van Gestel and Mol, 2003).

Response to a specific pollutant can be greatly influenced by many aspects of the environment, as well as by other pollutants. According to Duffus (1980) soil characteristics

affecting toxicant persistence include mineral and organic matter content, hydrogen ion concentration, microbial activity and particle size. Smaller soil particles have the ability to retain the toxic substances for longer periods, prolonging the effect it has on the environment. The mobility of certain metals are enhanced by a decrease in pH (Yu, 2001) and the bioavailability of metals also decreases with addition of certain substances such as phosphate (Ownby *et al.*, 2004).

Pollutants are of great concern because of their effects on terrestrial- and aquatic communities occurring at the specific site of pollution. Therefore, any alteration to a habitat is likely to force change on the community structure (Fent, 2004). The question is not whether it will change, but to what extent it will change. Metal pollution leads to an accumulation of these elements, not only in the physical environment, but also in the soil biota (Van Straalen *et al.*, 2001). Once soil organisms have accumulated metals, the food web might also be adversely affected, e.g. Pb, Cu and Zn, slowing down cellulose degradation rates of soil microbial communities (Chew *et al.*, 2000). Metals also tend to be persistent in the soil environment and might therefore accumulate in organisms that have slow dispersal abilities and a high metal tolerance. It is, however, very important to distinguish between the terms bioaccumulation and biomagnification. According to Moriarty (1999) bioaccumulation is the increase of pollutant concentration in individual organisms by consumption of contaminated water and food. Biomagnification on the other hand, is an increased concentration of pollutant in animal tissue, as a direct result of one organism consuming another. Though both of these processes occur within the environment from which the samples for this study were taken, bioaccumulation will be used as collective term for both. Bioaccumulator species have the capacity to accumulate certain contaminants directly from their habitats through the trophic levels of a food chain up to levels higher than the level of contamination of the physical environment (Jamil, 2001). This would indicate that predatory organisms, such as certain mite species and pseudoscorpions found in the soil, might have accumulated higher metal concentrations in their body tissue than mesofauna feeding on plant material.

Moriarty (1999) states that although the effects may vary with both type of pollutant and the community, the general effect of pollution is a decrease in species diversity, productivity, biomass and also the structural complexity of a community. Over the years, the focus of

studies has been on species diversity and is the indicator most commonly used to determine if a disturbance exists in a certain area or particular ecosystem (Nahmani *et al.*, 2003).

1.3 Bioindicators

Soil is certainly one of the most abundant and most precious non-renewable resources in the world (De Bruyn, 1997; Bedano *et al.*, 2006), forming an intricate part of any terrestrial ecosystem - from deserts to rainforests. A major problem we face in the modern world is the increasing pollution that comes with population- and economic growth. For this reason, the soil ecosystem has become the focus point of many scientific investigations, e.g. assessing soil health by means of microbial community structure (Avidano *et al.*, 2005), determining if a metal tolerance occurs in certain bacteria present in metal polluted sites (Piotrowska-Seget *et al.*, 2005), developing methods for indication of soil metal pollution (Singleton *et al.*, 2003) and also investigating the distribution of soil organisms within the soil environment (Ou *et al.*, 2005).

Soil health or quality can be assessed by means of chemical, biological or physical indicators. Chemical analysis is often unsuitable, as it requires knowledge of the classes of pollutants to be analysed and also gives little information about the bioavailability (toxicity) of pollutants or their degradation products (Crouau *et al.*, 2002). This suggests that chemical analyses should be complemented with bioindicators (Schloter *et al.*, 2003). Bioindication is the scientific analysis of field-collected ecological information, with the aim of using this information to make inferences about the quality of the environment at the place under investigation (Van Straalen, 1998). According to Jamil (2001), a bioindicator can be defined as an organism or set of organisms that enables the characterisation of the state of an ecosystem or an ecocomplex. These bioindicators can be associated with one or more physical and chemical factors such as pollution levels, temperature ranges and moisture availability. Organisms used for bioindication reflect the state of the environment and are suitable for indicating pollution because of their occurrence, absence or presence, frequency, distribution, reactions and response change under certain environmental conditions (Vargha *et al.*, 2002). Soil mesofauna evaluation and interpretation of their abundance offers an assessment of the condition of the soil ecosystem (Laiho *et al.*, 2001).

Soil organisms can be divided into distinct categories based on size as pointed out by Richards (1994). Firstly, very large burrowing vertebrates, e.g. mice, moles and rabbits are

grouped as megafauna and are capable of creating series of interconnected tunnels, increasing the volume of water being carried underground during rainstorms. Large invertebrates, e.g. earthworms, molluscs and larger arthropods, which are of a burrowing type and spend most of their lives underground, are called macrofauna. This group performs important ecological functions such as mixing organic matter with soil and creating biopores, ultimately promoting the humification process. Mesofauna consists of small invertebrate animals representative of smaller Arthropoda, Nematoda and Collembola, and are responsible for decomposing plant material and creating biopores that promotes nutrient turnover during the humification process. The final category comprises the microfauna, which are less than 0.2mm in length and consists mostly of bacteria, algae, protozoa and fungi. One of the main functions of this group in the soil is to mineralise and immobilise nutrients, as well as breaking down organic matter. When considering the nutrient turnover in the soil as a result of these processes and their habitat, it is evident why soil fauna are utilized as bioindicators. Soil faunal communities occupying specialised habitats, are sensitive to change in their environment (Dittmer and Schrader, 1999). Many of these are localised organisms, sometimes living their entire lives in a small area of soil, making them good representatives of local conditions (Migliorini *et al.*, 2004).

According to Richards (1987), there are some criteria that have to be taken into account before deciding on which organisms to use for bioindication. These include the amount of time the animals spend in the soil, habitat preference of the animals, feeding preferences, means of locomotion, and the size of the animals. Cortet *et al.* (1999) also lists some requirements needed for organisms to be successful bioindicators. Bioindicators should play an important role in the functioning of the soil ecosystem, have a wide distribution and should be easy to sample. From a toxicological view, bioindicators should also be tolerant to low levels of pollutants, have measurable responses, and responses need to be reproducible (Paoletti and Bressan, 1996). Based on these criteria, the euedaphic (soil dwelling) species of mesofauna are most likely to be the best bio-indicator group to determine the presence of soil pollution. This is due to the fact that the soil mesofauna spend most of their lives underground or forms a part of the soil community, and therefore also play a vital role in the restoration of degraded biological habitats (Skubala, 1997a).

1.4 Soil mesofauna

The phylum Arthropoda makes up the majority of organisms categorised as soil mesofauna or euedaphon, of which the subphylums Chelicerata and Uniramia are the most prominent (Hickman *et al.*, 2001). Uniramia can be divided into several classes, including Chilopoda, Diplopoda, Pauropoda, Symphyla and Insecta. Chelicerata includes the class Arachnida, which can be subdivided into orders, *viz.* Scorpionida, Pedipalpida, Araneae, Solpugida, Pseudoscorpionida and Opiliones. Within the subphylum Chelicerata, the subclass Acari can also be categorized. The Acari, which are commonly referred to as mites and ticks, can be divided into Astigmata, Prostigmata (Actinedida), Cryptostigmata (Oribatida), Metastigmata and Mesostigmata (Gamasina) (Krantz, 1971; Koehler, 1997).

Mesofauna is one of the most abundant groups of soil biota and plays an important role in the soil community (Parisi *et al.*, 2005). Mites are well suited as indicator organisms for monitoring the impact of management practices on soil biodiversity, because of their high population density, species richness, sensitivity to soil conditions and the availability of well-developed sampling methods (Minor *et al.*, 2004). Further, mites may be utilised as bioindicators, because they have the ability to accumulate metals (Skubala and Madej, 1998, Skubala and Kafel, 2004) especially the Cryptostigmata (Zaitsev and Van Straalen, 2001). In the northern hemisphere Cryptostigmata and Mesostigmata are more prominent, while high numbers of the Prostigmata are present in the southern hemisphere (Theron, 2007, personal communication). Mite species of the Cryptostigmata and Mesostigmata groups are more sensitive to disturbance such as mining activities and agricultural practices than are species of the Prostigmata and Astigmata (Behan-Pelletier, 1999; Skubala, 2002a; Bedano *et al.*, 2006). In previous studies it was found that species richness of Mesostigmata were generally lower on nickel- and copper-mine tailings than on the control sites (St. John *et al.*, 2002). Similar results were obtained for cryptostigmatic communities on dumps formed from wastes of zinc metallurgy and the zinc-lead industry (Skubala, 1997b; Skubala, 2002b).

Collembola are amongst the most abundant soil microarthropods and play an important role in the decomposition of organic material (Endlweber *et al.*, 2006). They are also known to be present in high densities and have high reproduction rates (Greenslade and Vaughan, 2002), which makes them ideal bioindicators (Sousa *et al.*, 2005). Collembola as a group are more generalist species than soil mites, Cryptostigmata in particular (Huhta and Ojala, 2006), which is in part due to collembolans feeding on detritus (dead organic material). Compared to other arthropods such as mites, Collembola have a thin cuticula and is therefore in close

contact with substances adsorbed to soil particles and dissolved in soil water, thereby increasing the uptake of contaminants already accumulated through ingestion of food (Debus, 1998). Cortet *et al.* (1999) determined that after isopods, Collembola can be ranked second amongst detrivorous invertebrates for copper accumulation, which may be up to 45 times higher than normal values. Despite the label of being a more generalist organism, it was determined that in metal-contaminated soils a decrease in the density and sometimes diversity of Collembola is known to occur and therefore fewer springtails should occur closer to the source of pollution (Fountain and Hopkin, 2000; Niklasson *et al.*, 2000).

1.5 Effects of metals on mesofauna

Certain organisms can tolerate the toxic effects of metals by one or more of several means including the following: adjusting metal assimilation efficiency, adjusting the binding/immobilisation capacity, altering the excretory rate, modifying certain enzymes, incorporating avoidance reactions (Marino and Morgan, 1999a; 1999b), storage detoxification strategies or by discharge of assimilated metals (Rabitsch, 1994). Springtails have the ability to avoid metal-contamination, such as Zn and Cu (Greenslade and Vaughan, 2002), while some species may even tolerate metal contamination by selecting less-contaminated micro-sites or by changing their reproductive, excretory (by means of midgut epithelium) or feeding behaviour, thereby increasing its dominance in metal-polluted soils (Gillet and Ponge, 2002; Chauvat and Ponge, 2002). Metal tolerance has also been fairly conclusively demonstrated in some mite species, especially those belonging to the taxon Mesostigmata (Marino and Morgan, 1999a). The lack of metal specificity in detoxification mechanisms of soil invertebrates and the presence of free ionic forms of Al, Fe, Mn and other metals at low pH, suggests that tolerance to acidity could also allow tolerance to a broad range of metals (Garnier and Ponge, 2004). Invertebrate taxa, which follow a storage detoxification strategy are often grouped as macro-concentrators, while those taxa with the capacity to discharge assimilated metals are grouped as de-concentrators (Rabitsch, 1994). Macro-concentrators seem to provide the most direct information about environmental contamination (Cortet *et al.*, 2000).

Any soil community contains populations of different species that interact with each other, and these interactions amongst species are a major determinant of community composition and soil quality, but are also influenced by environmental conditions, including the soil pH, soil texture and structure, temperature, soil organic matter and the percentage of moisture in

the soil. These factors should be taken into account during ecological studies, as mesofauna are likely to be influenced by more than one environmental aspect. While the emphasis on a single species could obscure interspecies relationships, considering all the species in a community might not reveal effects on rare species, which may be more affected than abundant species (Cortet *et al.*, 2000). In contrast to laboratory studies, ecological studies are also more complicated, but would theoretically yield more realistic results. Focusing on species richness in soil communities for ecological studies, still provokes a matter of uncertainty among scientists (Ekschmitt and Griffiths, 1998). This may be due to the emphasis on single species or even single groups of soil organisms and the lack of utilisation of entire mesofaunal communities with regards to ecological studies. Concentrating on a community as a bioindicator can be a daunting task because of its complexity due to varying toxicity resistance and taxonomic implications. Therefore, more studies are needed to obtain certain benchmark values and community structure reports, which may be inadequate in some parts of the world. Despite all the difficulties that may be encountered, it will form an integrated part of our understanding of how pollution affects the environment. Once that has been established, better and more environmentally safe methods for obtaining resources can be researched.

1.6 Aim and objectives

Studies involving mining areas and the effect it has on the environment in South Africa has been few and far between. Most of these investigations have focused on one or only a few species as bioindicators of disturbance. Although very accurate, such studies may give a distorted view of the total effect pollutants can have on an ecosystem.

Taking all of the above into consideration, the aim of this study was to investigate the utilization of soil mesofauna in the assessment of environmental disturbance at different distances away from a platinum tailings dam. This was accomplished by comparing species data with soil metal concentrations and determining which species or functional groups were the most sensitive bioindicators. No such studies have ever been performed from a South African perspective. Although this study is unique and independent, it forms a part of a greater rehabilitation study at the mine, in which different aspects of soil ecology is being investigated and measures are being taken to improve the quality of the soil in the mining area.

The specific objectives of this study were to:

- assess the metal content in the soil by means of chemical analysis.
- determine the composition of the edaphic mesofaunal community in order to determine if disturbances occurs.
- investigate the use of soil mesofauna as bioindicators of environmental pollution by determining the heavy metal content in the mesofauna community.
- evaluate if seasonal variations occur within the different mesofaunal species and within the soil.

2. Materials and methods

2.1 Site description and sampling method

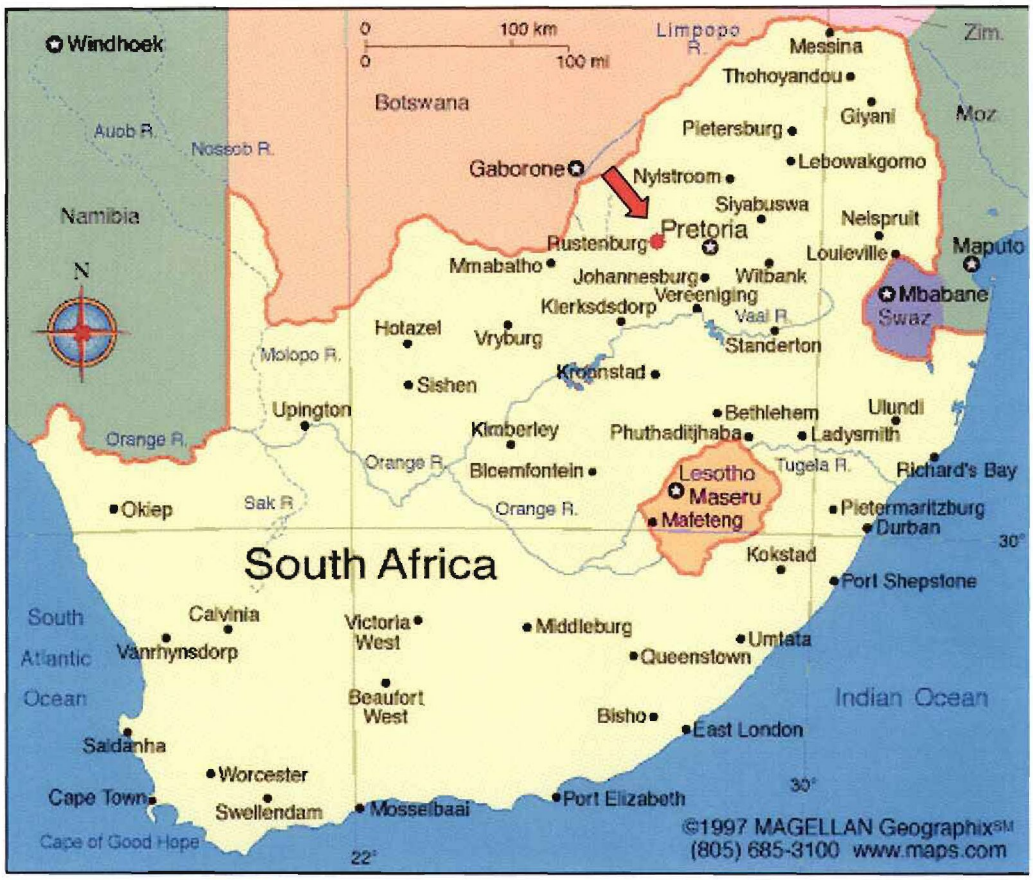


Figure 1: Map of South Africa to show Rustenburg, Northwest Province (Magellan geographix, 1997).

Samples were taken at one of the TDFs at a platinum mine, situated a few kilometers north of Rustenburg in the Northwest province of South Africa (Figure 1). It has the largest tailings footprint in the southern hemisphere, covering an area of 964 ha (Figure 2), and has been moderately rehabilitated. Fertilizers which were applied to the tailings material were Super Phosphate, $(NH_4)_2SO_4$ and KCl (Van Rensburg *et al.*, 2004). A mixture of *Cynodon dactylon* and *Cynodon nlemfuensis* stolons and rhizomes were collected in the vicinity and planted in equal proportions on the TDF (Van Rensburg *et al.*, 2004). The vegetation surrounding the mining area is part of the greater Savanna biome (Acocks, 1988) and has been described by Low and Rebelo (1998) as the Clay Thorn Bushveld, which is dominated by various *Acacia*

species. It has also been described by Van der Meulen and Westfall (1980) and Van der Meulen (1979) as the Springbok Flats Turf Thornfeld. Due to continual grazing, the vegetation assemblage is representative of a pioneer to sub-climax community. It is an erratic and extremely variable summer rainfall area, with an average rainfall of 450 to 750mm per year and temperatures varying between -6°C and 40°C, with an average of 19°C (Low and Rebelo, 1998).

Figure 2: Aerial photo of the tailings dam facility (TDF) at which the sampling was done during August 2005, December 2005, March 2006 and May 2006 (Photo by M.S. Maboeta).

Generally the quantitative investigation of a mesofaunal assemblage consists of two steps: taking soil samples and then the subsequent extraction of organisms from such samples (Frouz, 1999). Six random samples (replicates) were collected at seven sites on and away from the TDF: 0- (site 1), 0.07- (site 2), 0.15- (site 3), 0.3- (site 4), 0.5- (site 5), 0.85- (site 6) and 1.35 (site 7) kilometers from the TDF. Coordinates of the sites are as follows: S25 30.394 E27 13.598 (site 1), S25 30.358 E27 13.583 (site 2), S25 30.323 E27 13.565 (site 3), S25 30.245 E27 13.542 (site 4), S25 30.127 E27 13.516 (site 5), S25 29.945 E27 13.459 (site 6) and S25 29.681 E27 13.401 (site 7). The replicates at each site were taken five meters apart,

in a linear formation parallel to the set of replicates at the next site. These sites were situated in a northwestern direction. The decision to use this transect formation was based on the dominant wind direction for this area. Therefore the sites are situated in a linear direction, downwind from the tailings dam. Desiccation of the tailings material occurs at a constant rate, due to the exposure to sunlight. Dry tailings material, in the form of dust, is then carried by the wind up to an undetermined distance, which in theory would create a pollution gradient.

Site 1 was situated on the level surface on top of the TDF. The samples taken at site 2 were situated on the slope of the same TDF. Site 3 to 7 was not situated on the TDF and extended away from the first two sites, site 3 being the closest to the TDF and site 7 being the furthest from the TDF. The reason for this layout was to determine if a gradient of pollution existed from the TDF towards a less disturbed environment.

Sampling was done four times over a period of one year during the following months: August 2005, December 2005, March 2006 and May 2006. These dates were chosen to determine what influence the seasonal variation had on the different variables. Soils were sampled to a depth of ten centimeters, as this is the depth at which most species of mesofauna is found (Larsen *et al.*, 2003). On average, about 1.5 kilograms of soil was collected for each sample.

2.2 Extraction and identification of mesofauna from soil samples

The funnel extraction method was used to extract the mesofauna (Figure 3) from the soil samples using a Berlese-Tullgren funnel (Evans *et al.*, 1961). The humidity gradient that formed, drove the mesofauna downward, forcing them through the sieve to the bottom of the funnel. A plastic jar (350ml) containing 75% ethanol was placed underneath the funnel, collecting all the extracted organisms. Extraction lasted for seven days and was maintained indoors at room temperature to prevent temperature and moisture fluctuations caused by the sun. The collected material was then stored in 75% ethanol.

Soil mesofauna was sorted and identified to determine the species diversity by means of a Nikon SMZ800 stereomicroscope and then entered into a species list. This list was then divided into functional groups based on feeding preferences of the different species, to aid with the statistical analysis.

Figure 3: Berlese-Tullgren funnels used for extracting terrestrial mesofauna.

2.3 Chemical and physical analysis

Snapshot samples of organisms occurring in different sites were taken to assess the metal content in their body tissue. This implies that only certain species occurring in a few of the samples were analysed. Initially only one or two species occurring throughout the sampling transect would have been chosen, but the inconsistency in the data for each site was a limiting factor. There were two reasons for this. Firstly, many of the species collected at the sites had a low number of individuals. Secondly, some species did have sufficient numbers, but their body weight still did not give a sufficient reading. The organisms, which were selected based on their size and weight, were then weighed to four decimals. A 0.5g portion of each soil sample was also weighed off to analyze the metal content at each site. Both the fauna and the soil samples were analysed by means of the following method as modified from Thi Vu *et al.* (2004) and Wayland and Crosley (2006).

All laboratory glassware was soaked in aqua regia and rinsed with deionized water. For the preparation of calibration solutions, the internal standard solution and the most dilute sample solutions were prepared in disposable, metal-free polyethylene tubes.

Samples were digested in a mixture of HNO_3 (60%) suprapure and HCl (40%) suprapure (Merck). Hereafter the samples were diluted to 100ml, using 18 Mohm MilliQ (Millipore) water.

Samples were introduced into the ICP-MS system (Agilent 7500c) by means of a Cetac ASX-510 auto sampler and the peristaltic pump of the ICP-MS. The operating conditions and components are summarized in Table 1. The total method run time was less than 4 min.

For the external calibration of the quantification, a 1% HNO_3 blank as well as five diluted standard solutions in 1% HNO_3 were used. The instrument was operated with the parameters given in Table 1. To prevent interference, the oxides (156/140) were tuned to 0.32% and the doubly charged (70/140) to 2%.

Table 1. Sample introduction system of the ICP-MS (Agilent 7500c) with shield torch system.

RF power	1530 W
Sample depth	9.0 mm
Carrier gas flow	1.14 L/min
Spray chamber temperature	2 °C
Nebuliser	V-grove PFA 100ml/min
Sample and Skimmer Cones	Nickel
Torch	Quartz
Spray chamber	Double-pass
Short Term Stability (RSD) (20min) 1ppb Co, Y, Tl	$\leq 2\%$

Due to the inconsistency in the number of organisms at each site, the bioconcentration factor (BCF = metal content in organism / metal content in the soil) was calculated for each sample of fauna to determine the ability of the organism(s) to accumulate metals.

In addition to the above-mentioned processes, the pH values for March 2006 and May 2006 and carbon content in the soil for each sample site for March 2006 was determined, as well as the sand, silt and clay content for March 2006. To be accurate regarding the results of the carbon content and particle size distribution, tests were carried out according to regulations of the following institutions:

a) Agrilaboratory Association of Southern Africa (AgriLASA).
b) International Soil Analytical Exchange (ISE), Wageningen, Netherlands.

The sand, silt and clay (SSC) fraction of the soil was determined by means of the hydro-method. One hundred grams of each soil sample was weighed off and sifted through a 2mm sieve. Fifty grams of the sifted soil was placed into a 500ml container, soaked with distilled water and 10ml hydrogen peroxide was carefully added. After leaving the suspension for ten minutes, it was stirred well and heated for four hours. The suspension was then cooled and 125ml Calgon, which contains sodium hexametaphosphate, was added and stirred well. A 53µm sieve was then placed into a funnel, which was set up to drain into a 1000ml sedimentation cylinder. Suspensions were transferred into the funnel and washed with running water and a small brush until water runs clear. Not more than 1000ml of water should be used to complete this process. The fraction of soil left in the funnel was then placed into a glass beaker and dried in an oven and sifted through a 53µm sieve. Sifted fractions were then weighed. The 1000ml suspension in the cylinder was shaken and the first reading was taken after exactly 40 seconds and the second reading was taken 7 hours later.

Schollenberger (1927) suggested that organic material in the soil could be oxidised if it was to be treated with a hot mixture of potassium dichromate and sulphuric acid which is evident in the following equation: $2Cr_2O_7^{2-} + 3C + 16H^+ = 4Cr^{3+} + 3CO_2 + 8H_2O$. Following the reaction, the excess dichromate is titrated with iron(II) ammonium sulphate hexahidrate. It can then be assumed that the reduced dichromate is equivalent to the organic carbon present in the sample, if it is assumed that the organic carbon in the soil has an average valence of zero. The process of determining the organic carbon content in the soil samples by means of the Walkley Black method (Walkley, 1935) was as follows:

Soil samples were dried, grinded and sifted through a 0.35mm sieve. 1 gram of soil (0.5g if the soil has a dark colour, which would indicate a high carbon content) was then weighed off and placed in an Erlenmeyer flask. A blanco mixture without soil was also made. 20ml potassium dichromate was added and mixed and then 20ml concentrated sulphuric acid was added and mixed again. The flask was gently stirred until the reagents and the soil sample have mixed completely. After cooling the flask for 30 minutes, 150ml deionised water was added and mixed. 10ml concentrated ortho-phosphoric acid was then added and once again mixed. 1ml bariumdiphenileaminesulphonate indicator was then added and mixed. The mixture was then titrated with iron(II) ammoniumsulphate solution. The percentage of organic carbon (Nelson and Sommers, 1982) was determined as follows:

Concentration iron(II) ammoniumsulphate (M) mol/l = $\frac{20ml\ K_2Cr_2O_7\ X\ 0.167\ X\ 6}{ml\ Fe(NH_4)_2(SO_4)_2\ (ml\ blanco\ mixture)}$

Organic C % = $\frac{[ml\ Fe(NH_4)_2(SO_4)_2\ blanco - ml\ Fe(NH_4)_2(SO_4)_2\ sample]\ x\ M\ x\ 0.3\ x\ f}{weight\ of\ soil\ per\ sample\ (g)}$

where M = Concentration $Fe(NH_4)_2(SO_4)_2$ in mol/l and f = 1.3

2.4 Statistical analysis

The results for the chemical component in the soil and the species data, were analysed by means of the Canoco software programme (ter Braak, 1994). Firstly, the species' names were shortened to accommodate the programme. These abbreviations, along with the number of species and the different metals noted for each site, were then entered into the database. From there, comparisons were plotted onto different types of graphs to visually illustrate the vast amount of data collected for this study. The Sigmastat software programme was also utilized to calculate statistical differences for the metal concentrations between sites and also over time.

CHAPTER 3

3. Results

3.1 Soil chemical analysis

Results regarding the soil chemical analysis are presented in Table 2 in which concentrations of the metals are shown. Indicated in these tables are the maximum permissible concentrations (MPC), earthworm- and microbial benchmarks. MPC values indicate the maximum concentration of metals, which are allowed in the soil under conditions in the Netherlands and were calculated using standard soil containing 10% organic matter and 25% clay (Crommentuijn *et al.*, 1997). Metals exceeding this concentration are considered a potential hazard to the environment under conditions in the Netherlands. Most of these metal concentrations, with the exception of Cr(III), Co and Ni which are based on the modified EPA method, are based on statistical extrapolation of 23 to 56 processes per metal and can therefore be considered reliable (Crommentuijn *et al.*, 1997). Earthworm- and microbial benchmarks indicate the metal concentrations in soil that should affect these organisms negatively. These benchmarks, based on literature values respectively, were divided into low confidence (10), moderate confidence (10-20) and high confidence (>20) (Efroymson *et al.*, 1997). Values give an indication at what concentrations certain soil organisms might be affected by the metal component in the soil under North American conditions. With the exception of Cd, Cu and Zn in which a moderate confidence exists, there is little confidence in the rest of the earthworm benchmarks due to the lack of information and experimental testing (Efroymson *et al.*, 1997). The same goes for the microbial benchmarks, with exception of Cd, Cr, Cu, Pb, Hg, Ni and Zn in which a high confidence exists, and Se, Ag and V in which moderate confidence exists (Efroymson *et al.*, 1997). Data for all the sampling sites of each sampling incidence are compared to these benchmarks to determine if the metal content in the soil poses a threat to the soil environment with regard to the Dutch and North American standards.

A significant difference ($p < 0.05$) in Al concentration can be observed between certain sites for August 2005 and for March 2006. For August 2005, the site at 0m, did not differ from any of the other sites. Concentrations of Al for the site at 70m, differed significantly ($p < 0.05$) from all the sites ranging from 150m to 1350m. Aluminum concentrations for March 2006

decreased ($p < 0.05$) further away from the TDF. Concentrations ranged from 1261.0 ± 304.25 $ug.g^{-1}$ at 0m to 790.94 ± 50.55 $ug.g^{-1}$ at the furthest site (1350m). The Al concentration for March 2006 of the site at 0m differed significantly ($p < 0.05$) from sites ranging from 70m to 1350m. Sites at 70m, 150m and 500m generally had the same concentration and differed ($p < 0.05$) from all the other sites, while sites at 300m, 850m and 1350m had more or less the same concentrations. All concentrations for Al in all samples exceed the microbial benchmark.

The [Al] generally did not show much variation throughout the sites, with the exception of the March 2006 data, in which it decreased in distances away from the TDF *viz.* 0m > 70m, 150m, 500m > 300m, 850m, 1350m ($p < 0.05$). All [Al] were above the microbial benchmarks.

Chromium has significant concentration differences ($p < 0.05$) between certain sites for August 2005, March 2006 and for May 2006. Data for August indicates a generally high concentration for the sites at 0m, 70m, 150m and 300m. These four sites did not significantly differ from each other, while the site at 850m differed ($p < 0.05$) from all the other sites. Sites at 500m and 1350m had more or less the same concentrations and differed significantly ($p < 0.05$) from all the other sites. For the March 2006 data, the sites at 70m and 150m, were the only sites which had similar concentrations. The rest of the sites differed from each other significantly ($p < 0.05$). Concentrations for chromium in May 2006 indicated that the sites at 0m, 70m and 150m had similar values and differed significantly ($p < 0.05$) from the last four sites. These last four sites, which were at 300m, 500m, 850m and 1350m, did not differ significantly from each other regarding metal concentrations. It is evident that all sampling incidents of the soil data, shows that Cr gradually decreases ($p < 0.05$) when moving away from the TDF. For example, the data for August 2005 shows that these concentrations range from 36.08 ± 7.62 $ug.g^{-1}$ on the level surface of the TDF (0m) to 10.74 ± 1.3 $ug.g^{-1}$ at the furthest site (1350m). All Cr concentrations exceed earthworm benchmarks and most of them, especially those on the TDF and closest to the TDF, exceed the microbial benchmarks as well.

The [Cr] showed a general decrease in distances away from the TDF *viz.* 0m, 150m, 300m > 500m, 850m, 1350m ($p < 0.05$). These concentrations were generally all lower than the MPC and higher than the earthworm benchmark. This was the case for all the sampling incidents,

except December 2005, where no statistical differences ($p > 0.05$) between the values were observed.

Table 2: Metal contents ($ug.g^{-1}$) of soils collected at increasing distances away from a platinum mine tailings dam facility (TDF) over a period of one year during different months (n=6) compared to different benchmarks. Coloured icons indicate which values exceed benchmark values.

August 2005.

	Al	Cr	Cu	Mn	Ni
MPC[o]		100	40		38
Mic Ben▼	600	10	100	100	90
Earthw.■		0.4	50		200
0 m	4210.5 ± 1215.61^{A,B} ▼	36.08 ± 7.62^{A} ▼ ■	81.88 ± 11.9^{A} ● ■	51.96 ± 10.06^{A}	95.22 ± 16.49^{A} ● ▼
70 m	3306.17 ± 1006.16^{A} ▼	31.07 ± 6.24^{A} ▼ ■	109.68 ± 44.52^{A} ● ▼ ■	65.23 ± 40.97^{A}	90.21 ± 17.2^{A} ● ▼
150 m	6236.17 ± 1924.74^{B} ▼	33.65 ± 16.19^{A} ▼ ■	90.49 ± 84.1^{B} ● ■	428.83 ± 190.68^{B} ▼	69.34 ± 42.48^{B} ●
300 m	5533.0 ± 1546.54^{B} ▼	34.73 ± 29.39^{A} ▼ ■	52.63 ± 17.64^{C} ● ■	723.44 ± 409.2^{C} ▼	54.62 ± 23.25^{B} ●
500 m	5929.83 ± 773.71^{B} ▼	10.86 ± 1.44^{B} ▼ ■	32.31 ± 16.49^{C}	886.17 ± 142.65^{C} ▼	28.85 ± 3.78^{C}
850 m	5168.33 ± 1089.86^{B} ▼	8.01 ± 1.36^{C} ■	57.17 ± 78.94^{C} ● ■	829.32 ± 118.78^{C} ▼	24.91 ± 2.45^{D}
1350 m	6240.83 ± 646.13^{B} ▼	10.74 ± 1.3^{B} ▼ ■	48.36 ± 45.39^{C} ●	1130.78 ± 112.31^{D} ▼	34.07 ± 2.91^{E}

December 2005.

0 m	3777.67 ± 844.79 ▼	28.05 ± 25.14 ▼ ■	353.77 ± 727.98 ● ▼ ■	353.83 ± 344.98 ▼	69.14 ± 44.01 ●
70 m	3052.33 ± 1212.89 ▼	20.98 ± 12.55 ▼ ■	45.19 ± 21.06 ●	326.92 ± 461.11 ▼	56.86 ± 26.22 ●
150 m	3636.67 ± 1682.71 ▼	22.34 ± 12.24 ▼ ■	38.53 ± 20.12	436.19 ± 534.34 ▼	53.42± 17.0 ●
300 m	3743.5 ± 2411.76 ▼	13.0 ± 5.96 ▼ ■	31.72 ± 17.4	521.35 ± 494.0 ▼	38.25 ± 17.09 ●
500 m	3976.33 ± 1588.48 ▼	13.78 ± 8.83 ▼ ■	32.85 ± 28.3	483.51 ± 417.94 ▼	41.25 ± 32.25 ●
850 m	4278.83 ± 2224.93 ▼	14.04 ± 12.03 ▼ ■	23.74 ± 14.74	622.82 ± 356.67 ▼	36.72 ± 22.61
1350 m	3913.33 ± 1447.23 ▼	12.72 ± 5.5 ▼ ■	29.48 ± 17.23	699.43± 449.62 ▼	39.81 ± 14.19 ●

March 2006.

0 m	1261.0 ± 304.25^{A} ▼	10.36 ± 2.09^{A} ▼ ■	14.16 ± 2.81^{A}	11.29 ± 2.51^{A}	24.34 ± 5.72^{A}
70 m	943.64 ± 110.96^{B} ▼	7.39 ± 2.09^{B} ■	11.97 ± 1.2^{A}	9.6 ± 0.75^{A}	18.75 ± 2.79^{B}
150 m	911.54 ± 89.86^{B} ▼	5.78 ± 2.16^{B} ■	7.43 ± 6.18^{B}	56.78 ± 32.41^{B}	10.25 ± 4.06^{C}
300 m	836.4 ± 73.23^{C} ▼	2.62 ± 0.11^{C} ■	2.29 ± 0.58^{C}	119.41 ± 34.37^{C} ▼	6.62 ± 0.9^{D}
500 m	947.57 ± 100.61^{B} ▼	2.19 ± 0.25^{D} ■	3.64 ± 4.0^{C}	140.71 ± 47.18^{C} ▼	6.08 ± 1.53^{E}
850 m	816.1 ± 44.08^{C} ▼	1.57 ± 0.1^{E} ■	1.45 ± 0.38^{D}	96.05 ± 13.43^{D}	4.16 ± 0.64^{F}
1350 m	790.94 ± 50.55^{C} ▼	1.92 ± 0.17^{F} ■	2.24 ± 1.63^{C}	133.68 ± 15.4^{C} ▼	5.31 ± 0.69^{E}

May 2006.

0 m	4103.3 ± 782.52 ▼	33.29 ± 4.29^{A} ▼ ■	60.71 ± 1.67^{A} ● ■	52.22 ± 7.64^{A}	101.86 ± 8.89^{A} ● ▼
70 m	3504.47 ± 1316.28 ▼	24.62 ± 3.7^{A} ▼ ■	56.4 ± 2.24^{B} ● ■	132.21 ± 221.77^{B} ▼	84.66 ± 10.33^{B} ●
150 m	3420.8 ± 873.5 ▼	24.32 ± 13.4^{A} ▼ ■	21.96 ± 10.81^{C}	303.12 ± 184.63^{C} ▼	46.72 ± 16.59^{C} ●
300 m	3049.17 ± 1610.53 ▼	7.93 ± 4.31^{B} ■	5.9 ± 2.97^{D}	455.71 ± 231.89^{D} ▼	23.92 ± 12.65^{D}
500 m	3495.97 ± 499.62 ▼	6.53 ± 1.19^{B} ■	6.36 ± 1.64^{D}	531.4 ± 69.25^{E} ▼	19.81 ± 4.45^{D}
850 m	3844.3 ± 572.87 ▼	6.08 ± 0.86^{B} ■	5.72 ± 1.05^{D}	578.55 ± 88.82^{E} ▼	21.91 ± 3.49^{D}
1350 m	3474.47 ± 617.6 ▼	6.18 ± 1.1^{B} ■	4.83 ± 1.42^{D}	690.89 ± 123.73^{E} ▼	23.89 ± 3.98^{D}

MPC: Maximum Permissable Concentration (Crommentuijn *et al.*, 1997) / Mic. Ben: Microbial Benchmark (Efroymson *et al.*, 1997) / Earthw: Earthworm Benchmarks (Efroymson *et al.*, 1997). A-F: Values sharing the same letter in superscript were not statistically different from each other.

August 2005.

	Fe	Se	Cd	Pb	Ba
MPC*		0.18	1.6	140	165
Mic Ben▼	200	100	20	900	3000
Earthw.▪		70	20	500	
0 m	3760.5 ± 698.67^{A}▼	1.41 ± 0.41 ●	0.05 ± 0.02	3.69 ± 0.47^{A}	11.21 ± 2.5^{A}
70 m	3362.67 ± 628.0^{A}▼	1.57 ± 0.45 ●	0.06 ± 0.02	3.53 ± 0.62^{A}	10.22 ± 1.81^{A}
150 m	3546.67 ± 1464.59^{A}▼	2.09 ± 0.62 ●	0.05 ± 0.01	4.98 ± 0.81^{B}	46.91 ± 14.33^{B}
300 m	2938.0 ± 1289.88^{A}▼	1.84 ± 0.36 ●	0.05 ± 0.02	5.05 ± 0.88^{B}	72.71 ± 36.88^{C}
500 m	1793.0 ± 199.01^{B}▼	1.77 ± 0.28 ●	0.04 ± 0.01	5.6 ± 0.65^{B}	90.9 ± 14.88^{D}
850 m	1517.0 ± 306.39^{B}▼	1.91 ± 0.39 ●	0.04 ± 0.01	4.75 ± 0.45^{B}	70.99 ± 17.78^{E}
1350 m	1991.5 ± 223.64^{C}▼	1.93 ± 0.35 ●	0.08 ± 0.05	6.68 ± 1.09^{C}	110.23 ± 22.7^{F}

December 2005.

0 m	2768.17 ± 1425.42 ▼	1.72 ± 0.26 ●	0.05 ± 0.02	4.49 ± 1.4	34.85 ± 24.45
70 m	2345.0 ± 823.91 ▼	1.7 ± 0.58 ●	0.05 ± 0.03	4.12 ± 1.83	30.55 ± 34.85
150 m	2286.67 ± 417.98 ▼	1.5 ± 0.45 ●	0.06 ± 0.03	4.51 ± 1.55	44.03 ± 45.58
300 m	1775.5 ± 523.12 ▼	1.85 ± 0.59 ●	0.05 ± 0.03	4.2 ± 2.06	43.63 ± 42.13
500 m	1892.5 ± 728.53 ▼	1.62 ± 0.08 ●	0.05 ± 0.02	4.43 ± 1.63	52 ± 40.31
850 m	1839.83 ± 1119.17 ▼	1.51 ± 0.37 ●	0.04 ± 0.02	5.04 ± 2.38	60.01 ± 36.55
1350 m	1757.35 ± 542.58 ▼	1.56 ± 0.29 ●	0.04 ± 0.01	4.8 ± 1.3	58.35 ± 36.01

March 2006.

0 m	868.1 ± 185.23^{A} ▼	0.33 ± 0.05^{A} ●	0.01 ± 0	0.6 ± 0.15^{A}	3.07 ± 0.58^{A}
70 m	697.05 ± 96.79^{B} ▼	0.33 ± 0.05^{A} ●	0.01 ± 0	0.57 ± 0.12^{A}	2.43 ± 0.12^{A}
150 m	572.37 ± 139.7^{C} ▼	0.24 ± 0.04^{B} ●	0.01 ± 0	0.57 ± 0.08^{A}	8.05 ± 4.12^{B}
300 m	351.65 ± 36.19^{D} ▼	0.27 ± 0.04^{A,B} ●	0.01 ± 0	0.76 ± 0.13^{A,B,C,D}	18.46 ± 8.76^{C}
500 m	353.44 ± 47.84^{D} ▼	0.25 ± 0.05^{B} ●	0.02 ± 0.03	0.86 ± 0.12^{B}	17.9 ± 2.26^{D}
850 m	285.92 ± 17.69^{E} ▼	0.2 ± 0.03^{B} ●	0.03 ± 0.05	0.72 ± 0.09^{C}	14.79 ± 1.3^{E}
1350 m	341.12 ± 71.11^{D} ▼	0.25 ± 0.06^{B} ●	0.04 ± 0.06	0.92 ± 0.11^{D}	18.39 ± 2.03^{D}

May 2006.

0 m	3133.19 ± 403.32^{A} ▼	0.25 ± 0.04^{A} ●	0.02 ± 0	3.43 ± 0.43	14.91 ± 2.33^{A}
70 m	2565.03 ± 406.53^{B} ▼	0.27 ± 0.05^{A,B} ●	0.02 ± 0.01	3.1 ± 1.31	22.29 ± 25.22^{A}
150 m	2050.19 ± 512.31^{B} ▼	0.26 ± 0.05^{A,B} ●	0.02 ± 0	3.43 ± 1.02	44.82 ± 23.65^{B}
300 m	1003.63 ± 531.54^{C} ▼	0.29 ± 0.1^{A,B} ●	0.02 ± 0.01	3.05 ± 1.45	59.38 ± 30.86^{C}
500 m	940.39 ± 110.32^{C} ▼	0.32 ± 0.05^{A,B} ●	0.03 ± 0.01	4.03 ± 0.87	72.79 ± 9.76^{D}
850 m	1050.99 ± 159.66^{C} ▼	0.36 ± 0.08^{A,B} ●	0.03 ± 0.01	4.21 ± 0.63	80.12 ± 9.76^{D}
1350 m	1067.04 ± 202.78^{C} ▼	0.36 ± 0.06^{A,B} ●	0.03 ± 0	4.52 ± 0.71	80.39 ± 13.77^{D}

MPC: Maximum Permissable Concentration (Crommentuijn *et al.*, 1997) / Mic. Ben: Microbial Benchmark (Efroymson *et al.*, 1997) / Earthw: Earthworm Benchmarks (Efroymson *et al.*, 1997). A-F: Values sharing the same letter in superscript were not statistically different from each other.

Copper concentrations varied significantly ($p < 0.05$) between certain sites for August 2005, March 2006 and May 2006. Data for August 2005 clearly states that the sites on the TDF (0m and 70m) differed significantly ($p < 0.05$) from sites off the TDF (150m to 1350m). The site at 150m, which is the first site next to the TDF, differed ($p < 0.05$) from all the other sites taken in August 2005. Sites at 300m, 500m, 850m and 1350m generally had similar concentrations and differed ($p < 0.05$) from the first three sites. Exactly the same pattern was observed for March 2006, with the exception of the site at 850m, which differed ($p < 0.05$)

from all the other sites. For the May 2006 data, the site on the level surface of the TDF (0m), the site on the slope of the TDF (70m) and the site right next to the TDF (150m) all differed significantly ($p < 0.05$) from each other and from the remaining four sites (300m to 1350m). Copper concentrations gradually decreases ($p < 0.05$) further away from the TDF for August 2005, March 2006 and May 2006. Concentrations seem to be exceptionally high ($p < 0.05$) at the first two sample sites (0m and 70m). For example, in the August 2005 data, concentrations range from 81.88 ± 11.9 ug.g^{-1} on the TDF to 48.36 ± 45.39 ug.g^{-1} further away from the TDF. For August 2005 most concentrations exceed the MPC and earthworm benchmarks. For December 2005 and May 2006, only those concentrations of the samples taken on the TDF, exceed the MPC and earthworm benchmarks.

The [Cu] generally decreases in distances further away from the TDF *viz.* 0m, 70m > 150m > 300m-1350 ($p < 0.05$). This was the case for all sampling incidences, except for December 2005, which had no statistical differences ($p > 0.05$) between different sites. Sampling incidences during December 2005 and May 2006 revealed that the concentrations of the two sites on the TDF (0m and 70m) exceeded the MPC and earthworm benchmarks, while concentrations of soil taken during March 2006 did not exceed any benchmarks and during August almost all concentrations exceeded the MPC and earthworm benchmarks.

Significant differences ($p < 0.05$) in Fe concentrations were observed between certain sites for August 2005, March 2006 and May 2006. In the August 2005 data, the first four sites (0m to 300m) had more or less the same Fe concentration and significantly differed ($p < 0.05$) from the last three sites (500m to 1350m). Sites at 500m and 850m had similar concentrations, but differed ($p < 0.05$) from the first four sites and the last site (1350m). Data for March 2006 revealed that the first site, which is on the level surface of the TDF (0m), the site on the slope of the TDF (70m) and the site closest to the TDF (150m) all differed significantly ($p < 0.05$) from each other and from the remaining four sites (300m to 1350m). Sites at 300m, 500m and 1350m had similar Fe concentrations, but differed from all the other sites significantly ($p < 0.05$). The site at 850m differed ($p < 0.05$) from all the other sites. For the May 2006 data, the site on the level surface of the tailings TDF (70m) differed ($p < 0.05$) from all the other sites. Sites at 70m, which is on the slope of the TDF, and at 150m had similar concentrations, but differed ($p < 0.05$) from all the other sites. Similar concentrations were detected at the last four sites (300m, 500m, 850m, 1350m). A gradual decrease ($p < 0.05$) in Fe concentration can be observed from the TDF to the last site (1350m). All

sampling incidences clearly indicate that the two samples taken on the TDF has significantly higher ($p < 0.05$) Fe concentrations than the rest of the samples, with the exception of the December 2005 data. For example, for the August 2005 data concentrations range from 3760.5 ± 698.67 ug.g^{-1} on the TDF to 1991.5 ± 223.64 ug.g^{-1} further away from the TDF. In every sample taken for this study, the Fe concentration exceeds the microbial benchmark.

The [Fe] showed a general decrease in distances from the TDF *viz.* 0m > 70m, 150m > 300m > 500m, 850m, 1350m ($p < 0.05$). This was the case for all the sampling incidences, except for December 2005 where no statistical differences ($p > 0.05$) were observed between the values. All [Fe] exceeded the microbial benchmarks.

Metal analysis indicates variation in Mn concentrations ($p < 0.05$) between certain sites for August 2005, March 2006 and May 2006. For August 2005, the samples taken on the level surface of the TDF (0m), as well as those taken on the slopes of the TDF (70m), had similar concentrations and differed ($p < 0.05$) from the remaining sites (150m to 1350m). The site at 150m differed ($p < 0.05$) from all other sites. Sites ranging from 300m to 850m had no significant concentration difference between them, but rather differed ($p < 0.05$) from the first three sites and the last site. Concentrations of Mn for March 2006, indicated that the first two sites, which are both situated on the TDF are similar, but differed ($p < 0.05$) from all the other sites. The site next to the TDF (150m) differed ($p < 0.05$) from all other sites. This was also the case for the site at 850m. Concentrations of the sites at 300m, 500m and at 1350m did not differ significantly from each other. For the May 2006 data, the first four sites (0m, 70m, 150m and 300m) all differed ($p < 0.05$) from each other and from the remaining sites, based on Mn concentration. It was only the last three sites (500m to 1350m), which had similar concentrations. Manganese has a significant increase ($p < 0.05$) in concentration when moving away from the TDF. This is evident in all sampling incidences except for December 2005. For example, for August 2005 concentrations ranged from 51.96 ± 10.06 ug.g^{-1} on the TDF to 1130.78 ± 112.31 ug.g^{-1} further away from the TDF. Most of the concentrations exceed the microbial benchmark, except those taken on the TDF.

Concentrations of Mn further away from the TDF were generally all higher than the microbial benchmarks, with the exception of March 2006, which had values lower than this benchmark. With the exception of December 2005, which had no statistical differences ($p > 0.05$) between values, [Mn] generally increased further away from the TDF *viz.* 0m, 70m < 150m < 300m-1350m.

Nickel concentrations varied ($p < 0.05$) amongst different sites for August 2005, March 2006 and May 2006. In the August 2005 data, it is noticeable that the first two sites (0m and 70m), which are both located on the TDF, differs in concentration from the rest of the sites (150m to 1350m). Sites at 150m and 300m share similar concentrations, but differ ($p < 0.05$) from the other five sites. The last three sites (500m, 850m and 1350m) all differ from each other ($p < 0.05$) and also differ ($p < 0.05$) from all the other sites. Data for March 2006 indicated that only the sites at 500m and 1350m had similar Ni concentrations. All other samples differed from each other significantly ($p < 0.05$). For May 2006, the two sites on the TDF (0m and 70m) and the third site (150m) all differed ($p < 0.05$) from each other and from the remaining sites (300m to 1350m). Sites at 300m, 500m, 850m and 1350m all had similar Ni concentrations. All sampling incidences, with the exception of December 2005, show a gradual decrease ($p < 0.05$) in Ni concentrations when moving further away from the TDF. Significantly high concentrations ($p < 0.05$) persist in the samples taken on and close to the TDF. For example, for May 2006 concentrations ranged from 101.86 ± 8.89 ug.g^{-1} on the TDF to 23.89 ± 3.98 ug.g^{-1} further away from the TDF. Only concentrations from those samples taken on and close to the TDF exceed the MPC and microbial benchmark, with the exception of the March 2006 samples.

A general decrease in [Ni] was observed in distances further away from the TDF *viz.* 0m > 70m > 150m > 300m-1350m ($p < 0.05$). This was not the case for December 2005, which showed no statistical difference ($p > 0.05$) between the values of the different sites. All of the sites taken in December 2005 exceeded the MPC values. Generally concentrations from the sites at 0m and 70m for both August 2005 and May 2006, exceeded the MPC and microbial benchmarks, while all [Ni] were lower than the earthworm benchmarks.

Concentrations for selenium varied significantly ($p < 0.05$) between different sites for March 2006. Selenium data for the March 2006 sampling revealed that the two sites on the tailings TDF (0m and 70m) had similar concentrations, but differed significantly ($p < 0.05$) from the sites at 150m, 500m 850m and 1350m. The site at 300m did not differ from any of the other sites. For March 2006, Se concentrations decrease ($p < 0.05$) further away from the TDF. The Se concentrations for March 2006 ranged from 0.33 ± 0.05 ug.g^{-1} on the TDF to 0.25 ± 0.06 ug.g^{-1} further away from the TDF. Concentrations of all the sampling sites and for all sampling incidences exceed the MPC value.

The general trend is that all [Se] were higher than the MPC and lower than the earthworm and microbial benchmarks. No statistical differences ($p > 0.05$) were observed for [Se] during August and December, but showed a general decrease ($p < 0.05$) further away from the TDF for May 2006 and an increase ($p < 0.05$) in the same direction for March 2006.

Cadmium has no significant change ($p > 0.05$) in concentration across the different sites for any sampling incidence.

Lead concentrations varied ($p < 0.05$) between sites of August 2005 and March 2006. Data for August 2005 indicated that the two sites on the TDF (0m and 70m) differed significantly ($p < 0.05$) with the rest of the sites (150m to 1350m). All sites from 150m to 850m had similar concentrations and differed ($p < 0.05$) from all other sites. The site at 1350m differed significantly ($p < 0.05$) from all other sites. For the March 2006 data, the two sites on the TDF (0m and 70m) and the site right next to the TDF (150m) had similar Pb concentrations. Concentrations for the site at 300m did not differ from any of the other sites. Although Pb concentrations are all below benchmark and MPC values, concentrations for all the sampling incidences gradually increase ($p < 0.05$) further away from the TDF. For example, concentrations for August 2005 ranged from 3.69 ± 0.47 ug.g^{-1} on the TDF to 6.68 ± 1.09 ug.g^{-1} further away from the TDF.

The [Pb] showed a general increase further away from the TDF *viz.* 0m, 70m < 150m, 300m, 500m, 850m < 1350m ($p < 0.05$). This was the case for August 2005 and March 2006, while the [Pb] for December 2005 and May 2006 showed no statistical ($p > 0.05$) difference between the different sites. All [Pb] were lower than the MPC, earthworm and microbial benchmarks.

Significant differences in barium concentration was observed for August 2005, March 2006 and May 2006. August 2005 data indicated that the two sites on the TDF (0m and 70m) had similar Ba concentrations, but differed significantly ($p < 0.05$) from all the other sites (150m to 1350m). All sites from 150m to 1350m differed ($p < 0.05$) from each other. For the March 2006 data the two sites on the TDF had similar concentrations, but differed from all the other sites. Sites at 500m and 1350m had similar concentrations, but differed ($p < 0.05$) from all other sites. The sites at 150m, 300m and 850m all differed from each other and also differed from all the other sites. In the May 2006 data, the sites at 0m and 70m, which is situated on the TDF, had similar concentrations, but differed from all the other sites (150 to 1350m).

Sites at 150m and 300m differed from each other and differed from all the other sites ($p < 0.05$). Concentrations were more or less similar for all of the sites from 500m to 1350m. There is a definite increase ($p < 0.05$) in Ba concentration when moving away from the TDF, which can be seen in the August 2005, March 2006 and May 2006 data. For example, for August 2005 concentrations ranged from 11.21 ± 2.5 ug.g^{-1} on the TDF to 110.23 ± 22.7 ug.g^{-1} further away from the TDF. All Ba concentrations are below MPC and microbial benchmark values.

The [Ba] generally increased further away from the TDF *viz.* 0m, 70m < 150m < 300m < 500m-1350m ($p < 0.05$). Only the December 2005 did not show this trend and did not have statistical differences ($P > 0.05$) between [Ba] of the different sites. Generally, [Ba] were lower than the MPC and microbial benchmarks for all sampling incidences.

Box and whisker plots (Figures 4 - 13) were drawn for each metal from all sampling incidences. These graphs indicate that for certain sampling incidences, the concentrations of Cr, Cu, Fe and Ni decrease ($p < 0.05$) when moving away from the TDF. Also, for certain sampling incidences the concentrations of Mn, Ba and Pb increases ($p < 0.05$) when moving away from the TDF, illustrating graphically what is given in Table 2.

Seasonal variation for the metals is also evident in the soil data. The data for August 2005 and December 2005 show a relatively high ($p < 0.05$) metal content in the soil. A lower ($p < 0.05$) soil metal concentration occurred in the samples taken for the May 2006 data. The metal content in the soil for March 2006 was the lowest ($p < 0.05$) of all the sampling incidences. Data for all of the metals showed more or less the same tendencies in terms of seasonal variation.

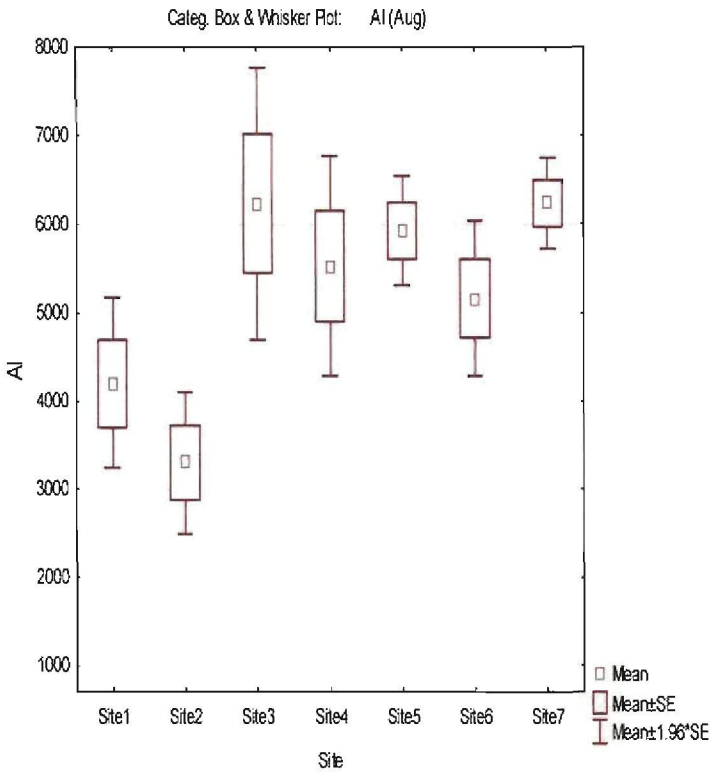
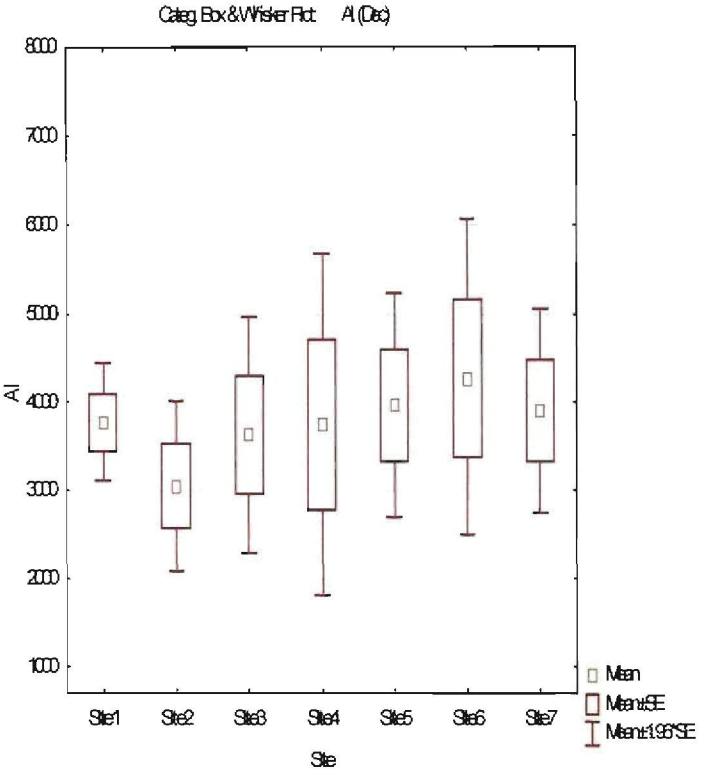


Figure 4.1



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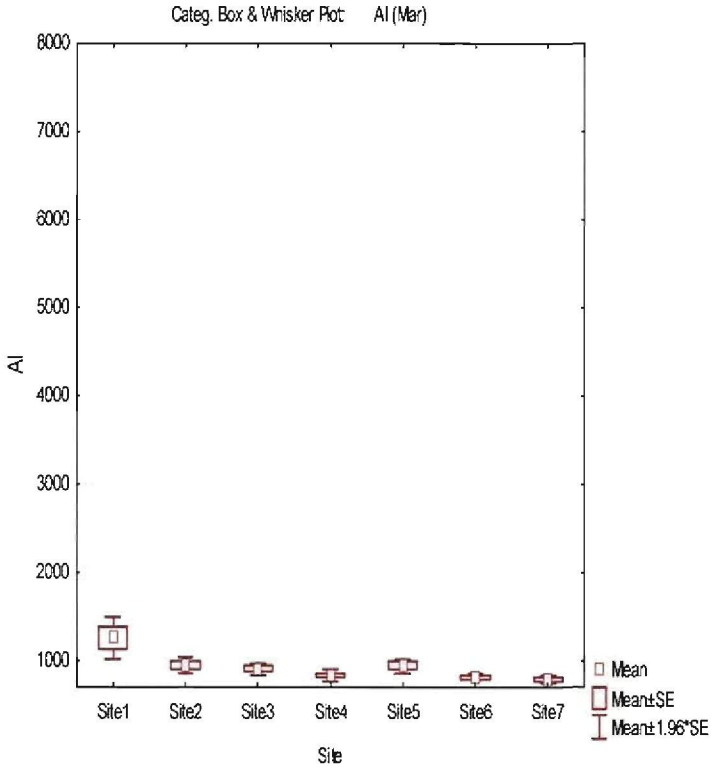


Figure 4.3

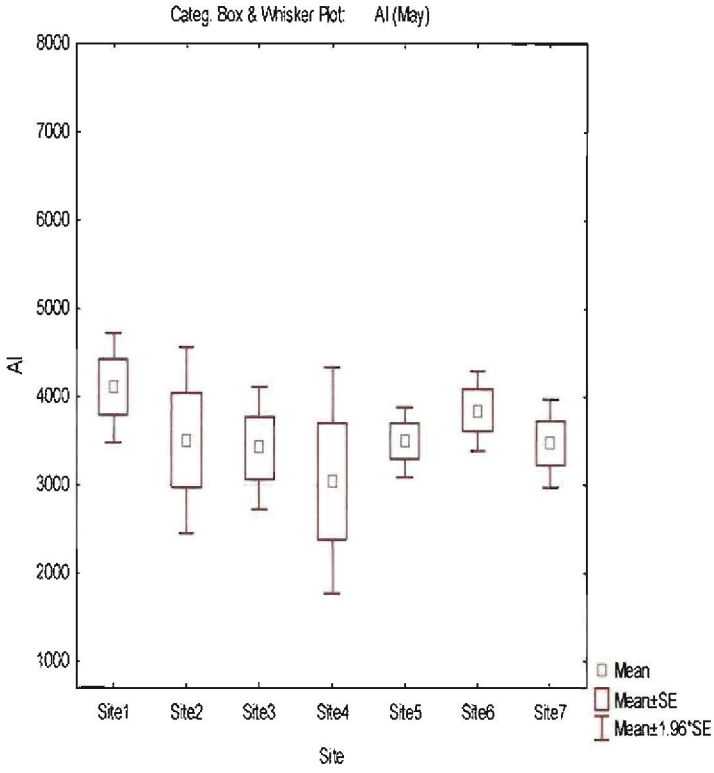


Figure 4.4

Figure 4: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Al in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

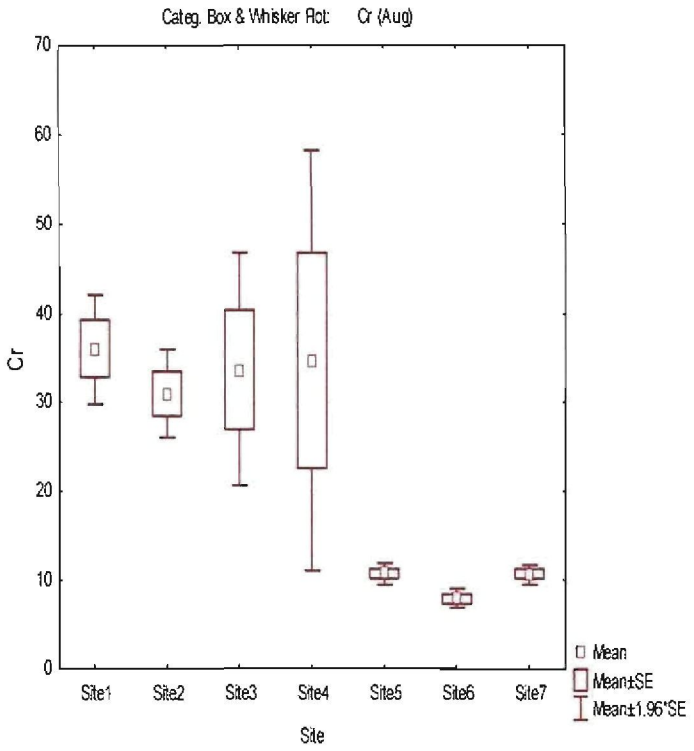
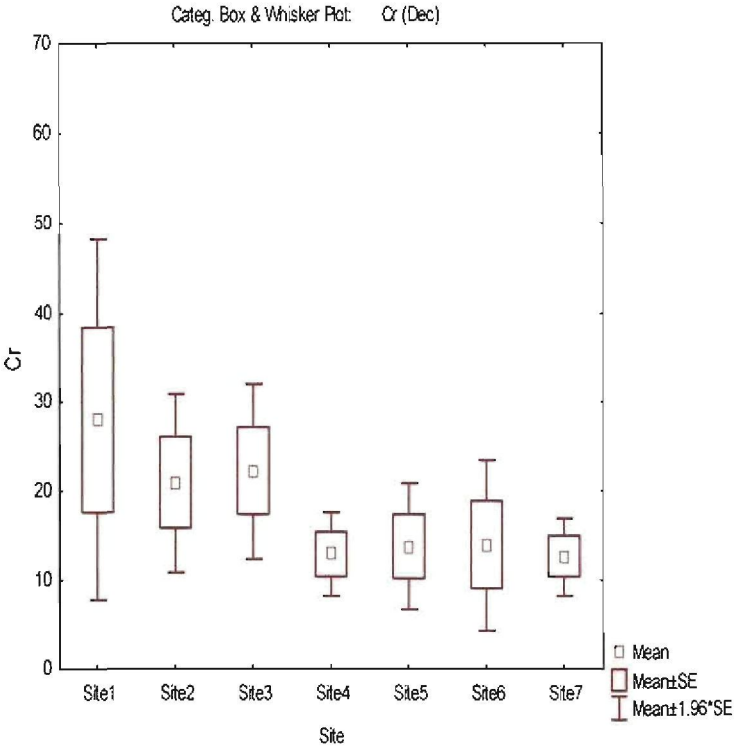


Figure 5.1



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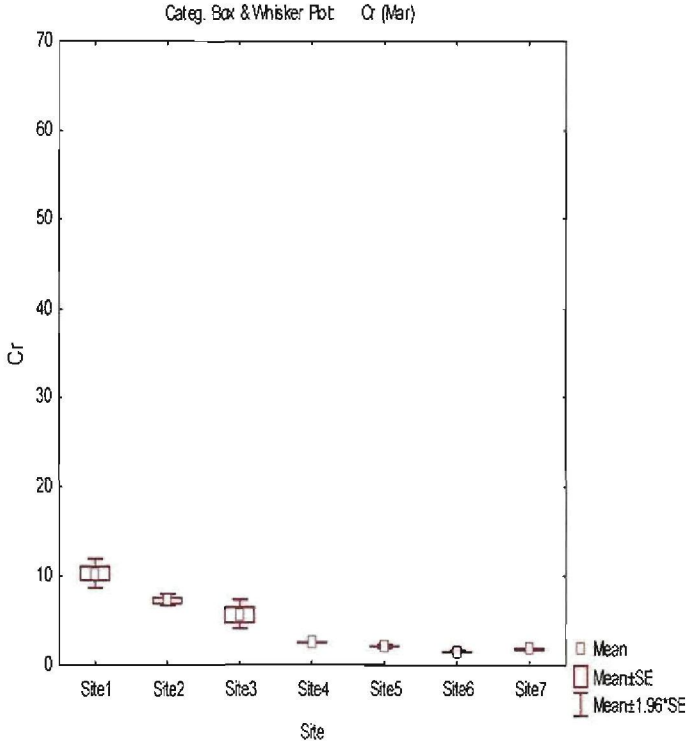

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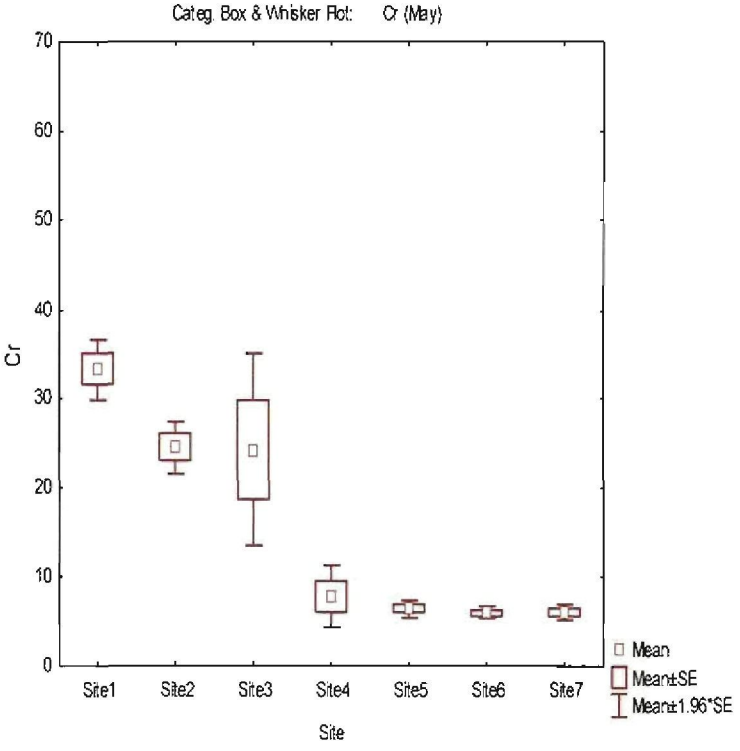


Figure 5.4

Figure 5: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Cr in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

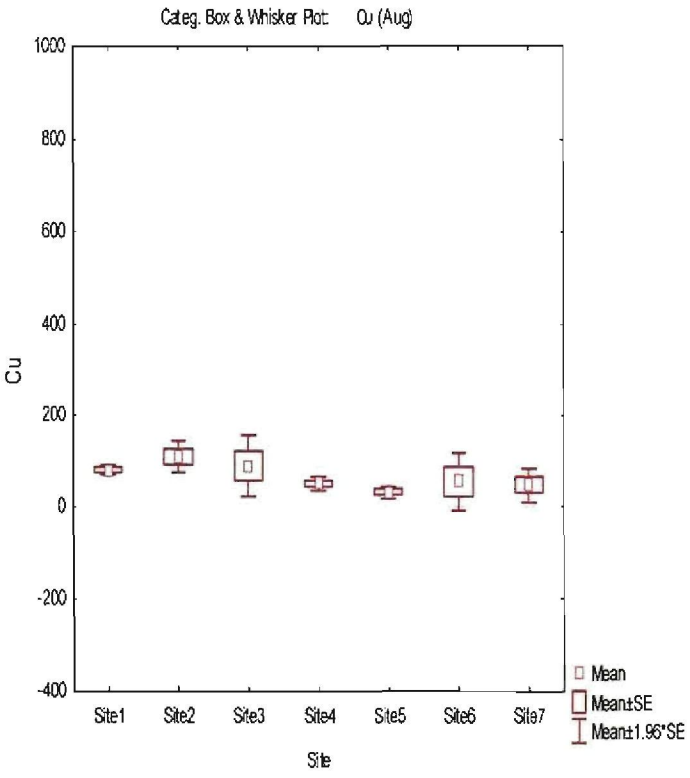
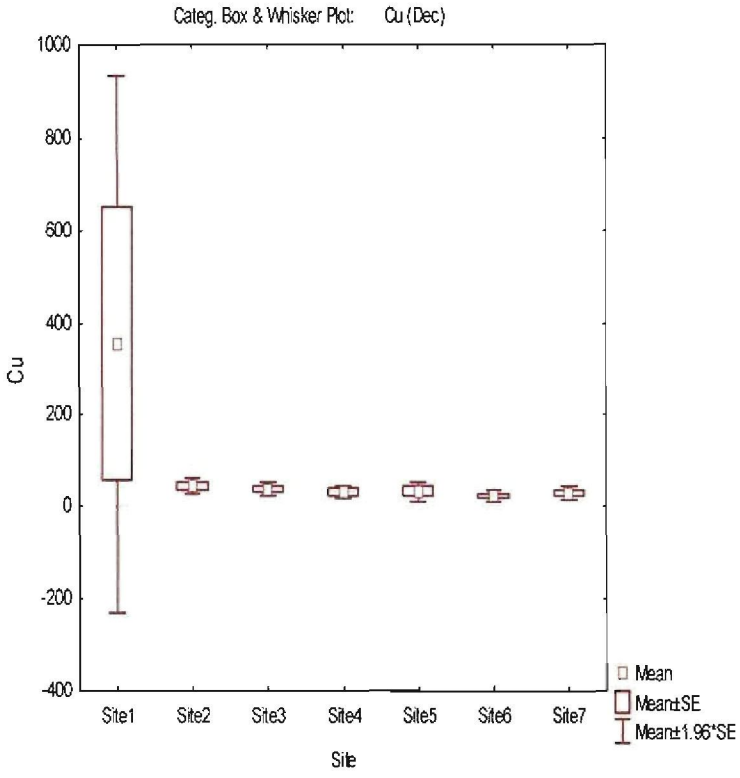


Figure 6.1



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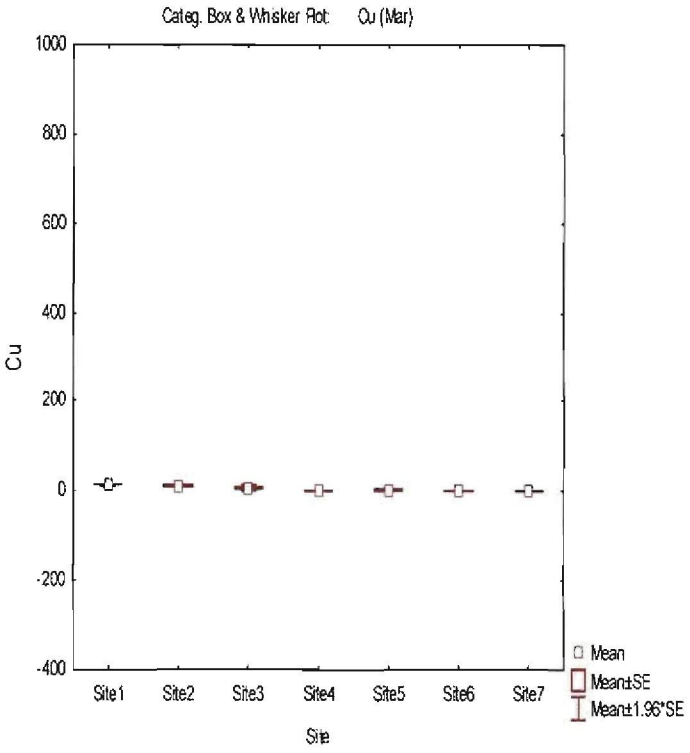

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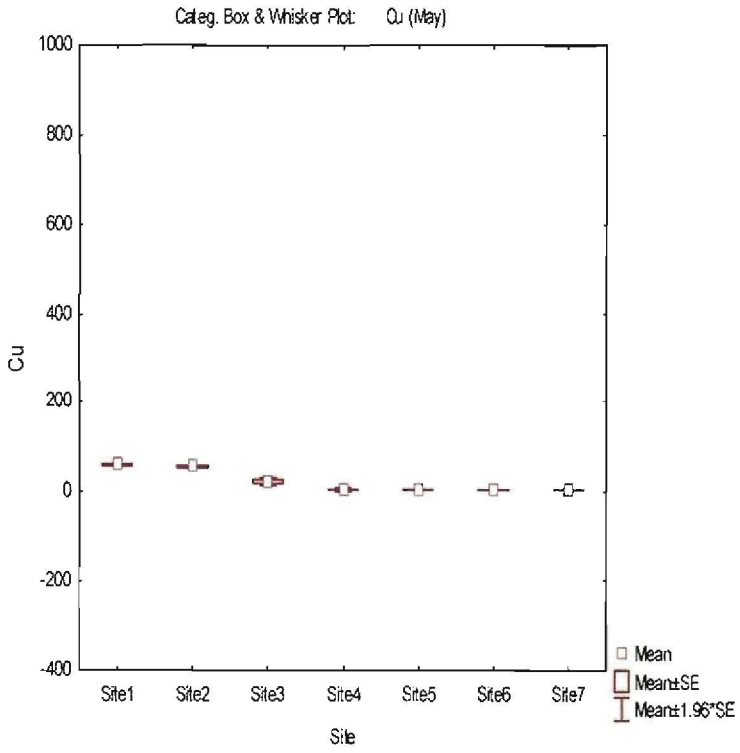


Figure 6.4

Figure 6: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Cu in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

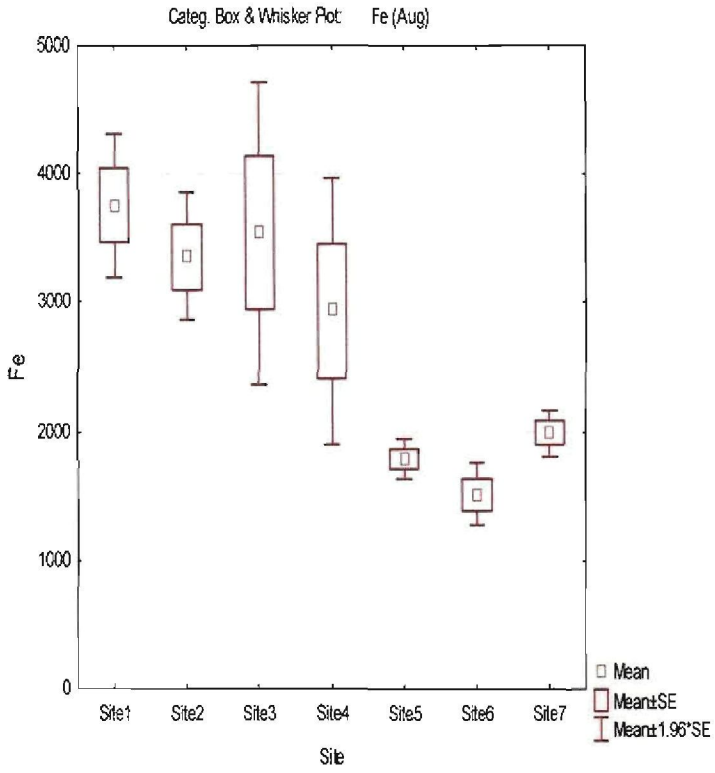
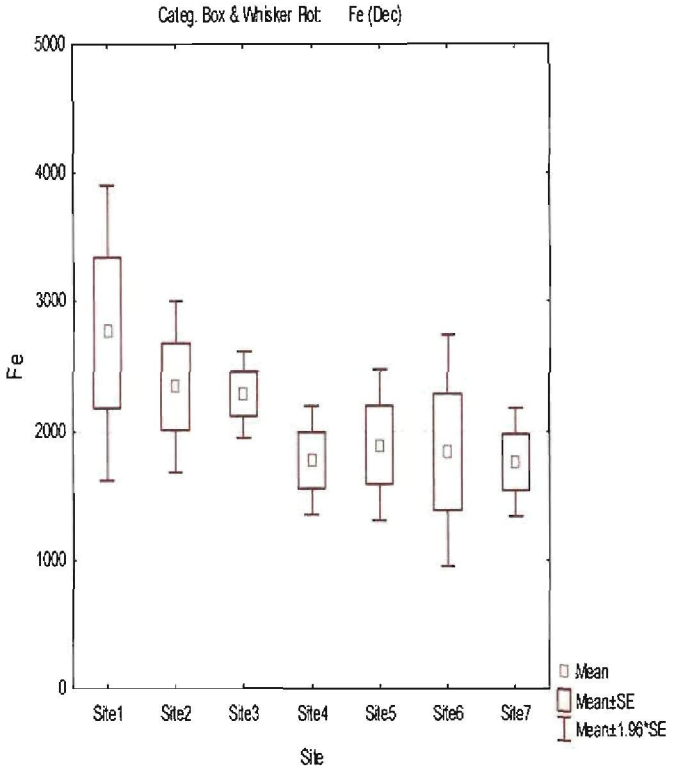


Figure 7.1



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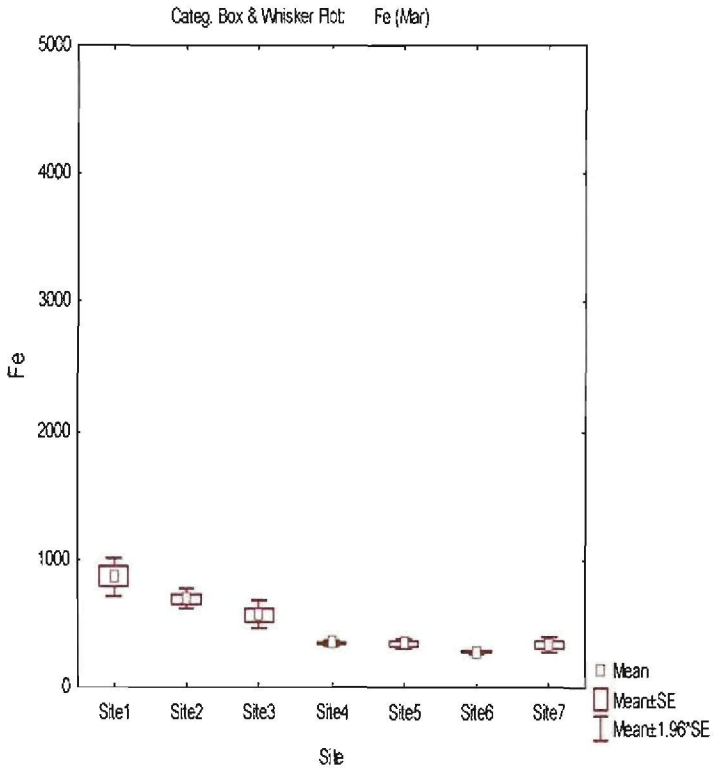


Figure 7.3

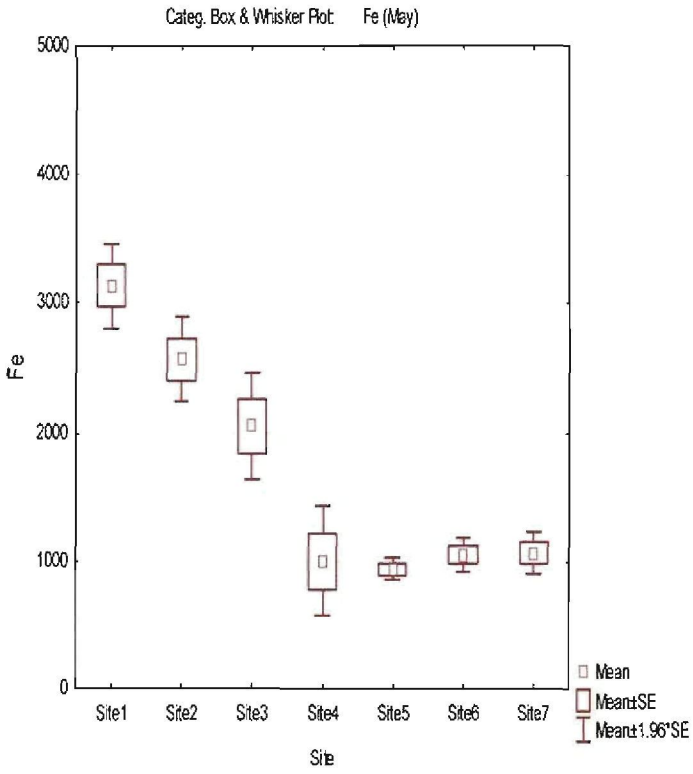


Figure 7.4

Figure 7: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Fe in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

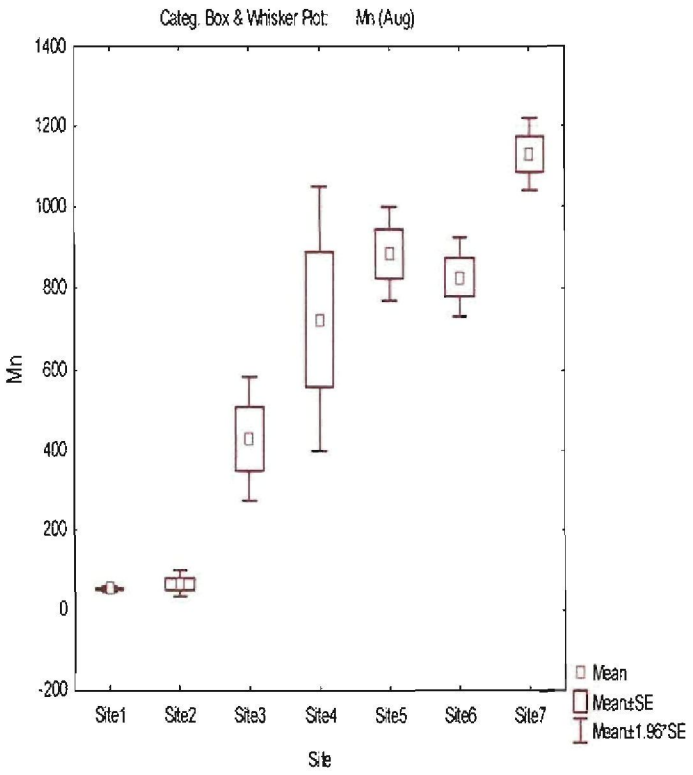
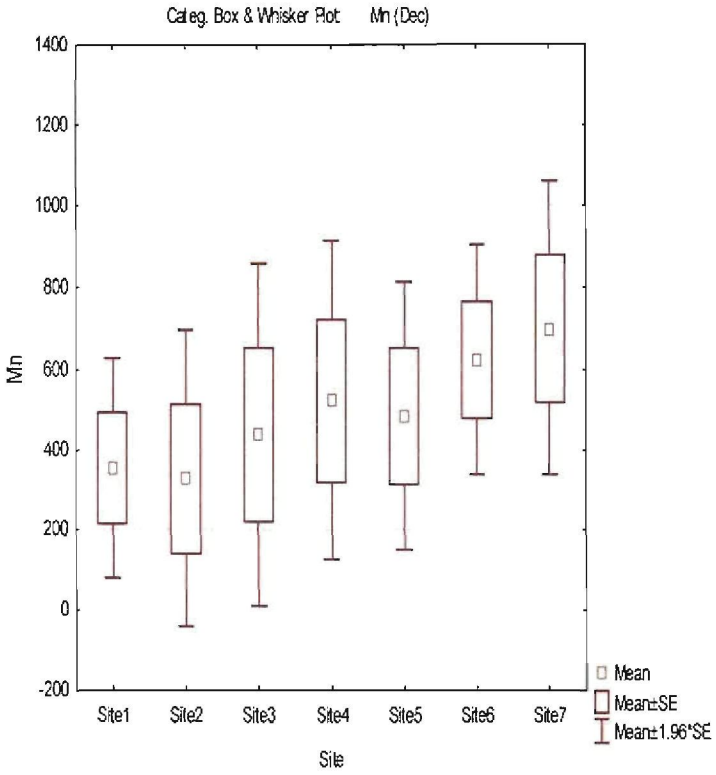


Figure 8.1



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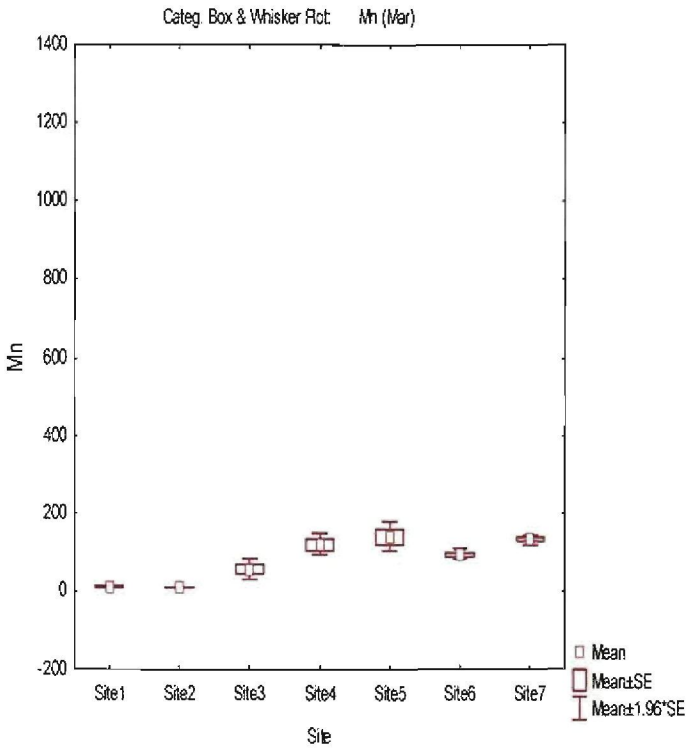

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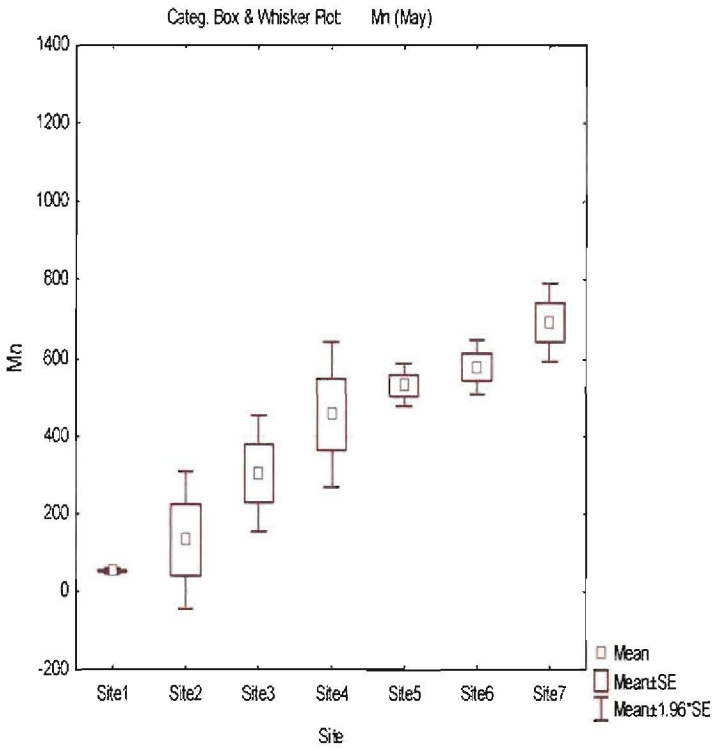


Figure 8.4

Figure 8: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Mn in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

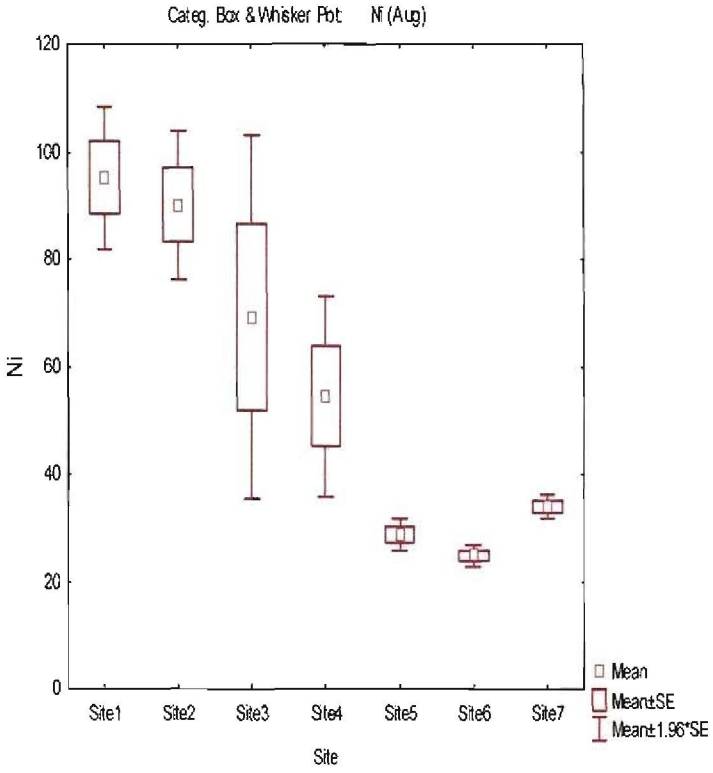
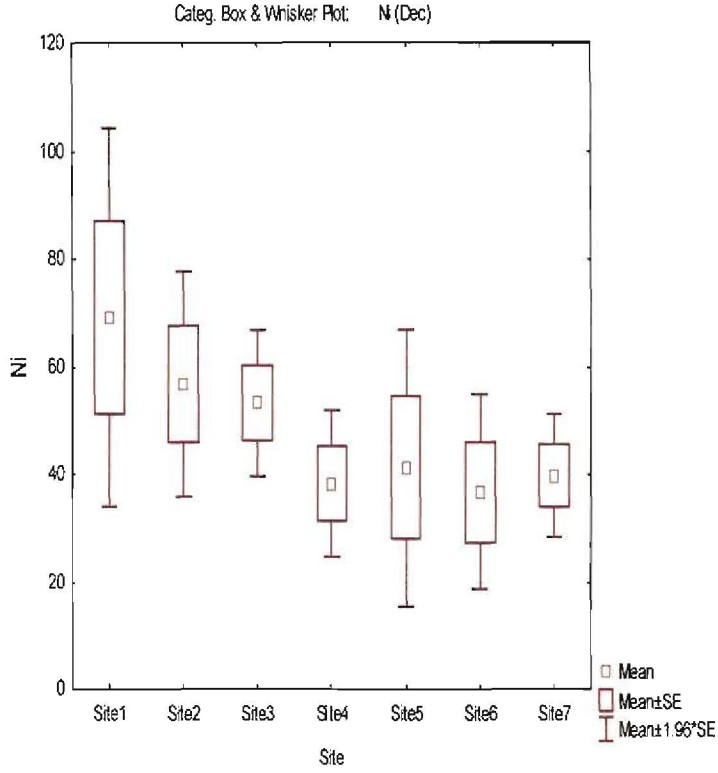


Figure 9.1



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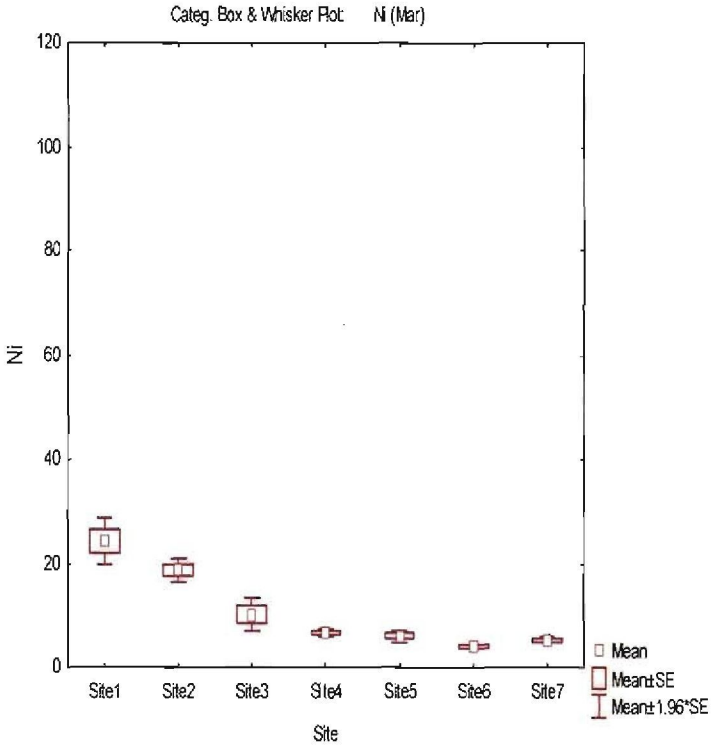

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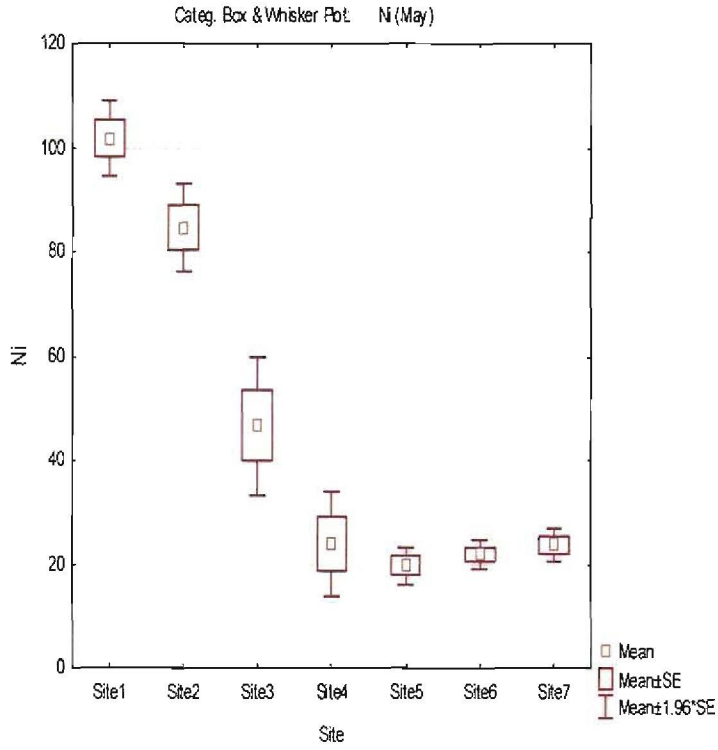


Figure 9.4

Figure 9: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Ni in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

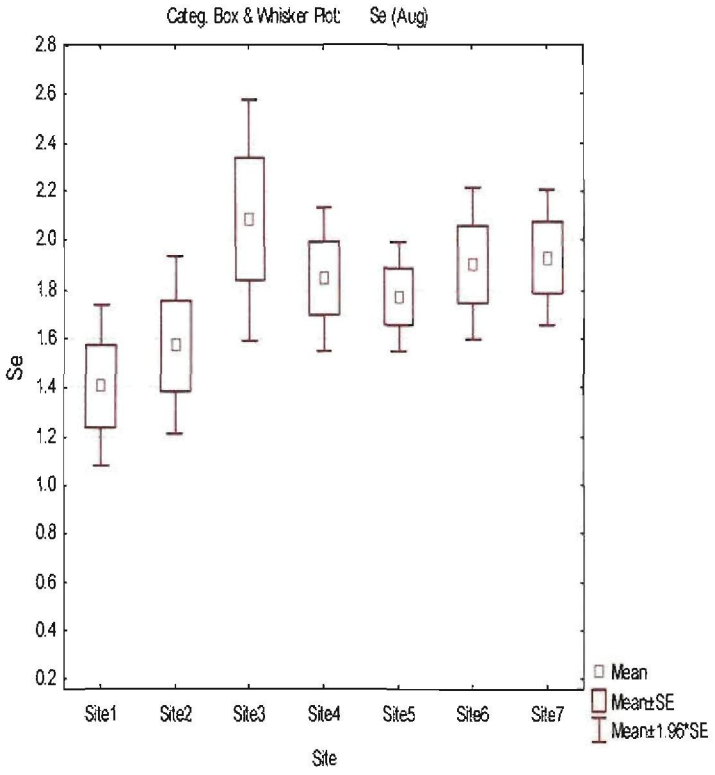
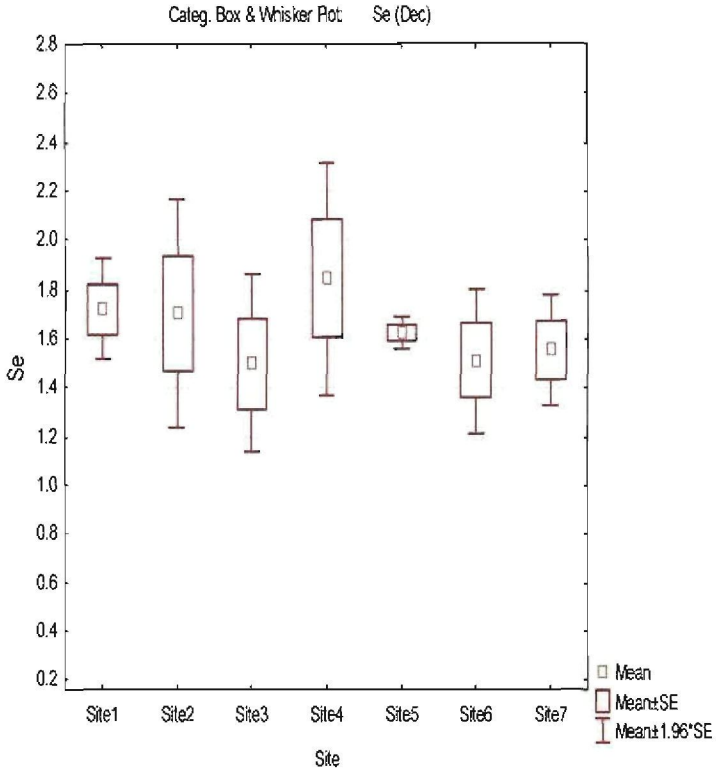


Figure 10.1



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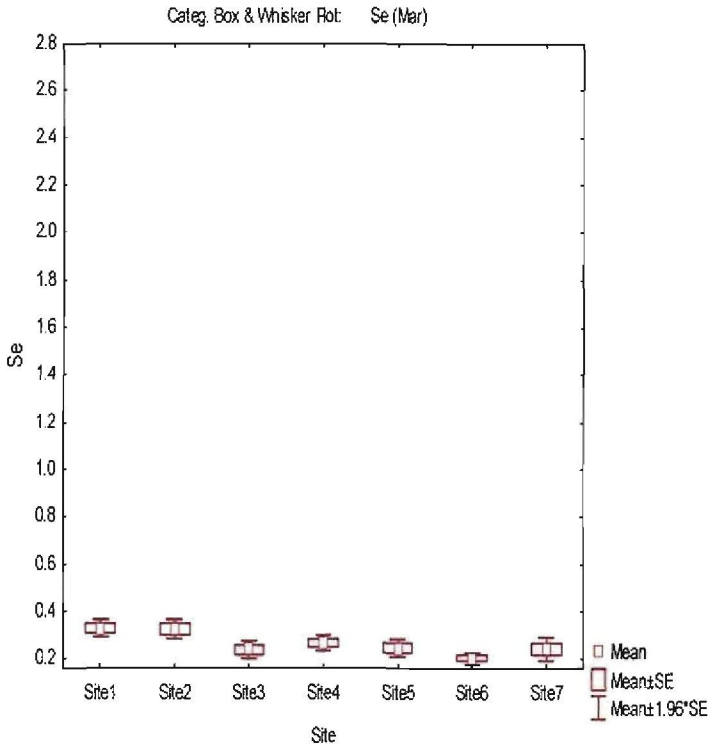

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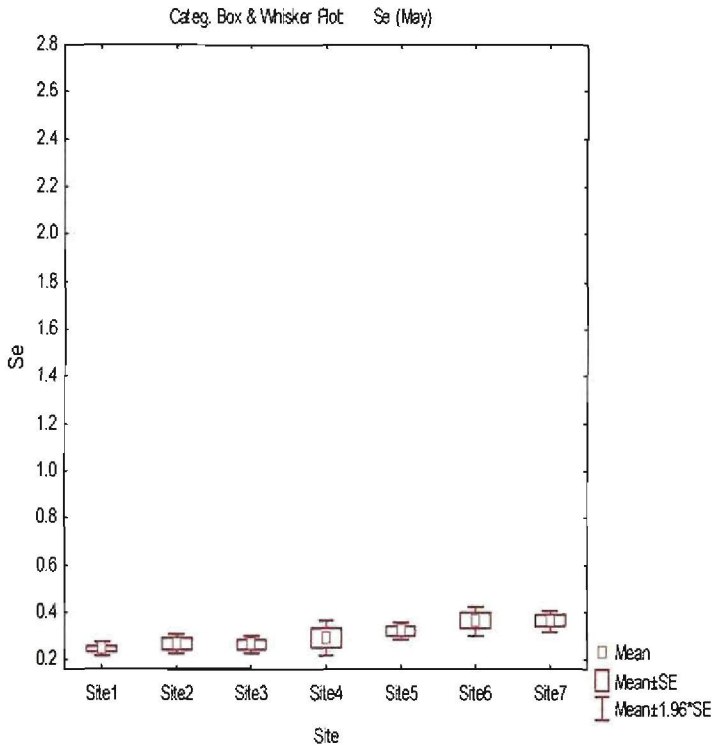


Figure 10.4

Figure 10: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Se in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

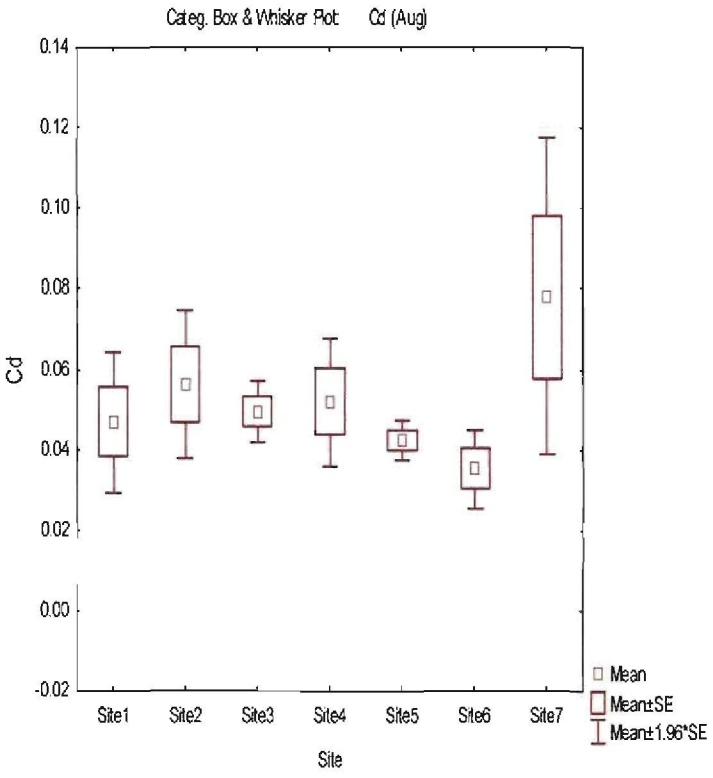


Figure 11.1

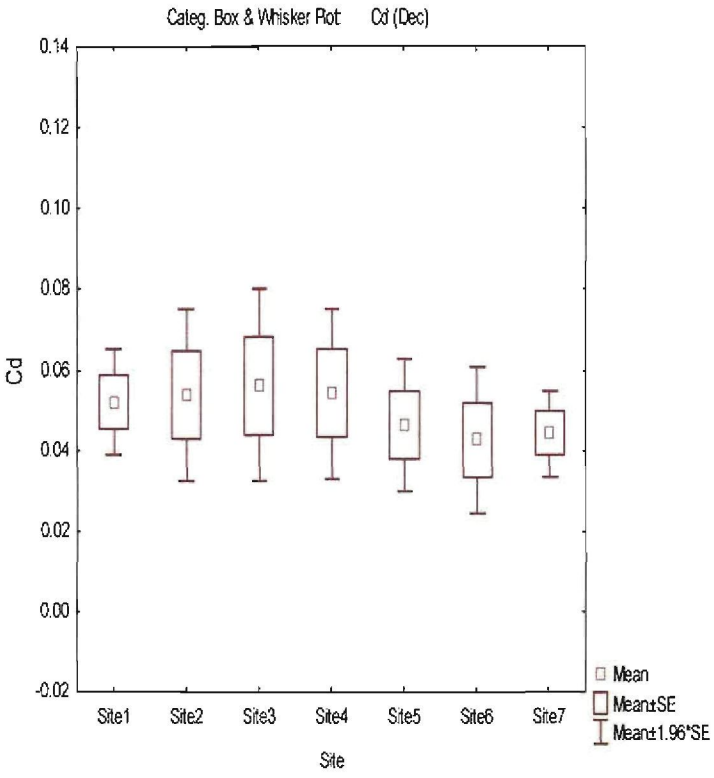


Figure 11.2

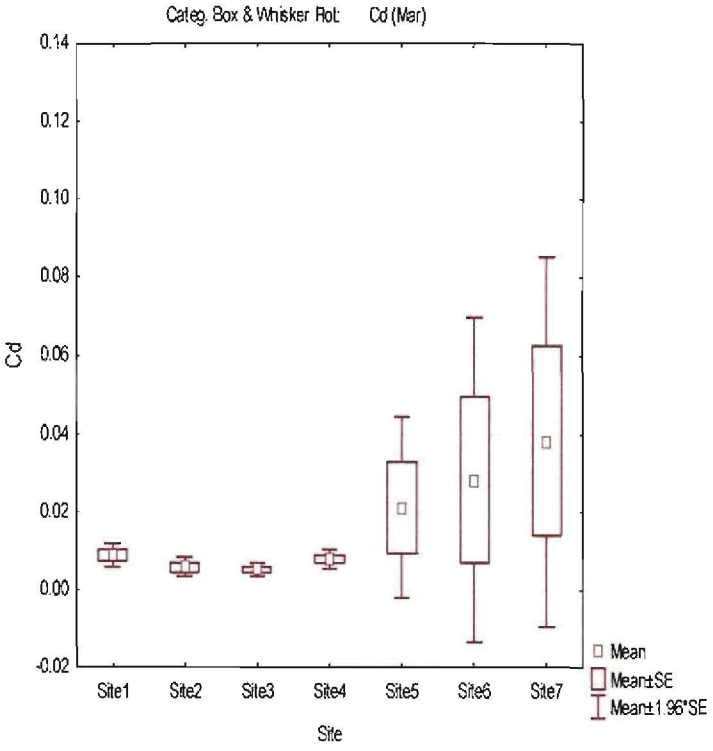


Figure 11.3

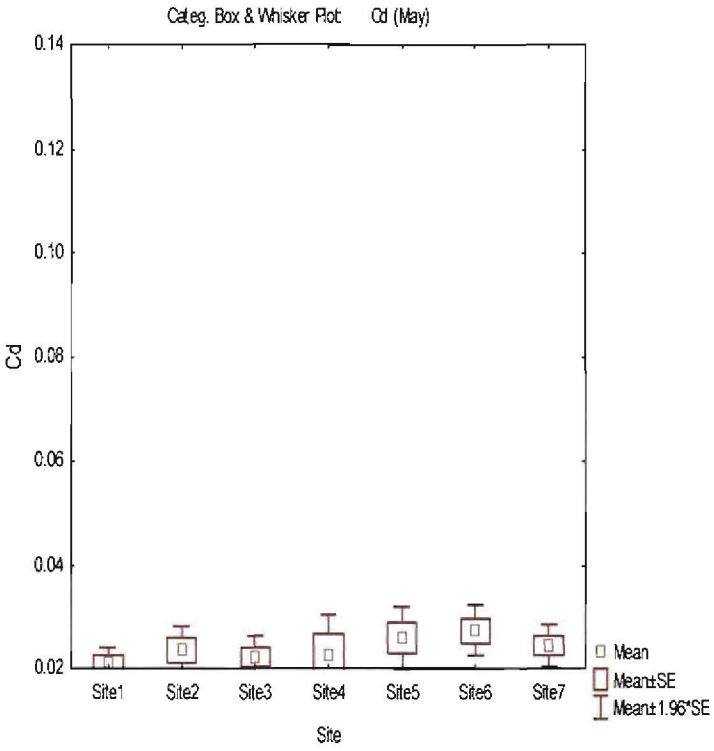


Figure 11.4

Figure 11: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Cd in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

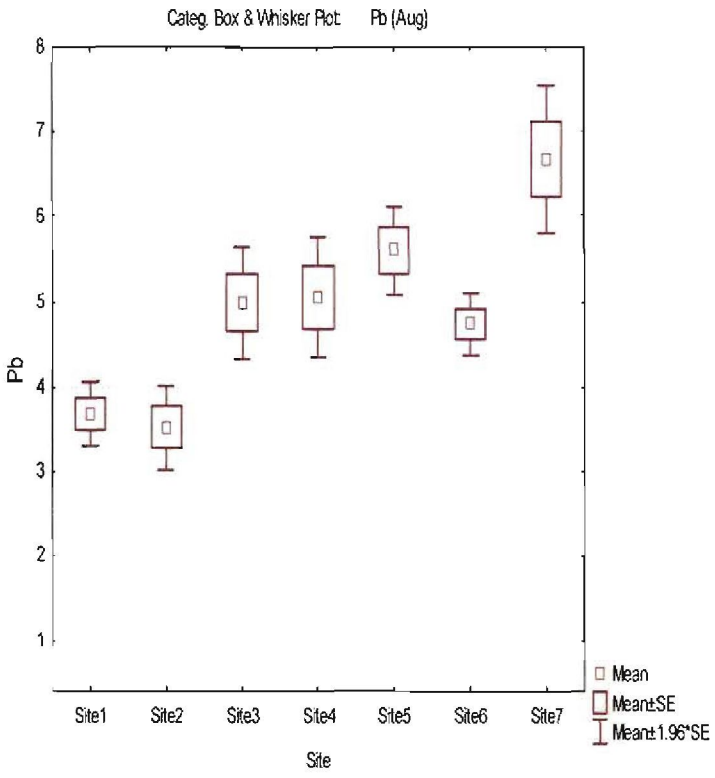


Figure 12.1

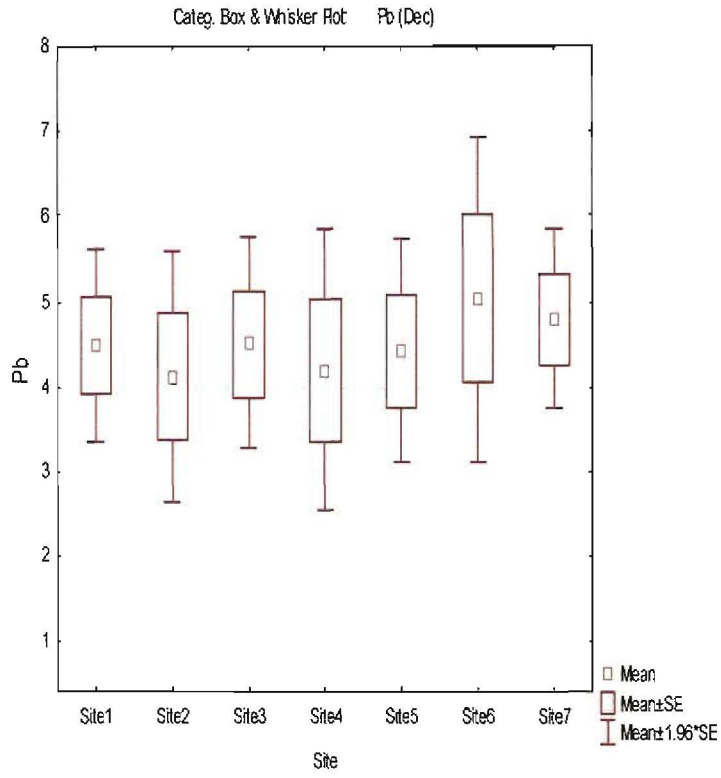
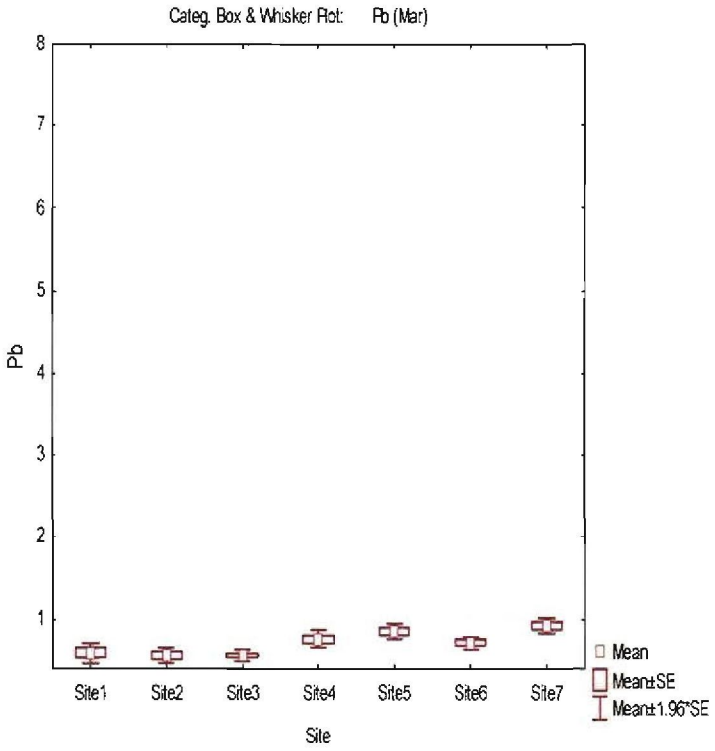


Figure 12.2



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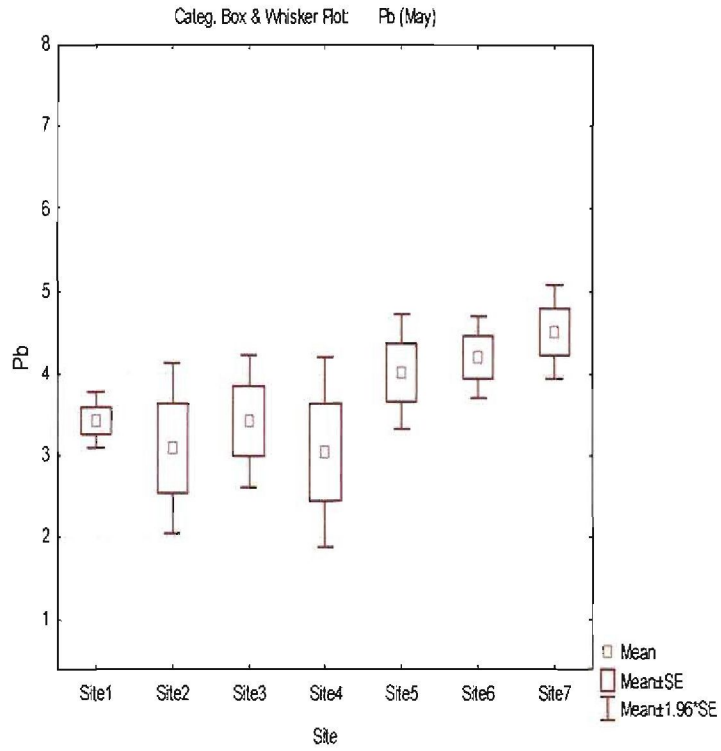


Figure 12.4

Figure 12: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Pb in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

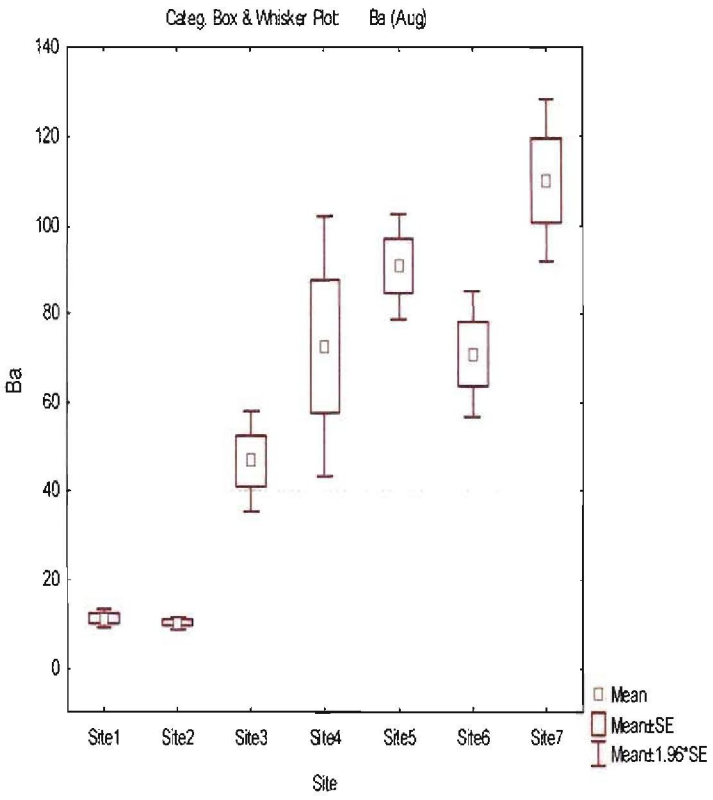


Figure 13.1

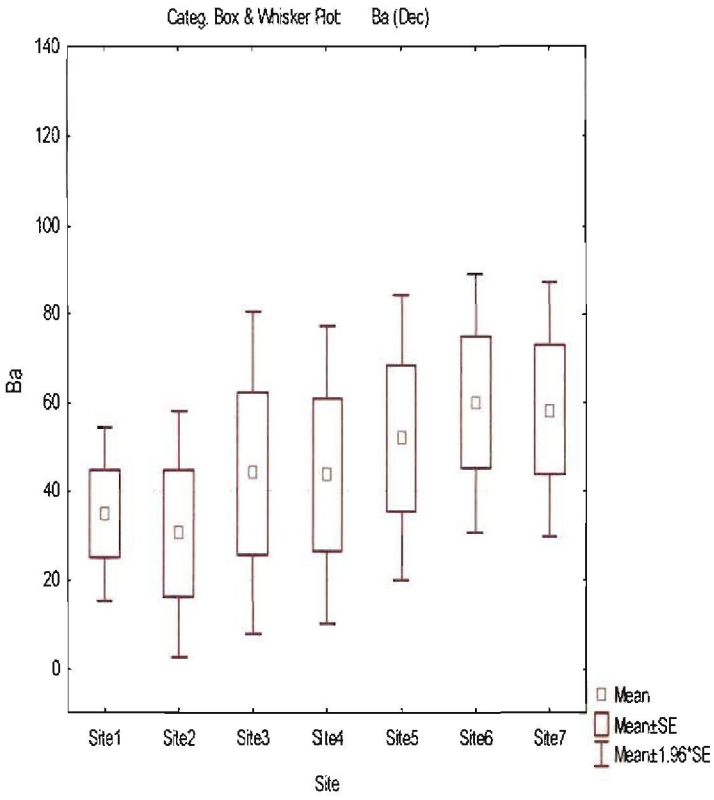


Figure 13.2

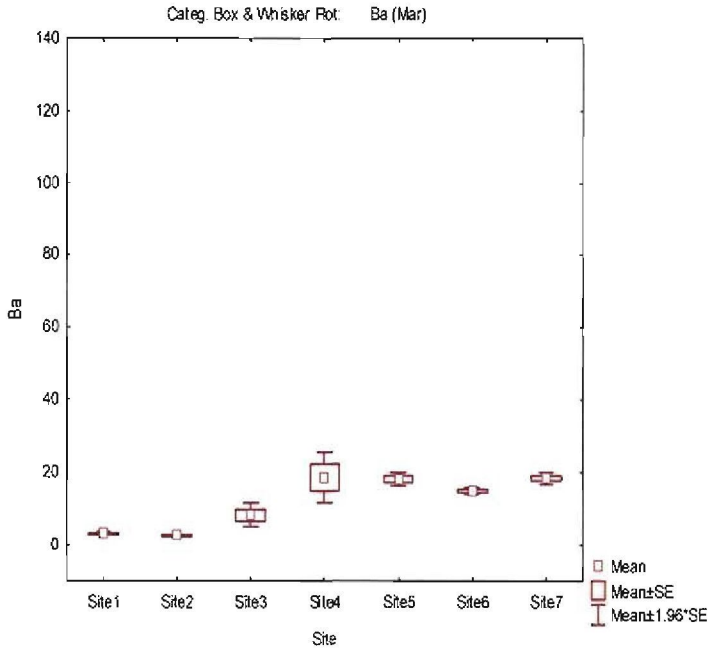


Figure 13.3

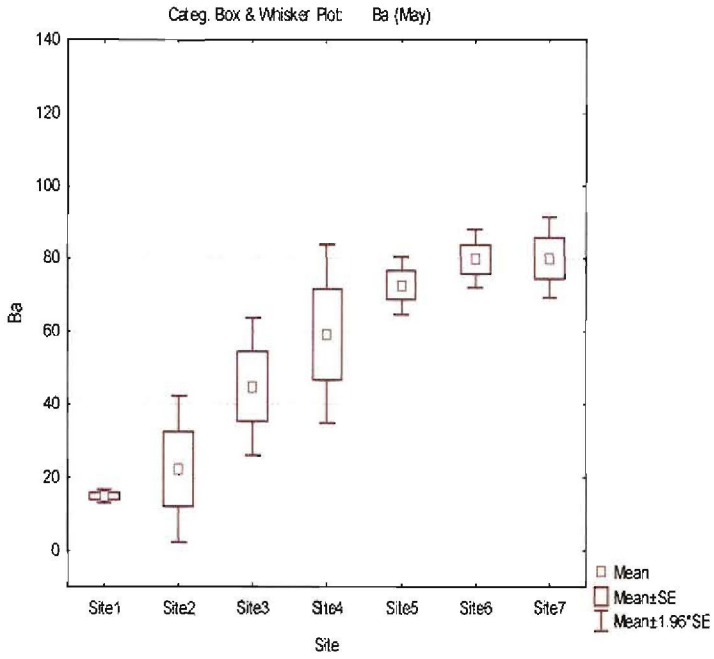


Figure 13.4

Figure 13: Box and whisker plots illustrating the concentrations ($\mu g.g^{-1}$) of Ba in the soil at increasing distances away from the tailings dam over a period of one year during different months (n=6).

Organic carbon content present in the soil, total rainfall, pH values of the soil, and the sand, silt and clay content of the soil was determined for each site and is illustrated in table 3.

Table 3: Mean (± std. dev.) of soil organic matter (% carbon) for each sampling site during March 2006 and the particle size distribution (sand, silt and clay content < 2mm) for each sampling site during March 2006, and mean pH values (± std. dev.) for each sampling site during March 2006 and May 2006 and total rainfall for entire sampling period.

	Org. matter	Particle size distribution				pH values		Total rainfall (mm)			
Site	% C	> 2mm	Sand%	Silt%	Clay%	March 2006	Ma y 2006				
0m	0.14 ± 0.03^{A}	0.0	68.3	19.0	12.7	7.65 ± 0.26^{A}	7.09 ± 0.13^{A}	Jun '05	0	Jan '06	240.2
70m	0.13 ± 0.02^{A}	0.0	76.3	13.8	9.9	7.22 ± 0.09^{B}	7.05 ± 0.09^{A}	Jul '05	0	Feb '06	154
150m	1.01 ± 0.06^{B}	2.3	45.9	28.0	26.1	7.29 ± 0.12^{C}	7.06 ± 0.02^{A}	Aug '05	2	Mar '06	36.6
300m	1.05 ± 0.11^{B}	11.5	28.1	27.1	44.8	7.43 ± 0.08^{D}	7.04 ± 0.03^{A}	Sept '05	0	Apr '06	18.2
500m	1.19 ± 0.1^{B}	6.1	26.4	25.4	48.2	7.36 ± 0.06^{E}	6.9 ± 0.1^{B}	Oct '05	6	May '06	2.8
850m	1.11 ± 0.06^{B}	5.6	32.9	16.0	51.1	7.37 ± 0.12^{E}	6.84 ± 0.07^{B}	Nov '05	76.6	Jun '06	0
1350m	1.13 ± 0.07^{B}	4.9	24.8	22.8	52.5	7.47 ± 0.07^{F}	6.97 ± 0.19^{A}	Dec '05	77.6		

A-F: Values sharing the same letter in superscript were not statistically different from each other.

Carbon content in the two soil samples taken on the TDF (0m and 70m), are much lower ($p < 0.05$) than the rest of the sites (150m to 1350m).

Soil particle size was analysed for each of the sampling sites and is given in Table 3. It is necessary for the texture of the soil to be known when dealing with soil organisms, due to the importance of the pore size, which creates a microhabitat for the organisms to occupy. Unlike the sites at 150m to 1350m, the two sites on the TDF (0m and 70m) had no particles larger than 2mm. These two sites also had the highest percentage of sand and the lowest percentage of clay in comparison to the other sites. The site at 150m, which is right next to the TDF, has a higher clay percentage and a lower sand percentage than the two sites on the TDF.

This site also differs from the sites at 300m to 1350m in the sense that it has a higher percentage of sand and a lower percentage of clay. Percentage of silt in the two sites on the TDF (0m and 70m) was somewhat lower than the rest of the sites, with the exception of the site at 850m.

A summary of the physical and chemical data of the collected samples illustrates the following general trends for all the sampling incidences:

- Cr, Cu, Fe, Ni, Al and Se concentrations generally decrease ($p < 0.05$) further away from the TDF.
- Mn, Pb, and Ba concentrations generally increase ($p < 0.05$) further away from the TDF.
- There is no significant difference ($p > 0.05$) in concentrations of Cd between sites.
- The metal concentrations at the different sites at increasing distances from the TDF towards the site at 1350m are as follows:
  Al > Fe > Mn > Cu, Ni > Ba > Cr > Pb > Se > Cd.
- Seasonal variation was observed for all the metals in the soil, with the lowest values occurring at the March 2006 samples.

3.2 Soil mesofauna

Two of the most prominent groups of soil mesofauna found throughout the sites were the mites and the collembolans (Figure 14). Mite species shown in the top row are representatives of Cryptostigmata (1,2), Mesostigmata (3) and Prostigmata (4,5). Collembola species in the bottom row are representatives of the families Sminthuridae (6), Entomobryidae (7) and Isotomidae (8).

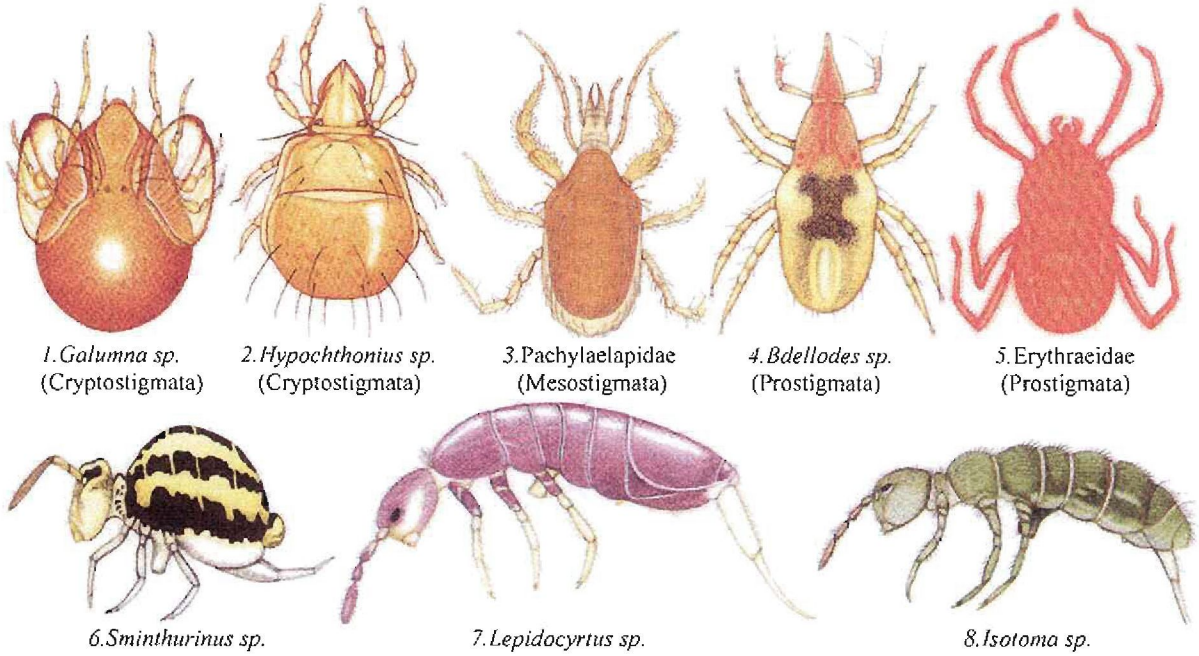


Figure 14: Representatives of mites (top) and collembolans (bottom) (Coineau *et al.*, 1997).

Species data makes up the bulk of this study and is also one of the main focus points of the investigation into metal pollution. It is therefore important to look at all the aspects regarding

the correct analysis of this section. All the species that were identified throughout this study were plotted in species lists according to the different sites and sampling incidences (Appendix 1). The species list was then divided into functional groups (Appendix 2) for reasons that will be given in the discussion. These groups were as follow: Mycophagous organisms (MP) which feed mainly on fungi (Walter, 1988; Evans, 1992; Walter and Proctor, 1999; Kang *et al.*, 2001; Addison *et al.*, 2003; Gormsen *et al.*, 2004; Kaneda and Kaneko, 2004); predatory organisms (Pred) which mainly prey on other living organisms (Walter, 1988; Evans, 1992; Walter and Proctor, 1999); saprophagous and omnivorous organisms (SO) which feed mainly on dead or decaying plant and animal material (Evans, 1992; Picker *et al.*, 2002); mycophagous, bacteriophagous and micro-algivorous organisms (MBM) which feed mainly on fungi, bacteria and algae (Evans, 1992; Walter and Proctor, 1999); and lastly the plant parasitic and herbivorous organisms (Ppar) which feed mainly on living plant material (Evans, 1992; Walter and Proctor, 1999; Picker *et al.*, 2002). Note that abbreviations given in brackets are not standard and only serve as a way of identification in some of the graphs drawn for this specific study.

When examining the species lists presented in Appendixes 1 and 2, certain taxa are clearly dominant in the two sites on the TDF. Probably the most dominant were the prostigmatic mites. The site at 0m had seven species while the site at 70m had ten species. The two species that were the most dominant in both these sites were *Speleorchestes meyeri* and *Coccotydaeolus sp.* Both these species are part of the mycophagous, bacteriophagous and micro-algivorous functional group. *Pronematus ubiquitus* of the predatory group and *Bakerdania sp.* of the mycophagous group, were the other two prostigmatic mites dominating the second site.

The number of Prostigmata species dominating the different sites seemed to be higher from 150m to 1350m. *Coccotydaeolus sp.* was dominant in all of the sites and *Speleorchestes meyeri* was dominant at the first three sites, but had lower population numbers at the sites from 300m to 1350m. One species showing dominance at all the sites from 150m to 1350m, is *Eupodes parafusifer*, which is also part of the mycophagous, bacteriophagous and micro-algivorous functional group.

Another taxon showing dominance in the first two sites is the Cryptostigmata, which had a species count of ten for the first site and seven for the second. *Hypozetes sp.* was dominant in both sites, while *Scheloribates sp.* dominated the first site (0m).

The cryptostigmatic species listed as cf *Jacotella sp.*, showed low dominance in the first two sites, but was one of the dominant species at 300m and 850m. *Cosmochthonius sp.* also showed dominance at 300m. All these cryptostigmatic species are part of the mycophagous group.

Mesostigmata were also present in high numbers at the first two sites. The first site had four species present and the second had eight species. *Protogamasellus sp.* was most dominant at the second site (70m) and *Rhodacarus sp.* dominated both sites. Both these species are part of the predatory functional group.

Collembola were also prominent based on their numbers at the first two sites. Two species were present at 0m and four species at 70m. Sminthuridae *sp.1* was the most dominant at 0m and Isotomidae at 70m. Collembolans are part of the mycophagous functional group.

Four species of Collembola were dominant at the sites from 150m to 1350m. These were Entomobryidae *sp.1*, which was prominent at sites from 150m to 850m. Sminthuridae *sp.1* was prominent at 150m, 500m and 1350m. Isotomidae and Poduridae *sp.1* were both prominent at 850m and 1350m. Collembolans are part of the mycophagous functional group.

Symphyla was also prominent at 500m and 1350m and falls into the herbivorous and plant parasitic functional group.

For each functional group of the different sampling incidences a Detrended Correspondence Analysis (DCA) graph was drawn to compare the different species with the sites (Figure 15). These graphs show the degree to which a certain species correlates with a site: the closer a species is plotted to a site, the larger the number of that species at the specific site. Therefore, it indicates the spatial distribution of the species regarding the different sites. The number of species for each functional group is also of importance in the interpretation of these graphs and can be found in Appendix 2.

In some of the graphs, for example the graphs for the saprophagous and omnivorous functional group for all four sampling incidences, the first site (0m) was not plotted due to the fact that these sites contained no species of this particular functional group.

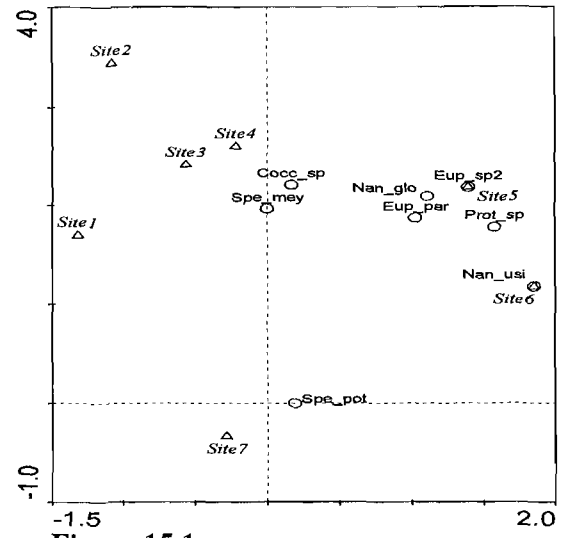


Figure 15.1

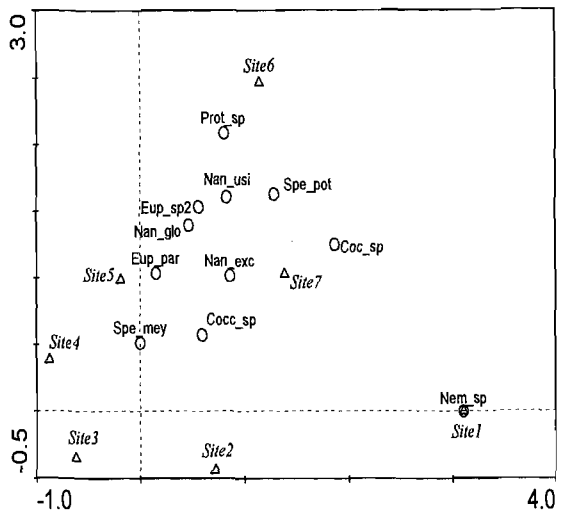


Figure 15.2

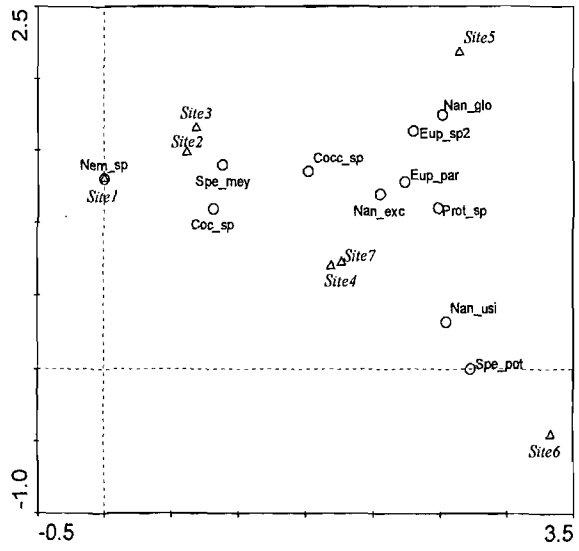


Figure 15.3

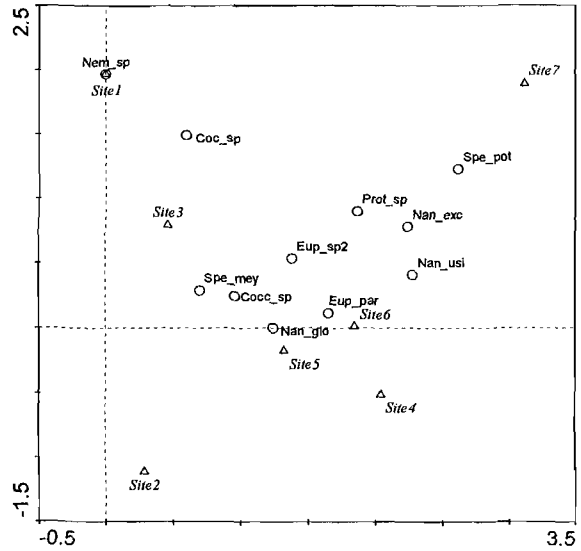


Figure 15.4

Figure 15: DCA graphs of the mycophagous, bacteriophagous and micro-algivorous group (MBM) where species are plotted according to their distribution throughout the sites for August 2005 (15.1), December 2005 (15.2), March 2006 (15.3) and May 2006 (15.4). For clarification of abbreviations see Appendix 2.

The mycophagous, bacteriophagous and micro-algivorous group was plotted for the four sampling incidences (Figure 15) and indicate that first site (0m) and second site (70m) each have about two or three species, while the third site (150m) has an average of four species of the total eleven species occurring there. These three sites thus have less species ($p < 0.05$) than the rest of the sites. The first three sites (0m to 150m) are also plotted further away from the other sites, which indicate that these sites correlate less with the other sites. Sites at 300m to 1350m had a higher number ($p < 0.05$) of species than the first three sites.

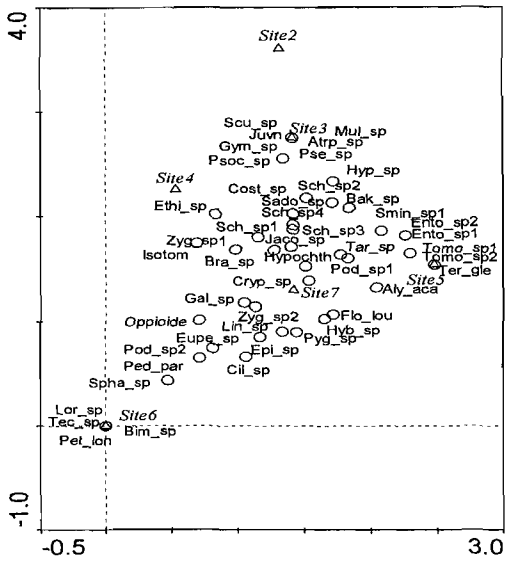


Figure 16.1

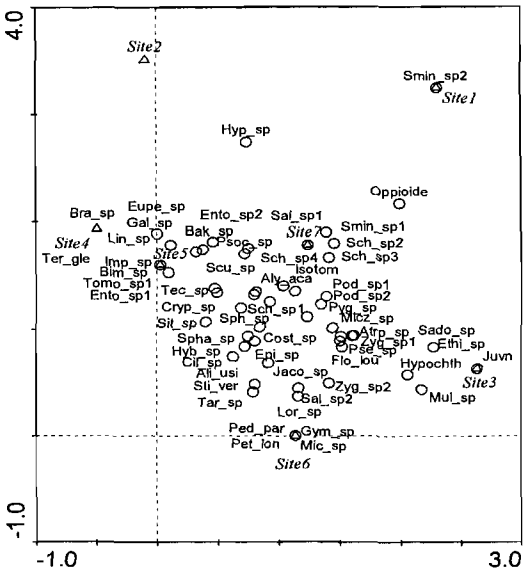
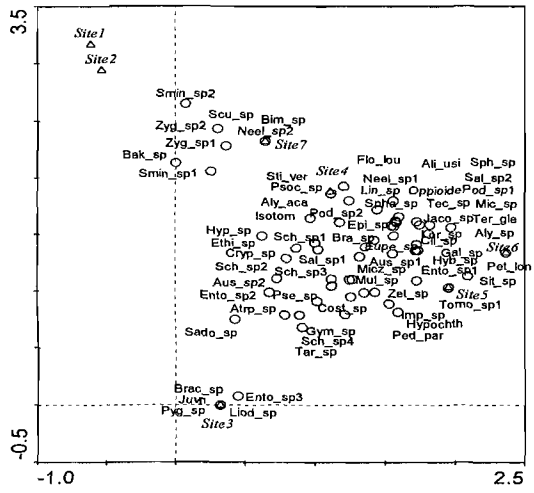


Figure 16.2



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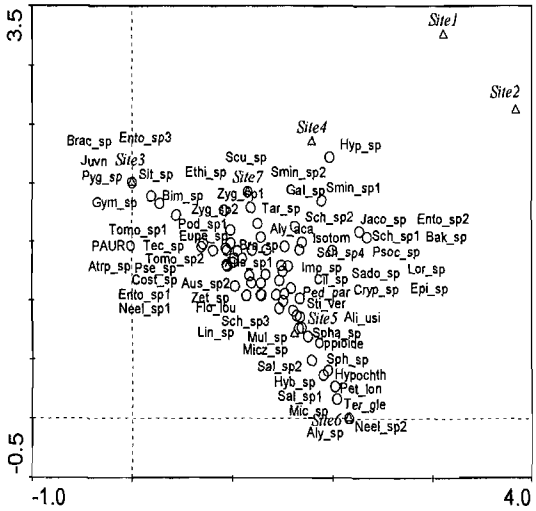


Figure 16.4

Figure 16: DCA graphs of the mycophagous group (MP) where species are plotted according to their distribution throughout the sites for August 2005 (16.1), December 2005 (16.2), March 2006 (16.3) and May 2006 (16.4). For clarification of abbreviations see Appendix 2.

Mycophagous fauna plotted for the four sampling incidences (Figure 16) also indicate very few ($p < 0.05$) species at the two sites on the TDF (0m and 70m), around eight of the total 66 species recorded for this group. These two sites also correlate well with each other. The third site (150m) has a few more ($p < 0.05$) species (an average of 34 species), but shows very little correlation with the first two sites (0m and 70m). A large number ($p < 0.05$) of species are present at the sites ranging from 300m to 1350m.

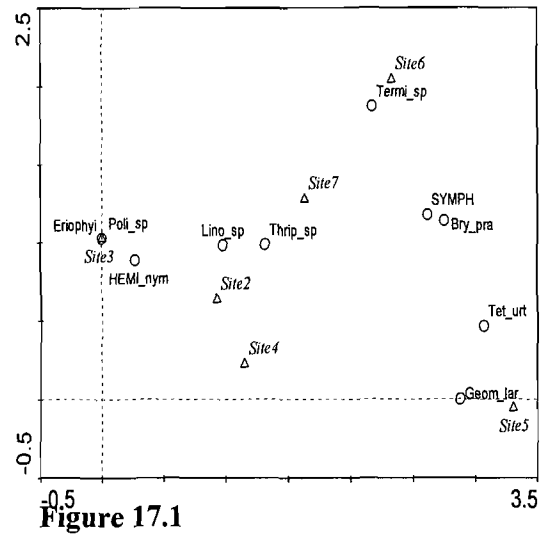


Figure 17.1

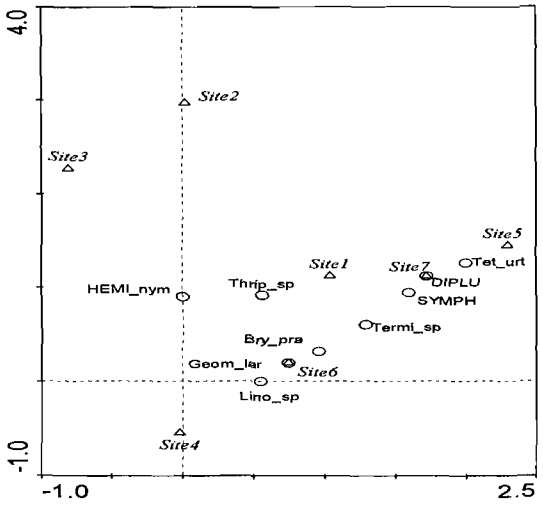
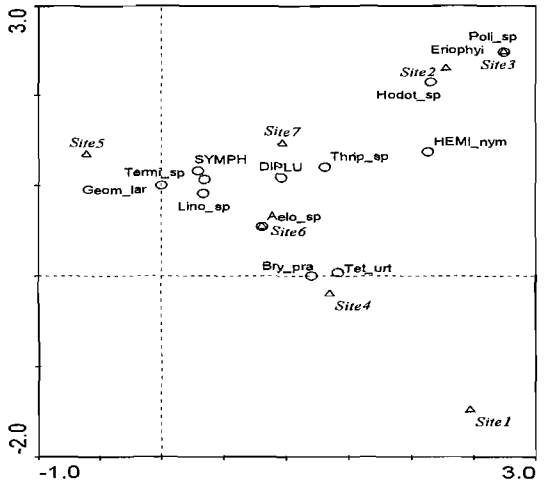


Figure 17.2



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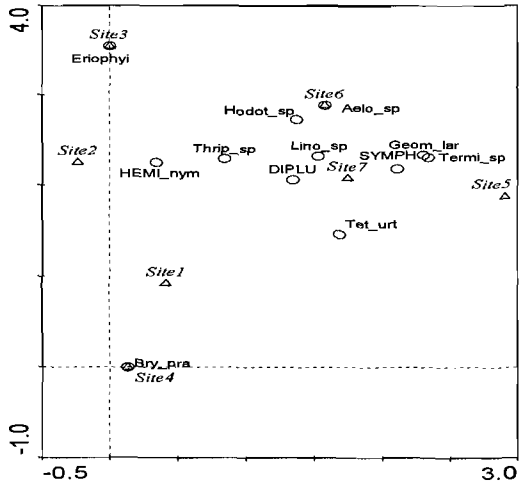


Figure 17.4

Figure 17: DCA graphs of the plant parasitic and herbivorous group (Ppar) where species are plotted according to their distribution throughout the sites for August 2005 (17.1), December 2005 (17.2), March 2006 (17.3) and May 2006 (17.4). For clarification of abbreviations see Appendix 2.

The plant parasitic and herbivorous group (Figure 17) for all four sampling incidences shows that although the sites at 0m and 70m once again has very few ($p < 0.05$) species (not more than two), the site at 150m has significantly more ($p < 0.05$) species, an average of five of the 13 species listed for this group. Sites ranging from 300m to 1350m again have a higher ($p < 0.05$) number of species than the first three sites.

Predatory group data plotted in Figure 18 indicates that the sites on the TDF (0m and 70m) have a low ($p < 0.05$) species number of five for the first site and ten for the second site, while the site at 150m has a few more ($p < 0.05$) species (about 30 of the 74 listed species for this group). Once again sites from 300m to 1350m have a noticeably higher ($p < 0.05$) number of species than the first three sites.

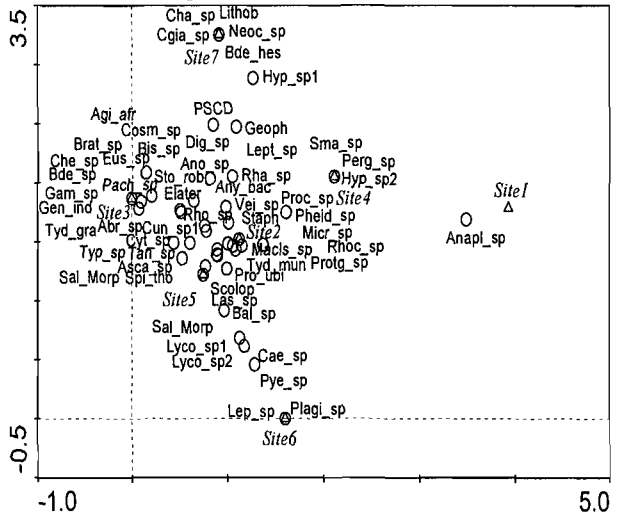
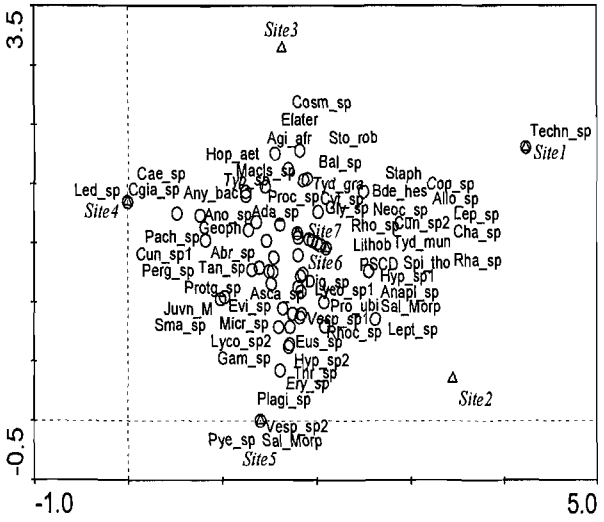


Figure 18.1



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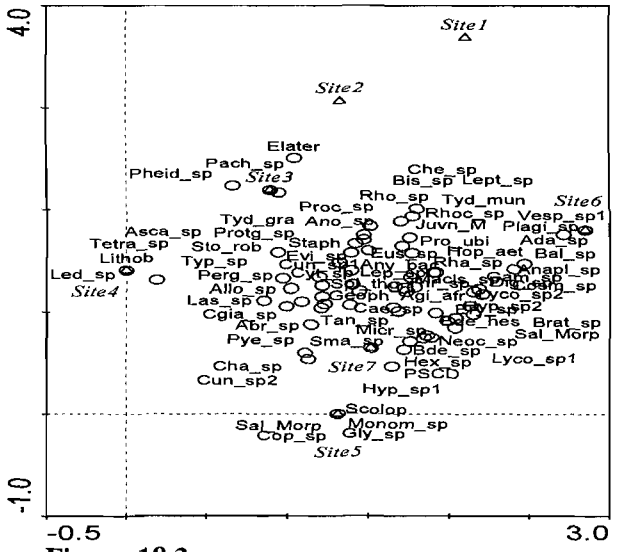

Figure 18.3

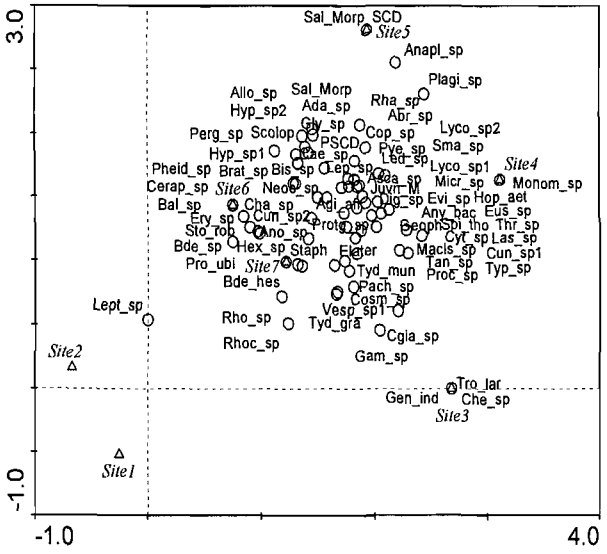

Figure 18.4

Figure 18: DCA graphs of the predatory group (Pred) where species are plotted according to their distribution throughout the sites for August 2005 (18.1), December 2005 (18.2), March 2006 (18.3) and May 2006 (18.4). For clarification of abbreviations see Appendix 2.

Data for the saprophagous and omnivorous group (Figure 19) was plotted for all four sampling incidences, except for the site at 0m, as there were no species of this functional group present. Having no species data for this specific site, the Canoco software programme

does not recognize the need to plot it. Only a few ($p < 0.05$) species was present at 70m (an average of one per site), when compared to sites at 300m to 1350m. The site at 150m, had less species than sites at 300m to 1350m, but still had more species (about five of the 13 species listed for this group) than the first two sites. These last four sites (300m to 1350m) generally had more ($p < 0.05$) species than the sites at 70m and 150m.

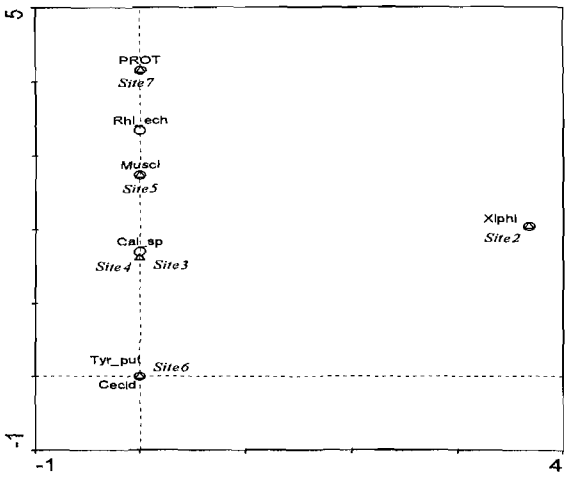

Figure 19.1

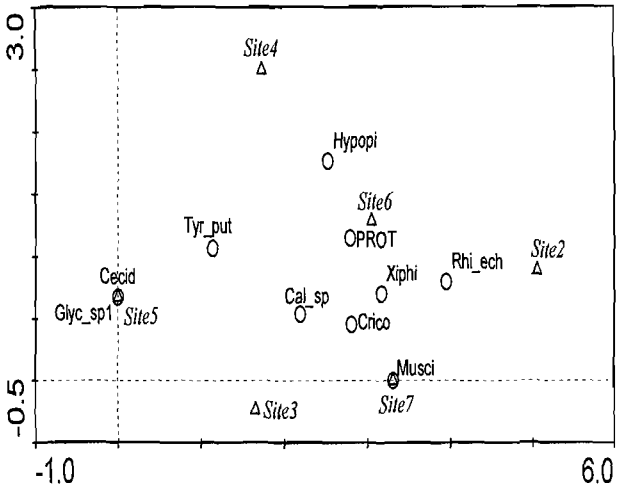

Figure 19.2

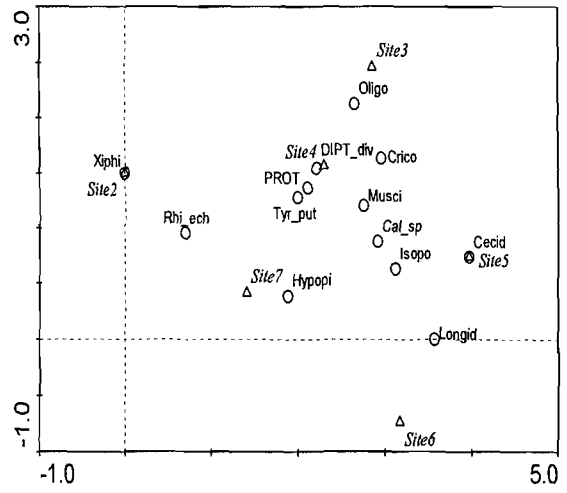

Figure 19.3

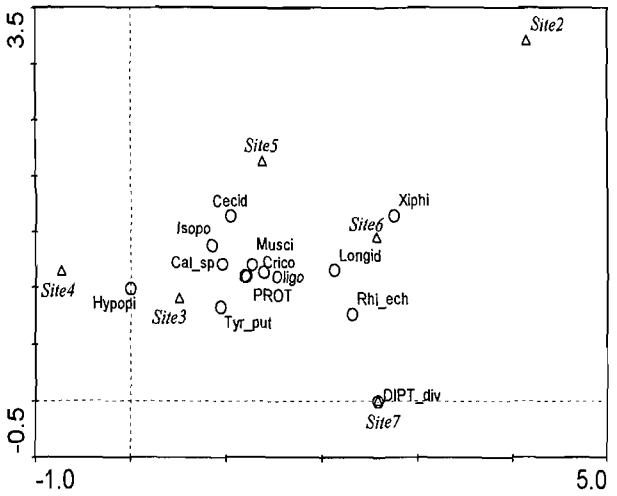

Figure 19.4

Figure 19: DCA graphs of the saprophagous and omnivorous group (SO) where species are plotted according to their distribution throughout the sites for August 2005 (19.1), December 2005 (19.2), March 2006 (19.3) and May 2006 (19.4). For clarification of abbreviations see Appendix 2.

The general tendency is that the two sites on the TDF (0m and 70m), as well as the site right next to the TDF (150m), has lower species richness ($p < 0.05$) than sites ranging from 300m

to 1350m. This could mean that the two sites on the TDF (0m and 70m) and perhaps the site right next to the TDF (150m), are too disturbed for the more sensitive species and only certain hardy species have colonised the specific environment. The increase ($p < 0.05$) in species richness from 300m to 1350m would indicate a less disturbed area.

Canonical Correspondence Analysis (CCA) was used to compare the species data for all the sites and the metals found in the soil. Longer lines connecting the different sampling incidences for each site, indicates greater variation between the seasons. Lines originating from the centre of the graph show the metals present in the soil. The length at which each line is extrapolated, indicates how much the concentration of the metal varied over the total sampling transect.

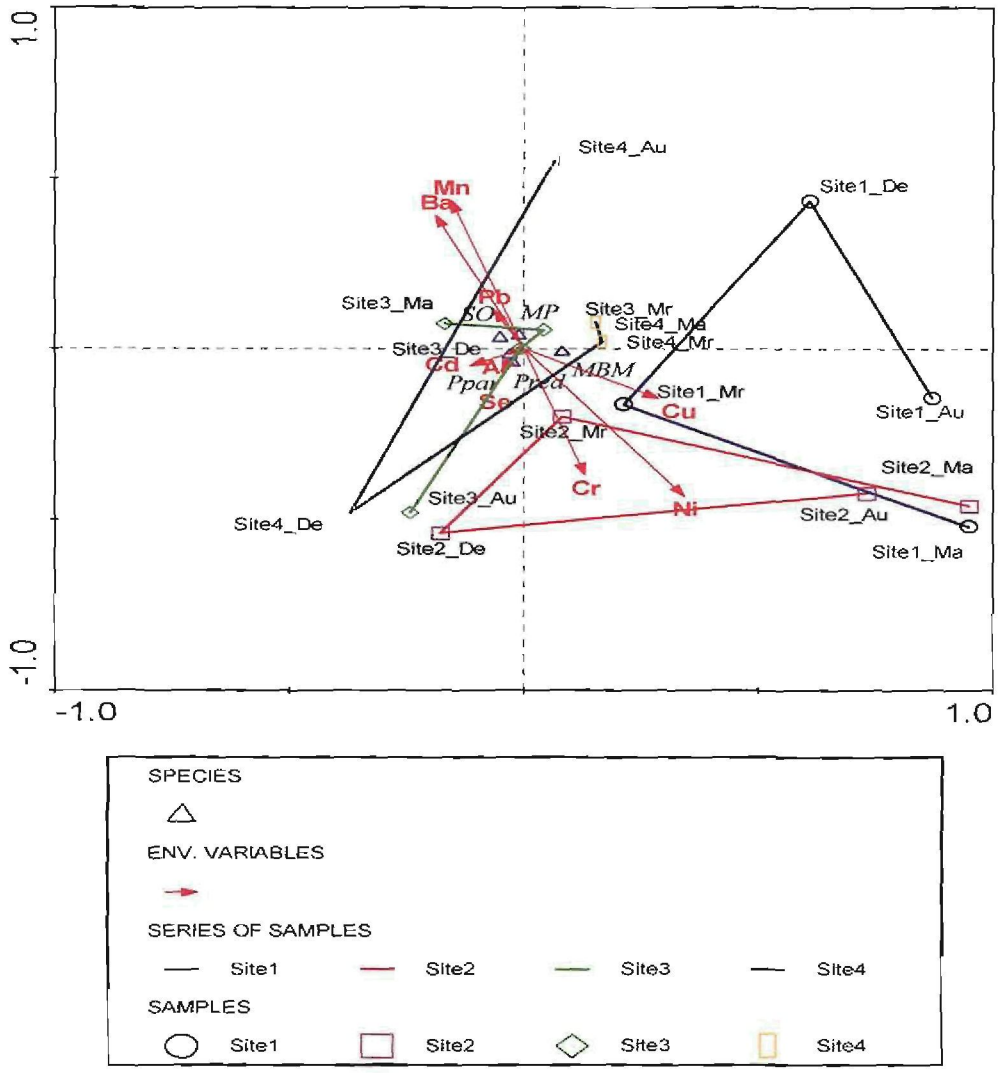

Figure 20: CCA graph of all functional groups plotted against different metals for sites at 0m to 300m for samples taken during August 2005, December 2005, March 2006 and May 2006.

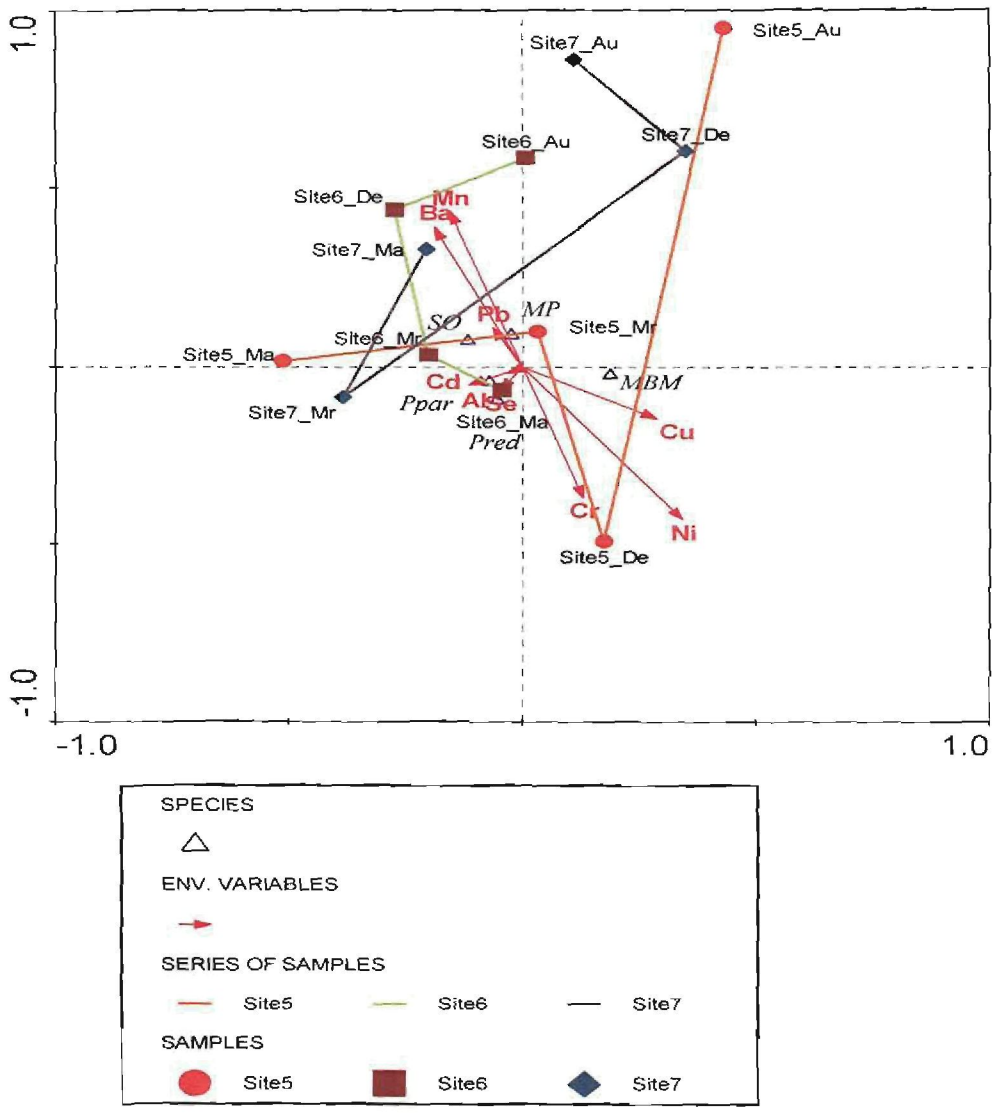

Figure 21: CCA graph of all functional groups plotted against different metals for sites at 500m to 1350m for samples taken during August 2005, December 2005, March 2006 and May 2006.

The first CCA graph (Figure 20) has the first four sites (0m to 300m) plotted against the metals present in the soil. Sites situated on the TDF (site 1 and 2), had a great seasonal variation ($p < 0.05$) and are also plotted further away from the other sites. This shows that these two sites differ from the other sites on species and pollution level. It would seem that these two sites are also influenced most by Ni, Cr and Cu, and contain very little of the total number of species found throughout the study. Low seasonal variation is found for the site at 150m ($p < 0.05$) and is influenced by numerous metals. The site at 300m has greater seasonal variation ($p < 0.05$), except between the March and the May samplings. Ba and Mn are two of the metals that have an influence on the site at 300m.

In the second CCA graph (Figure 21), sites at 500m to 1350m were plotted. Of all the sites, these three were the sites on which seasonal variation had the greatest influence ($p < 0.05$). The site at 500m is influenced by almost all of the metals in the soil. Of the metals that have an influence on these sites, Mn, Ba and Pb are the metals that had the greatest impact on the sites at 850m and 1350m.

The metals indicating the most variation when plotted against time, are Ba, Mn, Ni, Cr and Cu. Graphs also show that Ba, Mn and Pb increase ($p < 0.05$) when moving further away from the TDF, while Ni, Cr and Cu decreases ($p < 0.05$) in the same direction. These results are in accordance with Table 2 and the box and whisker plots of these specific metals (Figures 4 - 13).

Barcharts for the species data (Figures 22 - 26) were also created by means of the Sigmastat programme. In these charts the four sampling incidences for each functional group were plotted against all seven sites. Within each functional group, these charts give a clear indication as to what extent the sites varied with one another, as well as the variation within the sites between the different sampling incidences.

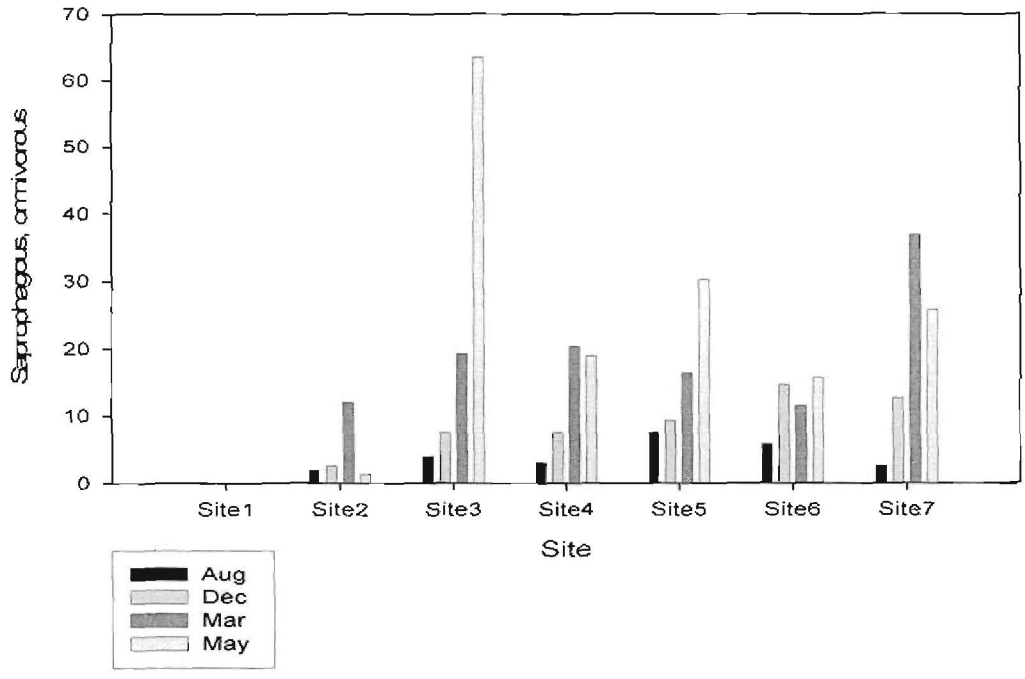

Figure 22: Species richness of the saprophagous and omnivorous functional group for all sites over a period of one year during different months (n=6).

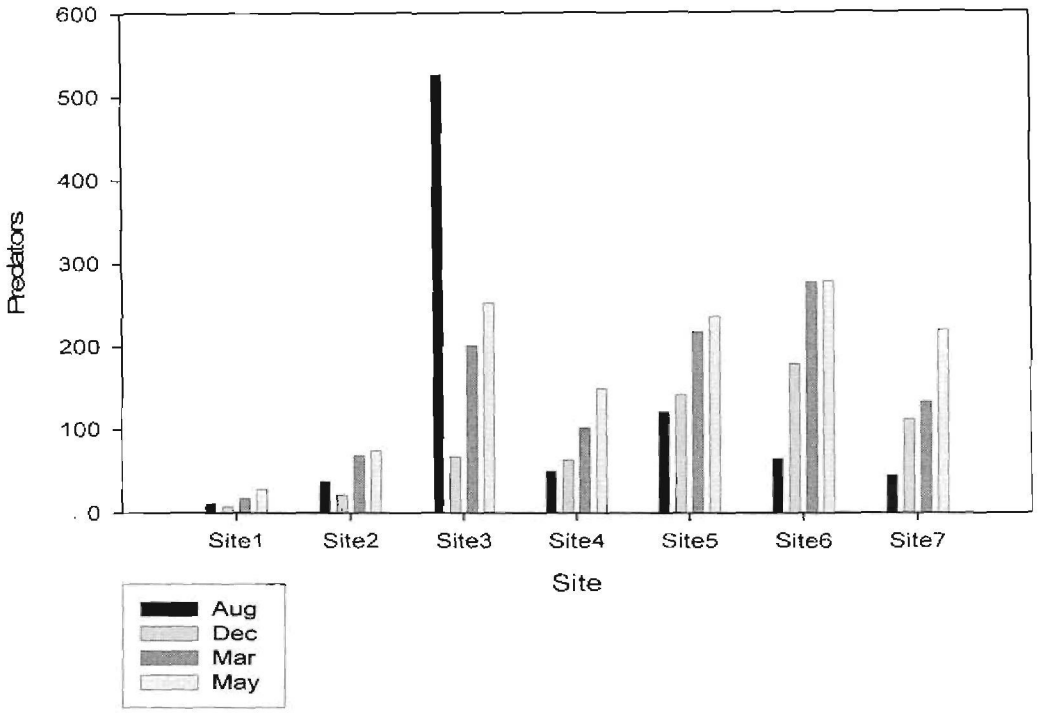

Figure 23: Species richness of the predatory functional group for all sites over a period of one year during different months (n=6).

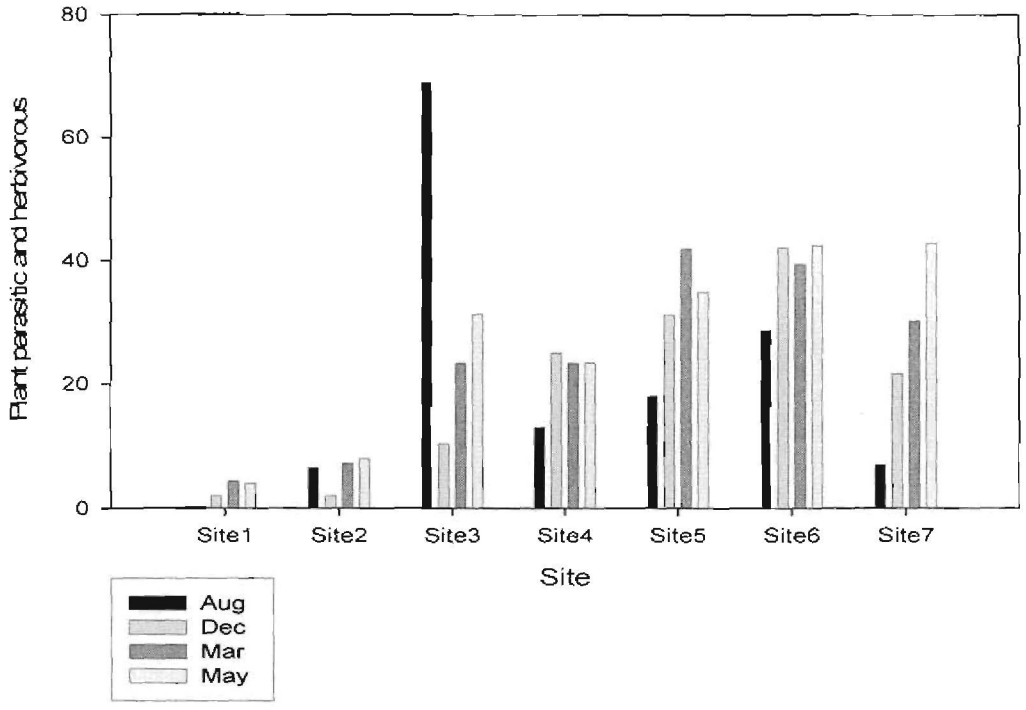

Figure 24: Species richness of the plant parasitic and herbivorous functional group for all sites over a period of one year during different months (n=6).

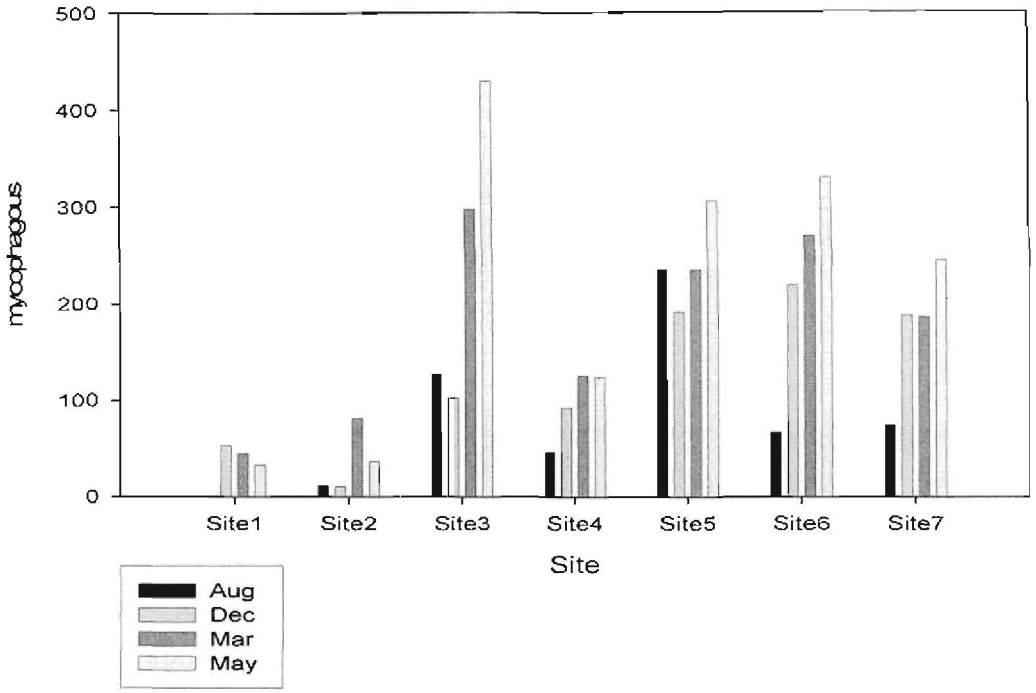

Figure 25: Species richness of the mycophagous functional group for all sites over a period of one year during different months (n=6).

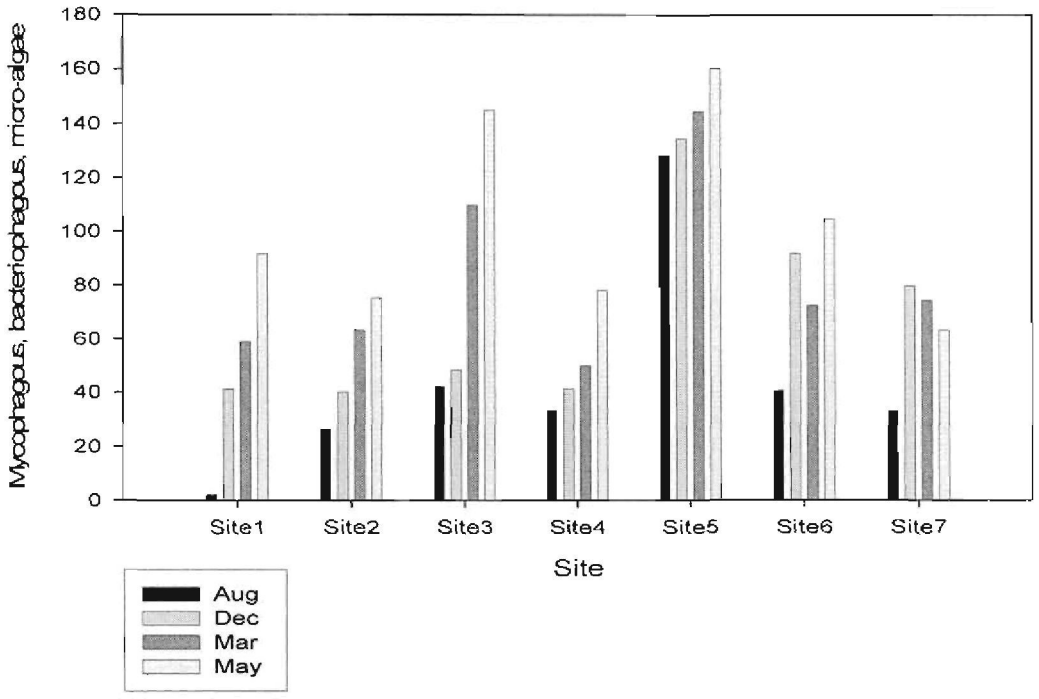

Figure 26: Species richness of the mycophagous, bacteriophagous and micro-algivorous functional group for all sites over a period of one year during different months (n=6).

For the mycophagous group, the data for August 2005 has the lowest ($p < 0.05$) number of organisms, while the May 2006 data has the highest ($p < 0.05$). Also, the populations occurring at each site generally increases ($p < 0.05$) from 0m to 1350m. The site at 150m has unusually high ($p < 0.05$) populations. The mycophagous, bacteriophagous and micro-algivorous group also shows that the total population for August 2005 is much lower ($p < 0.05$) than the other sampling incidences and May 2006 has the highest ($p < 0.05$). The total number of organisms generally increases ($p < 0.05$) from 0m to 1350m, although not as prominent as in the mycophagous group. Sites at 150m and 500m also show an increase ($p < 0.05$) in this regard, especially for the May 2006 data.

Data for the predatory group also gives a clear indication of an increase ($p < 0.05$) in populations from 0m to 1350m. Once again the August 2005 data has the lowest ($p < 0.05$) values, while the data for May 2006 has the highest ($p < 0.05$) across most of the sites. The August 2005 data for the site at 150m shows a dramatic increase ($p < 0.05$) in this regard. For the plant parasitic and herbivorous group, the August 2005 data has the lowest ($p < 0.05$) number of organisms of all the sampling incidences, while the May 2006 data generally has the most ($p < 0.05$). Relatively small ($p < 0.05$) populations are present at the two sites situated on the TDF (0m and 70m) for all the sampling incidences, but this increases ($p < 0.05$) towards 1350m. August 2005 data shows that the site at 150m has unusually high ($p < 0.05$) populations. The saprophagous and omnivorous group has no species at 0m. A low ($p < 0.05$) number of organisms are found at the site on the slope of the TDF (70m), but populations generally increase ($p < 0.05$) towards the site at 1350m. Data for August 2005 has the lowest ($p < 0.05$) number of organisms and March 2006 and May 2006 has the highest ($p < 0.05$). Populations are unusually high ($p < 0.05$) for the site at 150m of the August 2005 data.

3.3 Mesofauna chemical analysis

According to initial planning, a chemical analysis of soil organisms for each site would have been carried out, however only a snapshot analysis was done for certain sites. This is due to inconsistency in the number of usable species throughout the sampling transect.

The organisms chosen were chemically analysed to determine their metal content. For each sample analysed, a bioconcentration factor (BCF) was calculated. These values indicate the ability of the organisms to accumulate metals in their body tissue. If the BCF for a certain

Table 4: The concentration of metals ($\mu g.g^{-1}$) found at different sites and at different sampling incidences for the soil samples and the concentration of metals ($\mu g.g^{-1}$) within the body tissue of certain species found in the soil. Calculated BCF values for the different sites are also shown.

Sample date	Site	Test organism	No. of organisms	Metal	[Organism] ($\mu g.g^{-1}$)	[Soil] ($\mu g.g^{-1}$)	BCF
August 2005	0m	*Anaplolepis sp.* (Formicidae)	n = 13	Mn	307.11	50.89	**6.03**
				Fe	1345.5	3907	0.34
				Cu	9.75	69.61	0.14
December 2005	500m	*Lycosa sp. 1* Lycosidae	n = 1	Mn	20.36	26.38	0.77
				Fe	36.15	1679	0.02
				Cu	17.39	55.66	0.31
				Se	0.15	1.56	0.1
				Pb	0.09	2.7	0.03
March 2006	300m	*Tetramorium sp.* (Formicidae)	n = 1	Mn	60.09	154.2	0.39
				Fe	126.45	357.47	0.35
				Pb	35.31	0.96	**36.78**
March 2006	300m	*Plagiolepis sp.* (Formicidae)	n = 1	Mn	49.89	166.4	0.3
				Fe	777	324.17	**2.4**
				Pb	37.38	0.66	**56.64**
March 2006	850m	*Plagiolepis sp.* (Formicidae)	n = 148	Al	65.73	840.3	0.08
				Cr	2.35	1.56	**1.51**
				Mn	113.83	108	**1.05**
				Fe	194.1	196.67	0.65
				Ni	25.94	4.59	**5.66**
				Cu	25.44	2.2	**11.57**
				Cd	0.07	0.134	0.52
				Pb	12.73	0.89	**14.3**
May 2006	70m	*Pheidole sp.* (Formicidae)	n = 4	Mn	27.84	40.3	0.69
				Fe	847.13	2689.86	0.31
May 2006	500m	Scorpionidae	n = 1	Al	11.61	3736.97	0.31
				Cr	0.14	6.59	0.02
				Mn	10.86	547.4	0.02
				Fe	38.99	1003.86	0.04
				Ni	0.75	19.13	0.04
				Cu	38.33	6.16	**6.22**
				Se	1.23	0.31	**3.98**
				Cd	0.12	0.02	**5.22**
				Pb	0.54	4	0.135
May 2006	850m	*Cerapachys sp.* (Formicidae)	n = 32	Al	74.54	2886	0.03
				Cr	0.33	4.72	0.07
				Mn	36.76	430.6	0.09
				Fe	88.8	793.66	0.11
				Cu	37.65	4.92	**7.65**
				Pb	5.23	3.15	**1.66**

metal is 1 or higher, the organism indeed has the ability to accumulate that specific metal. In table 4, all those elements in bold indicate a bioaccumulation in the organism tested. Lead and Cu seem to be problematic elements based on the BCF.

CHAPTER 4

4. Discussion

4.1 Soil chemical analysis

Examining the chemical composition of the soil might give an indication of the conditions in that environment and for this study two general patterns were identified. Some metal concentrations present in the soil decrease when moving further away from the TDF, while other metal concentrations increase in the same direction, all of which are evident in the box and whisker plots (Figures 4 -13) as well as in Table 2.

Those metals decreasing ($p < 0.05$) in concentration when moving away from the TDF include Cu, Ni and Cr. It has been concluded that the presence of these three metals in the tailings material is consistent with platinum mining (Maboeta *et al.*, 2006). The high concentrations of these metals, along with the sandy nature of the tailings material (Table 3), increase the risk of metals leaching into the soil profile. This in turn may have possible negative effects on the vegetation (Van Rensburg *et al.*, 2004) and soil organisms (Maboeta *et al.*, in press). It is also possible that the polluted water leaching from the TDF could reach underground water reserves and be transported beyond the borders of the mining area, which might then be utilized by humans who use boreholes as their principle source of drinking water. Differences in metal concentrations from the TDF towards the furthest site indicate a pollution gradient across the sampling transect. The surface of TDF is directly exposed to the sun and would therefore desiccate over time. When it is exposed to windy conditions, dust particles are carried and settle in the surrounding area up to an undetermined distance (Bradshaw, 1997), theoretically producing a gradient of pollution. Other natural causes, for example rainfall, also might explain the pollution gradient observed for these three metals when moving further away from the TDF. The metal concentrations of Cu, Ni and Cr decrease by an average of 50% to 80% from the TDF to the sites further (up to 1350m) away. Theoretically, this sharp decrease over such a short distance may be expected when dealing with a source of pollution. However, other factors, such as soil particle size and organic matter content should also be taken into account as part of the explanation for the observed decrease in metal concentration. Toxicant persistence in the soil can be affected by more than one physical characteristic, such as organic matter content, microbial activity and particle size

(Duffus, 1980), which determine the water retention of the soil. Therefore, although certain metal concentrations decrease further away from the TDF, it may persist in the soil for longer, due to the higher clay content and higher carbon content in the soil from 150m to 1350m. This in turn would increase the effect of pollutants on the environment.

The phenomenon shown by the second group of metals, which increase ($p < 0.05$) in concentration by 50% to 95% when moving further away from the TDF, does not have such a clear-cut explanation. These metals are Pb, Mn and Ba and do not seem to be among the major constituents of the tailings material. Instead, high concentrations of these metals are found in the soil sampled at site seven (1350m). What should be noted is that a road runs in between the sites at 850m and 1350m, which is frequently used by motor vehicles and heavy machinery. Xiao-li *et al.* (2006) concluded that exhaust emissions contain metals such as Pb, Zn, Cu and Cd, which may be deposited by the wind in the surrounding environment next to the road for up to 100m or even further. Therefore, it is possible that these metals (especially lead) might have been secondarily deposited by means of exhaust emissions in the immediate area surrounding the road. This might then also influence the vegetation and soil ecosystem in that area negatively.

The MPC values indicate the maximum permissible concentration of metals in the soil and were calculated using standardised soil containing 10% organic matter and 25% clay (Crommentuijn *et al.*, 1997), almost similar to the soil constituents found at the sampling sites. Most of these metal concentrations, with the exception of Cr(III), Co and Ni which are based on the modified EPA method, are based on statistical extrapolation of 23 to 56 processes per metal and can therefore be considered reliable (Crommentuijn *et al.*, 1997). These values are particularly relevant in the South African context, due to the fact that these concentrations are compared directly to the metal component of the soil samples taken for this study. Copper, Ni and Se are the only three metals that had concentrations exceeding the MPC values during August 2005, December 2005 and May 2006. Also, most of the tables show that only sites on or close to the TDF exceed the MPC for Cu and Ni. This would indicate the TDF as the most likely source of metal pollution. The concentrations of metals exceeding these benchmarks, creates a hostile environment for fauna and flora occurring there. If no remediation occurs, the area may turn barren and contain very little soil life, increasing the volume of tailings material being carried into the surrounding environment by means of erosion. The barren nature of the tailings material is reflected in the number of

species present and will be discussed later in this chapter. These MPC values therefore have great relevance from a South African perspective, due to the large number of mines and the effect they have on the surrounding environment.

Earthworm- and microbial benchmarks indicate the concentration of the metals in the soil that might affect these organisms negatively and these were divided into low confidence, moderate confidence and high confidence. These confidence levels were derived from 10, 10 to 20, and 20 or more literature values respectively (Efroymson *et al.*, 1997). These values give an indication at what concentrations certain soil organisms might be affected by the metal component in the soil under North American conditions. There is little confidence in the earthworm benchmarks due to the lack of information and experimental testing, with the exception of Cd, Cu and Zn in which a moderate confidence exists (Efroymson *et al.*, 1997). Microbial benchmarks has shown the same tendency, with exception of Cd, Cr, Cu, Pb, Hg, Ni and Zn in which a high confidence exists, and Se, Ag and V in which moderate confidence exists (Efroymson *et al.*, 1997). It was observed that all metal concentrations higher than these benchmarks except for Mn, are situated on or close to the TDF (Table 2). Besides the MPC values, these benchmarks might also give a general indication of disturbance on the TDF and in the area surrounding the TDF. Most of the soil organisms, e.g. cryptostigmatic mites, some prostigmatic mites and the insect order Collembola, which are all responsible for decomposing organic material and for nutrient turnover, are placed under pressure by these high concentrations and might fail to reproduce. This in turn might lead to a reduction of biodiversity and number of mesofauna. In sites that are heavily polluted, only a few tolerant species of organisms are able to survive for long periods of exposure to toxicants (Stamou and Argyropoulou, 1995). This further increases the difficulty in rehabilitation of the soil to its "natural" state. Mine closure would yield a higher mite density, but will have no effect on the number of mite species occurring there, mainly because of their limited dispersal abilities (Gormsen *et al.*, 2006). Therefore, in the period following restoration, the mite and collembolan communities will be restored gradually to its pre-mining numbers, but this process may take up to several decades (Vanek, 1971; Frampton, 1999).

Seasonal variation ($p < 0.05$) was evident in the soil data. The soil chemical analysis indicated a decrease in soil metal content in the samples taken for March 2006 and May 2006. This is the case for most of the metals in the soil samples. Generally, the March 2006 data had the lowest ($p < 0.05$) metal content of all the sampling incidences and this might

have been caused by leaching of the metals due to summer rainfall (Table 3). High water content in the soil may cause some of the metal residues to go into solution and be carried into the soil profile, diluting the concentration in the topsoil where it is available for uptake by soil fauna. Some of the metal concentrations were up to ten times lower during March 2006 than the same metal concentration for August 2005.

4.2 Species data

The species data constitute one of the major components of this study. After being entered into a species list, all species were divided into functional groups to aid in the statistical analysis of the data. These functional groups were determined by the diet of the specific species, but can sometimes be quite arbitrary, as many of the organisms involved have not yet been extensively researched (Theron, personal communication, 2007). Some predatory mite species will e.g. forage on pollen if their normal prey species become scarce or absent (McMurtry and Croft, 1997), while some species utilize two or three different food sources. It is quite clear from the literature from different authors (Walter, 1988; Evans, 1992; Walter and Proctor, 1999; Kang *et al.*, 2001; Picker *et al.*, 2002; Addison *et al.*, 2003; Gormsen *et al.*, 2004; Kaneda and Kaneko, 2004) that up to ten groupings might arise for the species list gathered for this study, and therefore some authors might disagree on some of the groupings used in this study. However, it was decided to arrange the total mesofaunal complement identified during the planning of this study into five functional groups.

4.2.1. Functional groups and species numbers

A Detrended Correspondence Analysis makes it clear which sites are disturbed based on the number of species present. The general tendency is that the two sites situated on the TDF are those with the lowest species number and are therefore the most disturbed as was found in similar studies (Skubala, 1997a and 1997b; Skubala, 2002a and 2002b; Skubala and Kafel, 2004). All functional groups displayed this low diversity pattern and the saprophagous and omnivorous group was totally absent on the TDF (0m). Therefore, this group is either too sensitive to the metals in the soil, or there is an inadequate food supply for these organisms to sustain a population, due to the sterile nature of the tailings material (Van Rensburg and Morgenthal, 2004).

The site at 150m, although very fluctuating for certain sampling incidences, has a few more species ($p < 0.05$) present than the two sites on the TDF (0m and 70m). Although this site is

not situated on the TDF itself, it is only 80m from the second site. A small increase ($p < 0.05$) in species numbers at this site, designates less disturbance than for sites 1 and 2 at 0m and 70m, respectively. Another possible explanation might be the soil texture difference between the first two sites as to the third site. The third site has a moderate sand content and higher clay content than the two sites on the TDF, as indicated in Table 3. This means that desiccation is reduced, due to the more effective water holding capacity of the soil at the third site creating more favourable conditions for the soil fauna. The size of the pores created by the moderate sand content at this site, allows for aeration, water infiltration as well as storage and drainage (Singer and Munns, 1992). Organic carbon in the soil might also play a role. Table 3 indicates a sharp increase in the carbon content in the soil from the two sites on the TDF (0m and 70m), to the site right next to the TDF (150m).

The steady increase ($p < 0.05$) in species number from 300m to 1350m would be indicative of a less disturbed ecosystem and that a pollution gradient exists across the sampling transect. Metals such as Mn and Pb, of which the concentration in the soil increased ($p < 0.05$) further away from the TDF, had reasonably high concentrations ($p < 0.05$) at the last four sites. These concentrations also exceeded the microbial benchmark for sites from 300m to 1350m. This is contradictory to the data projected by the number of species and the population size for these sites. Some toxicants such as metals, which are present in a mixture, can have synergistic, antagonistic or additive effects on organisms (Moriarty, 1999). The effects of certain metals such as Mn and Pb, which are present in the soil further away from the TDF, are therefore very difficult to interpret.

Barcharts, which show the relationship between the functional groups for all sampling incidences and the sites, also indicate the increase ($p < 0.05$) in the number of organisms present from 0m to 1350m (Figure 22 - 26). Metals occurring in higher concentrations at the sites further away from the TDF did not have as much influence on the soil mesofauna as the metals that had a higher concentration on and close to the TDF. It can therefore be assumed that the higher metal concentrations further away from the TDF may be antagonistic, or may have less of a negative impact on the mesofauna. Even the lower pH levels further away from the TDF, which normally leads to a higher toxicity of the metals, had little or no effect on the mesofauna. All these aspects might explain the increase in populations from the sites on the TDF (0m and 70m), towards the last site (1350m). According to Migliorini *et al.* (2004), cryptostigmatic- and collembolan communities can survive at Pb concentrations far higher

than the lethal concentration for most tolerant plants, thereby stating the lowered effect this metal had on species further away from the TDF. Besides the metal concentrations, certain physical aspects also need to be taken into account. The percentage of organic carbon, as well as the clay content increases from 0m to 1350m as indicated in Table 3, and both these physical aspects could therefore exert an influence on the species richness at each site.

Interestingly enough, the site at 150m had unusually high ($p < 0.05$) populations for certain sampling incidences. This is an unexpected result, as it was expected that the site might be moderately disturbed due to the close proximity of the TDF. The explanation comes from the conditions at the site. It was observed that this site generally had more trees than the other sites. Therefore, desiccation due to sunlight is reduced, giving the organisms more ideal conditions for reproduction (Tsiafouli *et al.*, 2005; Russell and Griegel, 2006). Shade possibly also causes a lower soil temperature in this particular area, which in turn creates optimal conditions for the euedaphon (Kuznetsova, 2006; Jucevica and Melecis, 2006). Another physical aspect of this site, is the large amount of cattle dung found throughout the sampling area at this site, which would imply that cattle spend time at this specific spot. Although the carbon analysis did not indicate it due to the small samples taken for the study, an increased organic matter content in the general sampling area is possible, which can also explain the species richness present (Axelsen and Kristensen, 2000; Hasegawa *et al.*, 2006; Eaton *et al.*, 2004).

4.2.2. Species dominance

Taxa that have shown the most dominance on the two sites situated on the TDF based on the percentage of each group to the other mesofauna, are the acarine orders Prostigmata, Cryptostigmata, Mesostigmata and the insect order Collembola. This is consistent with findings from other authors, as Prostigmata are known to be present in soils with a low organic matter content (Osler *et al.*, 2000). The presence of Prostigmata have thus been utilised in the past for similar studies and the abundance of this group may be indicative of a disturbed ecosystem, which is mainly due to the fact that they are general opportunists and are able to reproduce rapidly after disturbance (Behan-Pelletier, 1999). Pioneer species are the first to recolonise the soil after disturbances such as mining activities (Skubala, 1995). This group of soil fauna would then theoretically be present in disturbed areas. Effects of disturbances on soil faunal communities are often stronger and more long-lived within cryptostigmatic mites than in collembolans (Lindberg and Bengtsson, 2005). This might

indicate that these mites are better suited as bio-indicator species than collembolans. Certain species from these taxa have dominated the most disturbed sites based on the population numbers and therefore seem to be the least sensitive. Species include the prostigmatic mites *Speleorchestes meyeri, Coccotydaeolus sp., Pronematus ubiquitus* and *Bakerdania sp.*, the cryptostigmatic mites *Hypozetes sp.* and *Scheloribates sp.*, and the mesostigmatic mites *Protogamasellus sp.* and *Rhodacarus sp.*. The presence of these species could be as a result of certain coping mechanisms during disturbances as mentioned in the introduction, e.g. metal tolerance, metal avoidance and the removal or neutralization of the metals in body tissue.

Dominance shifted somewhat in the sites from 150m to 1350m. The taxa Prostigmata, Cryptostigmata, Mesostigmata and Collembola were all prominent in these sites, but so was the Symphyla. Dominant species included *Coccotydaeolus sp.*, *Speleorchestes meyeri*, *Eupodes parafusifer*, cf *Jacotella sp.* and *Cosmochthonius sp.*. Collembola included Entomobryidae *sp.1*, Sminthuridae *sp.1*, Isotomidae and Poduridae *sp.1*. Species such as *Speleorchestes sp.* are usually present in disturbed areas (Theron, 2007, personal communication). Therefore, the high number of *Speleorchestes sp.* would indicate that the two sites on the TDF are at least moderately disturbed when compared to the sites in which a higher number of species were found.

Most of the species mentioned above are present either at the two sites on the TDF, which has the highest levels of pollution, or at the sites further away from the TDF. Being present in such disturbed areas would indicate that these are likely to be pioneer species. In highly disturbed areas where no remediation has been done, single species colonies will form. These can be seen as true pioneer species and may therefore be utilized in future studies. Possible candidates are *Speleorchestes sp.*, *Eupodes sp.* and *Coccotydeolus sp.* (Theron, 2007, personal communication).

4.2.3. Seasonal variation

When comparing the different sampling incidences of the mesofaunal data, the winter sample of August 2005 had the lowest ($p < 0.05$) species number overall. The species number generally increase ($p < 0.05$) with time to give a very high species number for May 2006. Increases ($p < 0.05$) in the species number between August 2005 and May 2006, ranged from an approximate 5% to about 70%. These increases ($p < 0.05$) can be attributed to seasonal

changes, such as temperature and variation in soil moisture (see rainfall data in Table 3), as well as an increase in organic carbon in the soil brought on by the first two aspects. During the summer months, these factors create the ideal conditions for these organisms to successfully reproduce and would explain the population growth over the months.

A decrease in soil metal content may be a contributing factor to the increase in the population of different species from August 2005 to May 2006, which is evident in the barcharts (Figures 22 - 26) for the total species number over time. Therefore, as time progressed during the study period, the lowered metal concentration in the soil had less of a burden on the physiological attributes of the organisms. During this time, the weather conditions gradually changed from cold, dry conditions in August 2005, to hotter and more humid conditions in March and May 2006 (Table 3). As previously noted, an increase in temperature and humidity generally brings about production of organic material, eventually building up as organic debris in the upper soil layer, which in turn causes an increase in the populations of mesofaunal species. The increase in rainfall might have more of an effect than anticipated. Besides creating more ideal conditions for the organisms through natural processes, it may also have caused the lowered metal concentrations in the soil. As it rains, water infiltrates the soil and comes in contact with metals present. Some of these metals "dissolves" in the water and is carried deeper into the soil profile, away from the topsoil. This upper layer, which contains most of the soil mesofauna, therefore becomes more hospitable for the organisms. These conditions could result in an increase in the population of the species present.

Although a gradual population increase ($p < 0.05$) was observed for most of the species, the total number of species at each site did not change dramatically over time. The ratio of species did therefore not change over time. It has also been confirmed in other studies that dominant species stay dominant over seasons, despite climatic variation (Kuznetsova, 2006). Consistency in the species number creates some confidence in the utilization of mesofauna as bioindicators in future studies.

A similar study (in progress) done at these specific sites revealed more or less the same trends. This study focused on the different bacteria present at these seven sites for the same time period. These TDFs were remediated some time before the onset of this study to promote organic matter production and bacterial growth. This caused an increase in the number of certain bacteria at the first two sites (0m and 70m). Species identified were selectively heterotrophic bacteria with a high tolerance to the metals occurring on the TDF.

Explanations for this could arise from the high adaptability of the microbes, manifesting in ordinary evolutionary processes (Prescott *et al.*, 2002). Selection takes place when only the most resilient or most adaptable species survive in a certain area. A current study is underway to determine if bacteria take up metals and if this process decreases the bioavailability of these metals.

4.3 Mesofaunal chemical analysis

Although the chemical analysis indicated that the Pb concentrations were lower than all of the benchmarks, it seems to have had an accumulative effect on some of the species analysed. Copper also seems to accumulate easily in some of the organisms. This concurs with studies on certain species of ants such as the red wood ant (*Formica sp.*), indicating an accumulation of Ni, Cu and Pb (Eeva *et al.*, 2004). Copper and lead also accumulate in certain soft-bodied organisms such as earthworms and gastropods (Gimbert *et al.*, 2006; Hobbelen *et al.*, 2006; Homa *et al.*, 2003). The main reason for the accumulation of these metals in the ants, spiders and scorpion tested in this study, is the fact that they are mainly predatory or omnivorous (Hickman *et al.*, 2001). Therefore, these fauna feed on prey species that have already accumulated some metals in their body tissue. This is true for many species that are at the top of the food web, due to the process known as biomagnification (Moriarty, 1999). Other species were not analysed due to an inconsistency in the number of each species sampled in the study area. An ideal situation would have been to analyse one or two species occurring at all sites, to note the difference in the degree of bioavailability at each site.

Effects of disturbances on soil faunal communities are stronger and more long-lived within cryptostigmatic mites than in collembolans (Lindberg and Bengtsson, 2005). This might indicate that these mites are better suited as bioindicator species than collembolans and could therefore be good candidates for similar studies. Something that should be taken into account is that most literature places a greater emphasis on species that are present in the northern hemisphere (eg. Cortet et al., 2000; Addison et al., 2003). It is therefore necessary to identify species or even taxonomic groups in the southern hemisphere that may be reliably utilised in bioindication studies. Species chosen for chemical analysis should have consisted of representatives from the lower levels of the food chain, to assess the more direct absorption of the metals occurring in the soil. Thus, primary consumers such as the Prostigmata might have yielded the best results for the mesofauna chemical analysis. A greater number of organisms should also be available for chemical analysis.

Being a relatively new field, focusing on primary consumers and other mesofaunal groups of the food chain as bioindicators could be advantageous in the South African context. Prostigmata seem to be resilient and able to colonise highly disturbed areas, making them suitable candidates for these types of studies. This group of mites should not be overlooked, since it is more diverse and abundant in the southern hemisphere than in the northern hemisphere (Theron, 2007, personal communication) and could therefore be one of the main focal points in bioindicator studies. Species of the prostigmatic mites that show potential to be bioindicators include *Speleorchestes meyeri, Coccotydaeolus sp., Pronematus ubiquitus* and *Bakerdania sp.* These species seem to be the least sensitive to the mining disturbance. This taxonomic group makes up a great deal of the mesofauna found in South African soils and could play a potentially useful role in similar future studies.

CHAPTER 5

5. Conclusions

Studies on soil mesofaunal communities and how they are affected by disturbances are few, which is mainly due to the fact that most authors focus on single species or small taxa to retrieve ecological and physiological data, e.g. the red wood ant *Formica* s. str. (Eeva *et al.*, 2004), the terrestrial isopod *Porcellio scaber* (Zidar *et al.*, 2004) and the most commonly utilised Collembola species in the northern hemisphere, *Folsomia candida* (Van Gestel and Mol, 2003). Although this may produce accurate results based on physiological and reproductive effects, it gives little indication as to how whole mesofaunal communities are affected by negative anthropogenic impacts. Community structure of the soil mesofauna in the northern hemisphere also differs from that which is found in the southern hemisphere. For example, European studies are mainly concerned with cryptostigmatic mites (also referred to as Oribatida) and Collembola, since they are more dominant in European soils. South Africa has a wide range of prostigmatic mites. This study is therefore somewhat unique due to the high diversity and large number of mesofaunal families involved, but also creates challenges and difficulties that have to be overcome. Difficulties include a wide range of taxonomic problems. In a mesofaunal study, many species are dealt with and these have to be identified as accurately as possible. As most acarologists are specialists on certain taxa only, it was necessary to travel a great distance in order to consult specialists who could be of assistance in identifying the cryptostigmatic species found in the soil samples taken for this study. Another factor contributing to the difficulty in identifying cryptostigmatic mites, is the fact that polymorphism occurs between juveniles and adults (Coleman *et al.*, 2004). Despite this, about 30 species of this taxon were identified. Several other taxa were identified, which implies that more than one acarologist and also some entomologists had to be consulted, lengthening the identification procedure. Although time consuming and labor intensive, it is crucial to the identification of dominant, rare and sensitive species, to determine the effect the disturbed environment have on them. Even with the assistance of all these experts, the huge diversity of species and the limited number of acarologists and entomologists had limitations on this study.

Representatives of Prostigmata, Cryptostigmata, Mesostigmata and Collembola were the arthropod taxa dominating the two sites on the TDF (0m and 70m) based on the number of

individuals of these species compared to other taxa. Some of the species included in these taxa were, *Speleorchestes meyeri, Coccotydaeolus sp., Pronematus ubiquitus, Bakerdania sp., Hypozetes sp., Scheloribates sp., Protogamasellus sp.* and *Rhodacarus sp.* These species seem to be the least sensitive and could therefore survive in such highly disturbed areas. Reasons for this could be, as previously mentioned, high metal tolerance in Cryptostigmata (Zaitsev and Van Straalen, 2001), metal avoidance in Collembola (Greenslade and Vaughan, 2002), or even mechanisms for removing or neutralizing metals from the body of the organism which is found in some deconcentrators (Rabitsch, 1994).

Some species also dominated the sites further away from the TDF. Species included *Coccotydaeolus sp., Speleorchestes meyeri, Eupodes parafusifer,* cf *Jacotella sp.* and *Cosmochthonius sp.*. Collembola included Entomobryidae *sp.1*, Sminthuridae *sp.1*, Isotomidae and Poduridae *sp.1*. These species seemed to be the most sensitive to the high concentrations of metals found in the tailings material and may therefore be utilised as bioindicators in the future when dealing with similar research questions and can also be tested in the laboratory. Species needed for laboratory testing, can be cultured in a laboratory. Cultured individuals can then be exposed to soil with different levels of metal concentrations, as well as different metals in mixtures, to determine lethal combinations of metals and also concentrations affecting these organisms. Possible pioneer species identified in this study may therefore be subjected to metabolic tests to determine some benchmark values.

Dealing with such a large number of species can be very difficult and quite labour-intensive. For this reason the species list was divided into functional groups based on their feeding preferences. Some authors have also used this technique for studies done on soil fauna with great success (Walter, 1988; Evans, 1992; Walter and Proctor, 1999). Thus, it is not a new concept and its design can be advantageous to community studies, especially on soil fauna. The reason for this is that it gives a clearer view of the different guilds within the soil ecosystem, resulting in easier interpretation of the results for such studies.

Three of the functional groups used in this study were represented by the species dominating the sites on the TDF (0m and 70m). These groups include the mycophagous, bacteriophagous and micro-algivorous functional group, the predatory functional group and the mycophagous functional group. The saprophagous and omnivorous functional group and the plant parasitic and herbivorous functional group were either absent or had low numbers of species at these two sites. This might be due to the sparse vegetation on the TDF. If a more diverse plant

community existed on the TDF, it may have been possible that a higher numbers or more species of the saprophagous and omnivorous functional group and the plant parasitic and herbivorous functional group would be present.

Contamination sites are important sources of pollution and may result in ecotoxicological effects on terrestrial, phraetic and aquatic ecosystems (Fent, 2004). Taking the soil metal analysis into account, two main patterns were identified. Some metals eg. Pb, Mn, and Ba increased ($p < 0.05$) when moving further away from the TDF and the concentrations of Cu, Ni and Cr decreased ($p < 0.05$) in the same direction. Despite the difficulty of determining the effect of a combination of metals in the environment, metals with a higher concentration on the TDF seem to have a greater effect on the mesofauna than those metals with a higher concentration further away from the TDF. Besides the influence of the soil metal concentrations, the physical and chemical aspects at each site may also have some influence on the species composition. These aspects include the soil texture, organic carbon content within the soil, pH, climate and the antagonistic, additive or synergistic effects of the combination of metals present at the sites (Moriarty, 1999).

The seasonal variation of the euedaphon, which showed an increase ($p < 0.05$) in the number of individuals per species over time, could be attributed to the seasonal variation of the metal concentrations ($p < 0.05$) in the soil, which decreased over the study period and had very low concentrations for the March 2006 sampling. Some physical aspects such as temperature and soil moisture also increased from August 2005 to March 2006 and could also have played a role.

Based on the results acquired during this study, the following conclusions can be made.

- A disturbance gradient exists over the sampling transect and indicates that the TDF is a definite source of pollution. Many physical and chemical aspects of the soil were measured, but not all physical attributes of the sites were considered. These include the soil temperature at each site, the plant cover in the area, as well as the soil moisture of the samples taken. The experimental layout of future studies could include measurement of these aspects.
- The number of species present in the soil is related to the metal concentrations in the soil. Species composition therefore gives an indication of the disturbance levels in the study area. There are some negative aspects when taking on a study such as this. A

lack of taxonomic expertise complicates the identification process of the fauna, creating the necessity for external input from specialists on the different taxa gathered during the sampling period. Also, all data had to be analysed and requires sound knowledge of statistical programmes being used. Once again experts had to be consulted for this aspect. Being very time-consuming, these processes retarded the progress of the study.

- Soil mesofauna can be successfully utilised as bioindicators to assess environmental pollution. Future studies could also be directed towards the bioavailability of the metals analysed to better determine the bioconcentration of metals within certain organisms. In the future, larger soil samples could be taken to collect large numbers of certain species for the chemical analysis of the biological material. The species chosen should preferably be from lower trophic levels, to minimise the effect of biomagnification.
- Seasonal variations do occur within the soil and therefore also contribute to changes in the number of organisms per species over the sampling period. Although this aspect causes a more complex analysis due to the added variables, it also helps to explain some changes in the edaphic mesofaunal community, contributing to the more holistic approach of ecological studies as opposed to laboratory studies.

South Africa has a great diversity of soil mesofauna. Despite the above mentioned difficulties that have to be overcome during such studies, focusing on these organisms for bioindication can only be advantageous. A wide variety of toxicological studies have been carried out in the northern hemisphere, especially in Europe. The focus of these European studies have been on the cryptostigmatic mites and collembolans, which is mainly due to the inconsistency in the number of species of the other taxonomic groups such as the prostigmatic mites. Although the southern hemisphere also has a good representative number of cryptostigmatic mites, mesostigmatic mites and collembolans, a wide range of prostigmatic species are also present in the soil. Such a great variety of species intensifies the results that can be conceived in such studies, especially if benchmark values can be established for certain taxonomic groups. Future studies can also be focused on certain taxonomic groups. An advantage to carrying out such studies would be if a scientist or group of scientists with good taxonomic knowledge work as a team to eliminate limitations and speed up the identification process.

This study may hopefully open the door to further research on mesofaunal communities and toxicological studies.

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Appendix 1:

Complete list of species collected at increasing distances away from the tailings dam over a period of one year during different months (n=6).

AUGUST 2005

			Site 1						Site 2						Site 3						Site 4					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
PROSTIG-MATA	Nanorchestidae	*Speleorchestes meyeri*	2												9	15	11	15		17		4	9	10		3
		Speleorchestes potchensis																								
		Nanorchestes globosus																			1	4	7		3	
		Nanorchestes usitatus																								
		Nanorchestes excertus																								
	Alicorhagiidae	*Alicorhagia usitata*																								
		Stigmalychus veretrum																								
	Alycidae	*Alycus acaciae*																								
		Bimichaelia sp.																								
		Petralycus longicornis																								
	Terpnacaridae	*Terpnacarus glebulentus*																								
		Alycosmesis sp.																								
	Oescherchestidae	*Lordalychus sp.*																								
	Micropsammidae	*Micropsammus sp nova*																								
	Hybalycidae	*Hybalicus sp.*																								
	Sphaerolichidae	*Sphaerolichus sp.*																								
	Iolinidae	*Pronematus ubiquitus*							2		7	8	27	3	5		4		6	1						
	Tydeidae	*Coccotydaeolus sp.*							21		17	11	70	13	8	66	11	5	4	14	17	11		5		24
		Coccotydaeus sp.																								
		Tydeus grabouwi														25	13	24								
		Tydeus munsteri		1														5								
		Brachytydeus sp.														4	6									
		Genus indet														5										
	Paratydeidae	*Tanytydeus sp.*														9	12	17			2	1		3	4	
		Sacotydeus sp.																								
	Rhagidiidae	*Rhagidia sp.*																								
		Coccorhagia sp.																								
	Eupodidae	*Eupodes parafusifer*														25	19	7	1	1	1	5	19	18	4	5
		sp. 2																								
		Linopodes sp.																								
		Proteroneutes sp.																								
TARSO-NEMINI	Tarsonemidae	*Tarsonemus sp.*													8											
	Scutacaridae	*Scutacarus sp.*														7										
		Imparipes sp.																								
	Pygmephoridae	*Bakerdania sp.*										4		2		31			1	4						

		Siteropsis sp.																								
		Pygmephores sp.																								
	Pyemotidae	*Pyemotes sp.*																								
	Tarsochelidae	*Hoplocheylus aethiopicus*																								
	Nematalycidae	*Nematalycus sp.*																								
	Cunaxidae	*Cunaxa sp. 1*												5	13	7		1	1		4		1		1	
		sp. 2																								
	Bdellidae	*Cyta sp.*																								
		Biscurus sp.													2											
		Bdella sp.														2										
		Bdellodes hessei																								
		Spinibdella thori													13	7	11			1	2	4	3			
		Hexabdella sp.																								
	Cheyletidae	*Cheyletus sp.*															7									
	Pseudocheylidae	*Neocheylus sp.*																								
		Anoplocheylus sp.										2				7				1			4			
	Linotetranidae	*Linotetranus sp.*														7	14				3		17	7		
	Caeculidae	*Microcaeculus sp.*																								
		Caeculus sp.																								
	Anystidae	*Anystis baccarum*																								
		Chausseria sp.																								
	Adamystidae	*Adamystis sp.*																								
	Stigmaeidae	*Agistemus africanus*														12	4									
		Ledermuelleria sp.																								
		Storchia robusta										2					7									
		Eustigmaeus sp.													365						19	4				
	Tetranychidae	*Tetranychus urticae*																								
		Bryobia praetiosa																								
	Eriopyidae	(diversi)													34											
	Erythraeidae	*Abrolophus sp.*													3								1		1	
		Leptus sp.																								
		Erythraeus sp.																								
		Balaustium sp.																								
	Smarididae	*Smaris sp.*																		1				3		
	Trombidiidae	*Allothrombium sp.*																								
		Thrombidium sp.																								
	Trombiculidae	*Trombiculus larva*																								

CRYPTO-STIG-MATA	(Oppioidea)	*sp 1*														1			1							
	Oppiidae	*Brachioppia sp.*											2			1					1		4		6
		Multioppia sp.														2			2							
	Oribatulidae	*Zygoribatula sp. 1*												4		1	1	1			3		4	1	7
		Zygoribatula sp. 2																		2				1	
	Scheloribatidae	*Scheloribates sp. 1*											4			4	4	4	1				3		3
		Scheloribates sp. 2											1			6		3							
		Scheloribates sp. 3														4	6	4							
		Scheloribates sp. 4											1												
	Liodoidea	*cf Liodes*																							
	Zetomotrichidae	*Floritrichus louisbothai*																							
		Saltatrichus sp. 1																							
		Saltatrichus sp. 2																							
		Zetomotrichus sp.																							
	Scutoverticidae	*Ethiovertex sp.*											1			25		3	1	4	14	20	4	4	3
	Tectocepheidae	*Tectocepheus sp.*																							
	Otocepheiae	*Pseudotocepheus sp.*														1									
	Cepheidae	*cf Sadocepheus sp.*															1								
	Ceratozetidae	*Hypozetes sp.*						2		3		1							1						
	Plateremaeidae	*Pedrocortesella parva*																							
	Gymnodamaeidae	*cf Jacotella sp.*														4	6					2		1	
		Gymnodameus sp.											2												
	Eremulidae	*Austroeremulus sp. 1*																							
		Austroeremulus sp. 2																							
	Galumnidae	*Galumna sp.*																			1		2		
	Phenopelopidae	*Eupelops sp.*																							
	Microzetidae	*Microzetes sp.*																							
	Phthiracaridae	*Atropacarus sp.*											3			5		3	1						
	Epilohmanniidae	*Epilohmania sp.*																							
	Lohmanniidae	*Cryptacarus sp.*																		4	1	2			1
	(Hypochthonioidea)	*sp 1*														5	7								
	Cosmochthoniidae	*Cosmochthonius sp.*														4	44		1	2		1			1
		Brachythonius sp.																							
	Sphaerochthoniidae	*Sphaerochochthonius sp.*																							
	Unidentified	juveniles														2									
MESOSTIG-MATA	Laelapidae	*Hypoaspis sp. 1*																					1		
		sp. 2																						1	

		Cosmolaelaps sp.														4	12	16									
		Leptolaelaps sp.						1				3		4									4				
		Pachylaelaps sp.															9									1	
	Rhodacaridae	*Gamasellus sp.*																8									
		Rhodacarus sp.										7		7													
		Rhodacarellus sp.																									
	Ascidae	*Protogamasellus sp.*										10									7	4	7	7		15	
		Proctolaelaps sp.																				5		1	4	4	
		Asca sp.												2				17		1							
		Lasioseius sp.																									
	Veigaiaidae	*Veigaia sp.*										1															
	Eviphididae	*Eviphus sp.*																									
		Copriphis? sp.																									
	Digamasellidae	*Digamasellus sp.*																									
	Macrochelidae	*Glypthlaspis sp.*																									
		Macrocheles sp.																				1					
	Phytoseiidae	*Typhlodromus sp.*															4	6	4								
	Parastidae	*Pergamasus sp.*																				1					
		Parasitus sp.																									
	Uropodidae	*Cilliba? sp.*																									
ASTIGMATA	Acaridae	*Caloglyphus sp.*														5	3							3			
		Rhizoglyphus echinopus																									
		Tyrophagus putrescentidae																									
		Hypopi																									
		Glycyphagus sp. 1																									
METASTIG-	Ixodidae	juveniles																									
ARANEAE	Lycosidae	*Lycosa sp. 1*																									
		Lycosa sp. 2																									
	Salticidae	Morphospecies 1																									
		Morphospecies 2																									
		Morphospecies 3																									
PSEUDOSCORPIONIDAE																											
SCORPIONIDAE																											

AUGUST 2005

			Site 5						Site 6						Site 7					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
PROSTIG-MATA	Nanorchestidae	*Speleorchestes meyeri*		4	13	7	6	1		2	4	1	2	2						4
		Speleorchestes potchensis							1	2		3	1	2	4	7	2	6	10	9
		Nanorchestes globosus		3	17	11		7				3								
		Nanorchestes usitatus							7	11	1	1	4	6						
		Nanorchestes excertus																		
	Alicorhagiidae	*Alicorhagia usitata*																		
		Stigmalychus veretrum																		
	Alycidae	*Alycus acaciae*		5	12	3	13	9		2		1	1					2		1
		Bimichaelia sp.									1		2							
		Petralycus longicornis												2						
	Terpnacaridae	*Terpnacarus glebulentus*			2		1													
		Alycosmesis sp.																		
	Oescherchestidae	*Lordalychus sp.*							4		1			3						
	Micropsammidae	*Micropsammus sp nova*																		
	Hybalycidae	*Hybalicus sp.*			2								1							
	Sphaerolichidae	*Sphaerolichus sp.*																		
	Iolinidae	*Pronematus ubiquitus*	4		21	9	7	17				10			6		3	4		
	Tydeidae	*Coccotydaeolus sp.*	15	40	66	19	10	45	10	3	19	15	9	5	17	7				
		Coccotydaeus sp.																		
		Tydeus grabouwi										1								
		Tydeus munsteri										2								
		Brachytydeus sp.																		
		Genus indet																		
	Paratydeidae	*Tanytydeus sp.*	2	7	4	7	9	10					3							
		Sacotydeus sp.																		
	Rhagidiidae	*Rhagidia sp.*		3	5	2	1	2	2	1				1			3	4	1	
		Coccorhagia sp.															2			
	Eupodidae	*Eupodes parafusifer*	15	35	70	169	89	67	28	13	7	19	30	5	17	7	4	10	9	16
		sp. 2				4														
		Linopodes sp.	1	2	3	10	3	5	3			4				1		2		
		Proteroneutes sp.	1		2	2	3				1		2	1						
TARSO-NEMINI	Tarsonemidae	*Tarsonemus sp.*	15													2		60		3
	Scutacaridae	*Scutacarus sp.*																		
		Imparipes sp.																		
	Pygmephoridae	*Bakerdania sp.*		12	21	4	17	18							14	4	4	3		

		Siteropsis sp.																		
		Pygmephores sp.		3		4						4	1							
	Pyemotidae	*Pyemotes sp.*				3					5									
	Tarsochelidae	*Hoplocheylus aethiopicus*																		
	Nematalycidae	*Nematalycus sp.*																		
	Cunaxidae	*Cunaxa sp. 1*		7	9	6	8	2	4	3	1	7	11	3				2		
		sp. 2																		
	Bdellidae	*Cyta sp.*		3	5		7	3											1	
		Biscurus sp.																		
		Bdella sp.																		
		Bdellodes hessei													1				2	
		Spinibdella thori		6	7	2	7	3	4	6		7	3	9						
		Hexabdella sp.																		
	Cheyletidae	*Cheyletus sp.*																		
	Pseudocheylidae	*Neocheylus sp.*																	1	
		Anoplocheylus sp.																		
	Linotetranidae	*Linotetranus sp.*									4		7		2					
	Caeculidae	*Microcaeculus sp.*		1			2	1					1	1	1		1			
		Caeculus sp.			3		1				2									
	Anystidae	*Anystis baccarum*		1		2		2		1					2	1				
		Chausseria sp.																	1	
	Adamystidae	*Adamystis sp.*																		
	Stigmaeidae	*Agistemus africanus*														1			2	
		Ledermuelleria sp.																		
		Storchia robusta								2			1		2		1		2	
		Eustigmaeus sp.		17	10	15	48	7												
	Tetranychidae	*Tetranychus urticae*			3						1									
		Bryobia praetiosa		2				1	2		1	1		4						
	Eriopyidae	(diversi)																		
	Erythraeidae	*Abrolophus sp.*		1	3		4		1					1				1		
		Leptus sp.										1		1						
		Erythraeus sp.																		
		Balaustium sp.			1	2														
	Smarididae	*Smaris sp.*																		
	Trombidiidae	*Allothrombium sp.*																		
		Thrombidium sp.																		
	Trombiculidae	*Trombiculus larva*																		

CRYPTO-	(Oppioidea)	*sp 1*											2				1				
STIG-	Oppiidae	*Brachioppia sp.*			2				1	4		2		1							
MATA		*Multioppia sp.*																			
	Oribatulidae	*Zygoribatula sp. 1*	4	2		3	6	4	2	1	3	1			1	2		2	1	1	
		Zygoribatula sp. 2	3				2			2				3	1		1	2	1		
	Scheloribatidae	*Scheloribates sp. 1*	2						4	1	2	1	1				1	2			
		Scheloribates sp. 2			1	1	2	3							1	1		1	2		
		Scheloribates sp. 3	1		1	4	2				2		1				1			1	
		Scheloribates sp. 4													1		2	1			
	Liodoidea	*cf Liodes*																			
	Zetomotrichidae	*Floritrichus louisbothai*	1	2	4		2						1								
		Saltatrichus sp. 1																			
		Saltatrichus sp. 2																			
		Zetomotrichus sp.																			
	Scutoverticidae	*Ethiovertex sp.*							3	7	4	1	2	2	1		2		1		
	Tectocepheidae	*Tectocepheus sp.*										3									
	Otocepheiae	*Pseudotocepheus sp.*																			
	Cepheidae	*cf Sadocepheus sp.*																1		1	
	Ceratozetidae	*Hypozetes sp.*	2												1		2		1		
	Plateremaeidae	*Pedrocortesella parva*										1						1			
	Gymnodamaeidae	*cf Jacotella sp.*		4	1	7	7	4			2	2	4		1					2	
		Gymnodameus sp.																			
	Eremulidae	*Austroeremulus sp. 1*																			
		Austroeremulus sp. 2																			
	Galumnidae	*Galumna sp.*		1	3	1		2			3		1				1				
	Phenopelopidae	*Eupelops sp.*										1	2							2	
	Microzetidae	*Microzetes sp.*																			
	Phthiracaridae	*Atropacarus sp.*																			
	Epilohmanniidae	*Epilohmania sp.*	1	2	3	4	1	1	1	3	3	4	2	3			2				
	Lohmanniidae	*Cryptacarus sp.*	5	4		6	7	3			2	2	1					2		1	
	(Hypochthonioidea)	*sp 1*	4		9	11	9	7		4		7	3		1		1	2			
	Cosmochthoniidae	*Cosmochthonius sp.*		13	5	4	3	7	3	1	3		1		1		2		1		
		Brachythonius sp.																			
	Sphaerochthoniidae	*Sphaerochochthonius sp.*							2		2						1				
	Unidentified	juveniles																			
MESOSTIG-	Laelapidae	*Hypoaspis sp. 1*														4	2		1		
MATA		*sp. 2*																			

		Cosmolaelaps sp.																2			
		Leptolaelaps sp.												2		1					
		Pachylaelaps sp.																			
	Rhodacaridae	*Gamasellus sp.*																			
		Rhodacarus sp.	2	7	6	3	9	2	7	11	9	2	7	8	2		4		7		
		Rhodacarellus sp.	1							2		1		2	1						2
	Ascidae	*Protogamasellus sp.*	11		3		4			4	3			5		2			1		1
		Proctolaelaps sp.	2																		
		Asca sp.		7	7	17	4	5		2	1	2									
		Lasioseius sp.		2		4		1													
	Veigaiaidae	*Veigaia sp.*																			
	Eviphididae	*Eviphus sp.*																			
		Copriphis? sp.																			
	Digamasellidae	*Digamasellus sp.*				2		1								1					
	Macrochelidae	*Glypthlaspis sp.*																			
		Macrocheles sp.		3																	
	Phytoseiidae	*Typhlodromus sp.*		4		4	7	11													
	Parastidae	*Pergamasus sp.*																			
		Parasitus sp.																			
	Uropodidae	*Cilliba? sp.*		1		2						2									
ASTIGMATA	Acaridae	*Caloglyphus sp.*		3		4				3	1	1	3	1							
		Rhizoglyphus echinopus		1		3									1			2			
		Tyrophagus putrescentidae										2	1	3							
		Hypopi																			
		Glycyphagus sp. 1																			
METASTIG-	Ixodidae	juveniles																			
ARANEAE	Lycosidae	*Lycosa sp. 1*		2				3			2										
		Lycosa sp. 2		1				1			1										
	Salticidae	Morphospecies 1						3			1		1								
		Morphospecies 2		2				2													
		Morphospecies 3																			
PSEUDOSCORPIONIDAE				2	1	3	4	1							4	7	1	4	2	4	
SCORPIONIDAE																					

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			Site 1						Site 2						Site 3						Site 4					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
COLLEMBOLA	Poduridae	sp. 1													7			4		4	7	1	4	2		7
		sp. 2																								
	Isotomidae								1		4		1	2	4						9					
	Entomobryidae	sp. 1													11	6	10	1				3	1	4		4
		sp. 2											1	1			3									
		sp. 3																								
	Tomoceridae	sp. 1																								
		sp. 2																								
	Sminthuridae	sp. 1													5		7			11						
		sp. 2																								
	Neelidae	sp. 1																								
		sp. 2																								
COLEOPTERA	Staphylinidae																2						2			
	Elateridae													1			4									
HYMENOPTERA	Formicidae	*Anaplolepis sp.*			13			8													2					
		Plagiolepis sp.																								
		Pheidole sp.								3																
		Tetramonium sp.																								
		Monomonium sp.																								
		Technomyrmex sp																								
		Cerapachys sp.																								
	Vespidae	sp.1																								
		sp.2																								
PSOCOPTERA	Psocidae	sp.										3	4					10				3		7	1	4
ISOPTERA	Hodotermitidae	sp.																								
	Termitidae	sp.																								
THYSANOPTERA	Thripidae								1				4			7										1
	Aelothripidae																									
HEMIPTERA	Nymphs												4			3		30				2				
DIPTERA	Muscidae																									
	Cecidomyiidae																									
	Diverse larvae																									
LEPIDOPTERA	Geometridae	larvae																								1
PROTURA																										
DIPLURA																										

CHILOPODA	Scolopendromorpha																										
	Lithobiomorpha																										
	Geophilomorpha															1						1			1	2
SYMPHYLA																											
PAUROPODA																											
DIPLOPODA		*Polixenus sp.*													1												
CRUSTACEA	Isopoda																										
NEMATODA		Criconema																									
		Xiphinema										2															
		Longidoridae																									
ANNELIDA		Oligochaeta																									

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			Site 5						Site 6						Site 7					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
COLLEMBOLA	Poduridae	sp. 1	40	9					2		3		4		7	9	1		8	10
		sp. 2							2									2		
	Isotomidae								7	4		1	11	9	1		2		4	
	Entomobryidae	sp. 1	40	209	60	141	13	3										3	3	
		sp. 2					29	3												
		sp. 3																		
	Tomoceridae	sp. 1				2		1												
		sp. 2			1															
	Sminthuridae	sp. 1	8	33	10	9	21	19									2	2		3
		sp. 2																		
	Neelidae	sp. 1																		
		sp. 2																		
COLEOPTERA	Staphylinidae						5			2					1			2	1	
	Elateridae										1					1			1	
HYMENOPTERA	Formicidae	*Anaplolepis sp.*							1				1							
		Plagiolepis sp.							2				2							
		Pheidole sp.																		
		Tetramonium sp.																		
		Monomonium sp.																		
		Technomyrmex sp																		
		Cerapachys sp.																		
	Vespidae	sp.1																		
		sp.2																		
PSOCOPTERA	Psocidae	sp.			3		1										3		1	
ISOPTERA	Hodotermitidae	sp.																		
	Termitidae	sp.												7				2		
THYSANOPTERA	Thripidae					3							4						1	
	Aelothripidae																			
HEMIPTERA	Nymphs																			
DIPTERA	Muscidae				2															
	Cecidomyiidae													2						
	Diverse larvae																			
LEPIDOPTERA	Geometridae	larvae		2		4	6													
PROTURA																		1		
DIPLURA																				

CHILOPODA	Scolopendromorpha							2												
	Lithobiomorpha																			1
	Geophilomorpha														1	1	2	2	2	1
SYMPHYLA				4	7	11	2	9		2		16	7	12				3	1	
PAUROPODA																				
DIPLOPODA		*Polixenus sp.*																		
CRUSTACEA	Isopoda																			
NEMATODA		Criconema																		
		Xiphinema																		
		Longidoridae																		
ANNELIDA		Oligochaeta																		

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			Site 1						Site 2						Site 3						Site 4					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
PROSTIG-MATA	Nanorchestidae	*Speleorchestes meyeri*							4	7	11	9	11	14	21	30	9	19	30	5		1	1	14	17	2
		Speleorchestes potchensis																								
		Nanorchestes globosus																								
		Nanorchestes usitatus																			4	1	4			5
		Nanorchestes excertus																								
	Alicorhagiidae	*Alicorhagia usitata*																								
		Stigmalychus veretrum																								
	Alycidae	*Alycus acaciae*														3						3	4			3
		Bimichaelia sp.																								
		Petralycus longicornis																								
	Terpnacaridae	*Terpnacarus glebulentus*																								
		Alycosmesis sp.																								
	Oescherchestidae	*Lordalychus sp.*																								
	Micropsammidae	*Micropsammus sp nova*																								
	Hybalycidae	*Hybalicus sp.*																								
	Sphaerolichidae	*Sphaerolichus sp.*																								
	Iolinidae	*Pronematus ubiquitus*							11	1	6		10	4		4			1	2						
	Tydeidae	*Coccotydaeolus sp.*	31				15		19	8	17	9	101	30	16	33	41	19	5	15	23	14	4	6	7	19
		Coccotydaeus sp.				11																				
		Tydeus grabouwi													1											
		Tydeus munsteri																								
		Brachytydeus sp.																								
		Genus indet																								
	Paratydeidae	*Tanytydeus sp.*														7		7			9		3		4	5
		Sacotydeus sp.																								
	Rhagidiidae	*Rhagidia sp.*														1				2						
		Coccorhagia sp.																								4
	Eupodidae	*Eupodes parafusifer*													5	11		4	1	17	11	44	10			9
		sp. 2																								
		Linopodes sp.																			3		2			4
		Proteroneutes sp.																								
TARSO-NEMINI	Tarsonemidae	*Tarsonemus sp.*																						1	4	
	Scutacaridae	*Scutacarus sp.*																								
		Imparipes sp.																								
	Pygmephoridae	*Bakerdania sp.*					3		4		6			3	3	1		4								

		Siteropsis sp.																										
		Pygmephores sp.													4			2		2								
	Pyemotidae	*Pyemotes sp.*																										
	Tarsochelidae	*Hoplocheylus aethiopicus*														2						3			4			
	Nematalycidae	*Nematalycus sp.*	7																									
	Cunaxidae	*Cunaxa sp. 1*													3			1	1	4	2	2	1			4		
		sp. 2																										
	Bdellidae	*Cyta sp.*																										
		Biscurus sp.																										
		Bdella sp.																										
		Bdellodes hessei																										
		Spinibdella thori													2				3	1	4					4		
		Hexabdella sp.																										
	Cheyletidae	*Cheyletus sp.*																										
	Pseudocheylidae	*Neocheylus sp.*																										
		Anoplocheylus sp.																										
	Linotetranidae	*Linotetranus sp.*																					11					
	Caeculidae	*Microcaeculus sp.*																										
		Caeculus sp.																										3
	Anystidae	*Anystis baccarum*																1		4	1		4					
		Chausseria sp.																										
	Adamystidae	*Adamystis sp.*																										
	Stigmaeidae	*Agistemus africanus*													3			4		7								
		Ledermuelleria sp.																						1				
		Storchia robusta																2										
		Eustigmaeus sp.																										
	Tetranychidae	*Tetranychus urticae*					1																					
		Bryobia praetiosa																					3					
	Eriopyidae	(diversi)																										
	Erythraeidae	*Abrolophus sp.*																				1				4		
		Leptus sp.																										
		Erythraeus sp.																										
		Balaustium sp.													1				3									
	Smarididae	*Smaris sp.*																					4			1		
	Trombidiidae	*Allothrombium sp.*																										
		Thrombidium sp.																										
	Trombiculidae	*Trombiculus larva*																										

CRYPTO-STIG-MATA	(Oppioidea)	*sp 1*				2									1												
	Oppiidae	*Brachioppia sp.*																		4	4				7		
		Multioppia sp.													3												
	Oribatulidae	*Zygoribatula sp. 1*													17		3			1							
		Zygoribatula sp. 2													1			1	1	4							
	Scheloribatidae	*Scheloribates sp. 1*		1				1							6		1	7		3				4	6		
		Scheloribates sp. 2		5	1		3								3			1		2				1	1		
		Scheloribates sp. 3				3												1		3							
		Scheloribates sp. 4													4			3					2				
	Liodoidea	*cf Liodes*																									
	Zetomotrichidae	*Floritrichus louisbothai*																		1							
		Saltatrichus sp. 1																									
		Saltatrichus sp. 2																									
		Zetomotrichus sp.																									
	Scutoverticidae	*Ethiovertex sp.*			1										3				17								
	Tectocepheidae	*Tectocepheus sp.*													4								3				
	Otocepheiae	*Pseudotocepheus sp.*													3												
	Cepheidae	*cf Sadocepheus sp.*																		1							
	Ceratozetidae	*Hypozetes sp.*	3	2				1		1	1	1	1											2	3		
	Plateremaeidae	*Pedrocortesella parva*																									
	Gymnodamaeidae	*cf Jacotella sp.*																		4	1	9	14			3	
		Gymnodameus sp.																									
	Eremulidae	*Austroeremulus sp. 1*																									
		Austroeremulus sp. 2																									
	Galumnidae	*Galumna sp.*																			1	2				1	
	Phenopelopidae	*Eupelops sp.*																			1	1	4			4	
	Microzetidae	*Microzetes sp.*													3			3									
	Phthiracaridae	*Atropacarus sp.*													10			3		1							
	Epilohmanniidae	*Epilohmania sp.*													2	1	3		1	4			2			3	
	Lohmanniidae	*Cryptacarus sp.*													1				3	4	9	1	4			3	
	(Hypochthonioidea	*sp 1*													17			13		1							
	Cosmochthoniidae	*Cosmochthonius sp.*													13			3		7	3			15		1	
		Brachythonius sp.																									
	Sphaerochthoniida	*Sphaerochochthonius sp.*																									
	Unidentified	juveniles																		3							
MESOSTIG-MATA	Laelapidae	*Hypoaspis sp. 1*																									
		sp. 2																									

		Cosmolaelaps sp.													7	4		9		14								
		Leptolaelaps sp.	1		2		1			5		6																
		Pachylaelaps sp.																				1		2	2	1		
	Rhodacaridae	*Gamasellus sp.*																										
		Rhodacarus sp.							3	3		1	1		9													
		Rhodacarellus sp.							2	1		2	4															
	Ascidae	*Protogamasellus sp.*							7	1				1	3	1				7	17	11	2	10	7			
		Proctolaelaps sp.													3				4									
		Asca sp.								1		1		4							5	6	1			8		
		Lasioseius sp.																										
	Veigaiaidae	*Veigaia sp.*																										
	Eviphididae	*Eviphus sp.*																										
		Copriphis? sp.																										
	Digamasellidae	*Digamasellus sp.*																										
	Macrochelidae	*Glypthlaspis sp.*																										
		Macrocheles sp.																1		3	1		4			1		
	Phytoseiidae	*Typhlodromus sp.*														4						3				3		
	Parastidae	*Pergamasus sp.*																				4		6				
		Parasitus sp.																										
	Uropodidae	*Cilliba? sp.*																										
ASTIGMATA	Acaridae	*Caloglyphus sp.*																		4	1	1						
		Rhizoglyphus echinopus							1			4																
		Tyrophagus putrescentidae													1				4			3						
		Hypopi																							2			
		Glycyphagus sp. 1																										
METASTIG-	Ixodidae	juveniles																			2							
ARANEAE	Lycosidae	*Lycosa sp. 1*																										
		Lycosa sp. 2																										
	Salticidae	Morphospecies 1																										
		Morphospecies 2																										
		Morphospecies 3																										
PSEUDOSCORPIONIDAE																												
SCORPIONIDAE																												

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			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
PROSTIG-MATA	Nanorchestidae	*Speleorchestes meyeri*	3	17	9	17	14		8	4	5	11	17	15			2		1	
		Speleorchestes potchensis							8	4	1	8	10	9		14	4	6	8	15
		Nanorchestes globosus	4	13	19	9	30	4	4		6	6	4	13	9	7	1	2	4	
		Nanorchestes usitatus		1		2	4		10	9	7	9	17	21	17	3	4	15	9	1
		Nanorchestes excertus		1												2		3		1
	Alicorhagiidae	*Alicorhagia usitata*		2			4						6	1						
		Stigmalychus veretrum				2	2					4	9	1						
	Alycidae	*Alycus acaciae*		3	7	9	10					3	4	5		4	17	2		5
		Bimichaelia sp.				2														
		Petralycus longicornis											4	6						
	Terpnacaridae	*Terpnacarus glebulentus*			3	4														
		Alycosmesis sp.																		
	Oescherchestidae	*Lordalychus sp.*										4	11	8			2		2	
	Micropsammidae	*Micropsammus sp nova*										3	4	6						
	Hybalycidae	*Hybalicus sp.*		4	7	5	9						8						2	
	Sphaerolichidae	*Sphaerolichus sp.*				3						3		1			2			
	Iolinidae	*Pronematus ubiquitus*		5	3	7	21		7	7		4	18	9			7	9	10	2
	Tydeidae	*Coccotydaeolus sp.*	16	70	111	81	66	11	29	10	1	18	11	24		70	20	18	14	9
		Coccotydaeus sp.										13				13	17	4		2
		Tydeus grabouwi										4		5						
		Tydeus munsteri											4						1	
		Brachytydeus sp.																		
		Genus indet																		
	Paratydeidae	*Tanytydeus sp.*		9	14	7	23		7		8	1	10	13						
		Sacotydeus sp.																		
	Rhagidiidae	*Rhagidia sp.*		2	2	1	4		7	1	4					2	2		2	1
		Coccorhagia sp.														3				
	Eupodidae	*Eupodes parafusifer*	19	41	32	60	79	4	20	7	4	31	24	17		21		13		17
		sp. 2		4	7	5	6			4		6		3					2	
		Linopodes sp.	3		7		7										4	5		7
		Proteroneutes sp.		4	1	3	1			2		6	9	9						
TARSO-NEMINI	Tarsonemidae	*Tarsonemus sp.*							14			6	6	11						
	Scutacaridae	*Scutacarus sp.*	7		23		4						3		4					
		Imparipes sp.					2													
	Pygmephoridae	*Bakerdania sp.*		3	61	7	4	1				4	7	1	16	6	7	4		1

	Siteropsis sp.			4								1	3								
	Pygmephores sp.				3						2				4		3		2		
Pyemotidae	*Pyemotes sp.*		4		11																
Tarsochelidae	*Hoplocheylus aethiopicus*							3			1	4	4				2				
Nematalycidae	*Nematalycus sp.*																				
Cunaxidae	*Cunaxa sp. 1*		4	7	10	9	1	4			2	7	9		6	4	3		2		
	sp. 2											2									
Bdellidae	*Cyta sp.*							6			7					3					
	Biscurus sp.																				
	Bdella sp.																				
	Bdellodes hessei															3		4			
	Spinibdella thori	1	7	11	15	14	1	8	1	1	6	9	12	9	7	9	16	11	4		
	Hexabdella sp.																				
Cheyletidae	*Cheyletus sp.*																				
Pseudocheylidae	*Neocheylus sp.*							3			1	3	1		4		2				
	Anoplocheylus sp.											2	1								
Linotetranidae	*Linotetranus sp.*										14						3	3			
Caeculidae	*Microcaeculus sp.*		2		1	4		2				3	1			2		1			
	Caeculus sp.												1								
Anystidae	*Anystis baccarum*		4		1	1		4			2	2	4		1						
	Chausseria sp.												2								
Adamystidae	*Adamystis sp.*							2				3			3		3		1		
Stigmaeidae	*Agistemus africanus*		1		2			2					1					1			
	Ledermuelleria sp.																				
	Storchia robusta							2		3			2		3	1		1	3		
	Eustigmaeus sp.		16	7	4	17		37			4	16	15								
Tetranychidae	*Tetranychus urticae*					13						2				1		2			
	Bryobia praetiosa		1	4				2			2	1	2								
Eriopyidae	(diversi)																				
Erythraeidae	*Abrolophus sp.*		2		3	1		4			2	4	1		2			2			
	Leptus sp.							1				2	2								
	Erythraeus sp.				2							2	1								
	Balaustium sp.											3							1		
Smarididae	*Smaris sp.*		1			4		1				2									
Trombidiidae	*Allothrombium sp.*												1								
	Thrombidium sp.			2								2	1								
Trombiculidae	*Trombiculus larva*																				

CRYPTO-STIG-MATA	(Oppioidea)	*sp 1*														2	1				2
	Oppiidae	*Brachioppia sp.*																2			
		Multioppia sp.										2	1	1							
	Oribatulidae	*Zygoribatula sp. 1*		3	4	1	4		4			2	3	2		4	3		2	4	
		Zygoribatula sp. 2				1			3			2	2	4							
	Scheloribatidae	*Scheloribates sp. 1*		6	4	3	1		5		1	6	4	5	2	2	3	4	1	2	
		Scheloribates sp. 2		1	2	2								1		1		2	1		
		Scheloribates sp. 3					3					2	1	2	2	2	3		4		
		Scheloribates sp. 4			2										2	3	1	2		2	
	Liodoidea	*cf Liodes*																			
	Zetomotrichidae	*Floritrichus louisbothai*							1				2	2		2			2	1	
		Saltatrichus sp. 1															2	1		1	
		Saltatrichus sp. 2								3							1	1		1	
		Zetomotrichus sp.																			
	Scutoverticidae	*Ethiovertex sp.*								2						2		1		1	
	Tectocepheidae	*Tectocepheus sp.*		6	4		3														
	Otocepheiae	*Pseudotocepheus sp.*		2		2	1	1				3	1	2		1	2		2		
	Cepheidae	*cf Sadocepheus sp.*										1	2			2		3		1	
	Ceratozetidae	*Hypozetes sp.*																			
	Plateremaeidae	*Pedrocortesella parva*											2								
	Gymnodamaeidae	*cf Jacotella sp.*		5	7	1	2		9	4	7	4	95	14		2		3		4	
		Gymnodameus sp.									2			7							
	Eremulidae	*Austroeremulus sp. 1*																			
		Austroeremulus sp. 2																			
	Galumnidae	*Galumna sp.*		2	2	3	7										4	2	1		
	Phenopelopidae	*Eupelops sp.*		1		3										1				2	
	Microzetidae	*Microzetes sp.*				2						1	2	1		1		2	2		
	Phthiracaridae	*Atropacarus sp.*		2		2						2	1	2					2		
	Epilohmanniidae	*Epilohmania sp.*	1	7	2	16	18	1	2	1		6	32	16		2			4	3	
	Lohmanniidae	*Cryptacarus sp.*		11	19		7		2			4	4	5		2	3		4	1	
	(Hypochthonioidea)	*sp 1*							16	4	1	1	1	6		2	1	2	2	2	
	Cosmochthoniidae	*Cosmochthonius sp.*		17	8	14	12	3	10			15	6	10		2		2	1		
		Brachythonius sp.																			
	Sphaerochthoniidae	*Sphaerochochthonius sp.*			2		3		2					4		2			1	1	
	Unidentified	juveniles																			
MESOSTIG-MATA	Laelapidae	*Hypoaspis sp. 1*		1		1	4		14		2	1		2		7	2		4		
		sp. 2			1	4			2												

		Cosmolaelaps sp.							10		4	1		8		3	4		7	1
		Leptolaelaps sp.	1	2	3	5	5	1	2					4		1		2	1	4
		Pachylaelaps sp.							3				2	2						
	Rhodacaridae	*Gamasellus sp.*		2		2											2			2
		Rhodacarus sp.	1	7	8	13	15	1	1			3	8	4						
		Rhodacarellus sp.		4	4	1	2								3		5			
	Ascidae	*Protogamasellus sp.*	5	38	17	21	8	6	18			11	9	18	11	9	2	7	4	
		Proctolaelaps sp.		3												3			3	
		Asca sp.			2		1		3			7	4	4	8	7			10	3
		Lasioseius sp.																		
	Veigaiaidae	*Veigaia sp.*																		
	Eviphididae	*Eviphus sp.*		2			2											3		
		Copriphis? sp.											1							
	Digamasellidae	*Digamasellus sp.*		3	3		1		4			4	4	1		4			3	
	Macrochelidae	*Glypthlaspis sp.*														2				
		Macrocheles sp.							4			4	6	2						
	Phytoseiidae	*Typhlodromus sp.*		2							1	2		2					1	
	Parastidae	*Pergamasus sp.*					1		3				1	2		1				
		Parasitus sp.																		
	Uropodidae	*Cilliba? sp.*			3								4	3						
ASTIGMATA	Acaridae	*Caloglyphus sp.*		7	2	1	1	1		4	4				4					
		Rhizoglyphus echinopus								3		1				2		1		
		Tyrophagus putrescentidae		3			4	1												
		Hypopi							4		1		4							
		Glycyphagus sp. 1			3															
METASTIG-	Ixodidae	juveniles			2								1							
ARANEAE	Lycosidae	*Lycosa sp. 1*			1	2	1					2	2	3		1		2	1	1
		Lycosa sp. 2			4	3	1						2				1		1	
	Salticidae	Morphospecies 1			1	2	1		4			1	2	1						
		Morphospecies 2																		
		Morphospecies 3				1		1												
PSEUDOSCORPIONIDAE				3	4	1	4					5	7	5	4	11	5	6	9	4
SCORPIONIDAE																				

DECEMBER 2005			Site 1						Site 2						Site 3						Site 4					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
COLLEMBOLA	Poduridae	sp. 1		4											17	1	3		4							
		sp. 2		1																						
	Isotomidae			2					1		2		1	1							19	1	27	7	8	3
	Entomobryidae	sp. 1																			13	67		4	5	
		sp. 2									2		3													
		sp. 3																								
	Tomoceridae	sp. 1																								
		sp. 2																								
	Sminthuridae	sp. 1		5	86	1		12							11			14	1	3	3	1	11		4	3
		sp. 2		3		1																				
	Neelidae	sp. 1																								
		sp. 2																								
COLEOPTERA	Staphylinidae			1	4										2	1		1								
	Elateridae					1									1			7	3		1		3			4
HYMENOPTERA	Formicidae	*Anaplolepis sp.*					2																			
		Plagiolepis sp.																								
		Pheidole sp.																								
		Tetramonium sp.																								
		Monomonium sp.																								
		Technomyrmex sp					1																			
		Cerapachys sp.																								
	Vespidae	sp.1																								
		sp.2																								
PSOCOPTERA	Psocidae	sp.		3			3		1		2		2	1							5	7	3			1
ISOPTERA	Hodotermitidae	sp.																								
	Termitidae	sp.																			2					
THYSANOPTERA	Thripidae								1		4		1		4		4		11		4		14	1		7
	Aelothripidae																									
HEMIPTERA	Nymphs					1	1												4	4	1	3	2			4
DIPTERA	Muscidae																									
	Cecidomyiidae																									
	Diverse larvae																									
LEPIDOPTERA	Geometridae	larvae																								
PROTURA																							2			1
DIPLURA																										

CHILOPODA	Scolopendromorpha																										
	Lithobiomorpha																										
	Geophilomorpha														3					2	1	2	4			3
SYMPHYLA																											
PAUROPODA																											
DIPLOPODA		*Polixenus sp.*																									
CRUSTACEA	Isopoda																										
NEMATODA		Criconema													1												
		Xiphinema																									
		Longidoridae																									
ANNELIDA		Oligochaeta																									

DECEMBER 2005

			Site 5						Site 6						Site 7					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
COLLEMBOLA	Poduridae	sp. 1		4		7	1	1	17	4	4	22	11	17	99	10	9	7	4	17
		sp. 2							3								3			
	Isotomidae								30	44	21	21	10	30	288	40	20	16	12	9
	Entomobryidae	sp. 1	4	27	41	21	56	19	14	2	1	7	10	15	7	6	10	4	2	5
		sp. 2		3		4		1		2								2		1
		sp. 3																		
	Tomoceridae	sp. 1		1		2														
		sp. 2																		
	Sminthuridae	sp. 1	4	37	16		3		14			10	9	10		10	7		8	10
		sp. 2																		
	Neelidae	sp. 1																		
		sp. 2																		
COLEOPTERA	Staphylinidae								3					4		2			3	
	Elateridae								2					1		2		1		
HYMENOPTERA	Formicidae	*Anaplolepis sp.*		2					4				1	2						
		Plagiolepis sp.			4				1				2	2						
		Pheidole sp.																		
		Tetramonium sp.																		
		Monomonium sp.																		
		Technomyrmex sp																		
		Cerapachys sp.																		
	Vespidae	sp.1				1			2					1						
		sp.2		2																
PSOCOPTERA	Psocidae	sp.		7	1	3	6	1	4	1		5	8	6	4	4		3	3	4
ISOPTERA	Hodotermitidae	sp.																		
	Termitidae	sp.					4		5	2	1									
THYSANOPTERA	Thripidae			7	1	4	7		14	11	2	7	11	7		1	2	3	6	4
	Aelothripidae																			
HEMIPTERA	Nymphs								2					4						
DIPTERA	Muscidae																	2		
	Cecidomyiidae			1	1	2	1													
	Diverse larvae																			
LEPIDOPTERA	Geometridae	larvae							3					2						
PROTURA														2		3		2	1	2
DIPLURA																1		2	2	1

CHILOPODA	Scolopendromorpha																				
	Lithobiomorpha												1								
	Geophilomorpha			4	1	7	2					2		1	11	7	5	9	10	4
SYMPHYLA				7	4	7	10		9	6	7	7		9	31	9	4	9	10	12
PAUROPODA																				
DIPLOPODA		*Polixenus sp.*																		
CRUSTACEA	Isopoda																			
NEMATODA		Criconema										2	2	1		1		2		
		Xiphinema											2			1		1		3
		Longidoridae																		
ANNELIDA		Oligochaeta																		

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		Sp naam	Site 1						Site 2						Site 3						Site 4					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
PROSTIG-MATA	Nanorchestidae	*Speleorchestes meyeri*	30	9	17		12		12	2	17	15	17	21	19	17	61	40	35	60	6	10	10	19	3	0
		Speleorchestes potchensis																								
		Nanorchestes globosus													2			1		1						
		Nanorchestes usitatus																			10	2	8	1	14	4
		Nanorchestes excertus																								
	Alicorhagiidae	*Alicorhagia usitata*																								
		Stigmalychus veretrum																								
	Alycidae	*Alycus acaciae*										1			4		1	1		6	9	7		5		9
		Bimichaelia sp.																								
		Petralycus longicornis																								
	Terpnacaridae	*Terpnacarus glebulentus*																						7	1	6
		Alycosmesis sp.																								
	Oescherchestidae	*Lordalychus sp.*													1				2	1						
	Micropsammidae	*Micropsammus sp nova*																								
	Hybalycidae	*Hybalicus sp.*																								
	Sphaerolichidae	*Sphaerolichus sp.*																								
	Iolinidae	*Pronematus ubiquitus*							16			11		7	15	8		5		6			3			
	Tydeidae	*Coccotydaeolus sp.*	31				15		37	3	11	33	147	41	35	40	53	101	20	110		16	6		30	19
		Coccotydaeus sp.				11						4														
		Tydeus grabouwi							3			2	5				12	11		4	1	4	3		6	1
		Tydeus munsteri										3		6				4		3						
		Brachytydeus sp.																								
		Genus indet																								
	Paratydeidae	*Tanytydeus sp.*													5	19		4	21	1	3		4	4	6	10
		Sacotydeus sp.																								
	Rhagidiidae	*Rhagidia sp.*																3	3	4						
		Coccorhagia sp.														3		4	4			1	7	8		
	Eupodidae	*Eupodes parafusifer*													5		11		7	9	19	20	6	5	30	16
		sp. 2																			1	4	1		1	1
		Linopodes sp.																					11			4
		Proteroneutes sp.													4				1	1						
TARSO-NEMINI	Tarsonemidae	*Tarsonemus sp.*													89			3	18		5	1	4		6	
	Scutacaridae	*Scutacarus sp.*																								
		Imparipes sp.																5					3			4

Pygmephoridae	*Bakerdania sp.*	2			7						30					16			7							
	Siteropsis sp.																									
	Pygmephores sp.													8			11		80							
Pyemotidae	*Pyemotes sp.*																7									
Tarsochelidae	*Hoplocheylus aethiopicus*																4									
Nematalycidae	*Nematalycus sp.*	4		7	7	9	13																			
Cunaxidae	*Cunaxa sp. 1*													25	13		10	7	17	4	1		7			
	sp. 2																			1		1		1		
Bdellidae	*Cyta sp.*													3				1		1		3		4		
	Biscurus sp.																4		3							
	Bdella sp.																									
	Bdellodes hessei																									
	Spinibdella thori													6			10			7	1	9		14	11	
	Hexabdella sp.																									
Cheyletidae	*Cheyletus sp.*																	4								
Pseudocheylidae	*Neocheylus sp.*																									
	Anoplocheylus sp.							2				3		3												
Linotetranidae	*Linotetranus sp.*																				5		8			
Caeculidae	*Microcaeculus sp.*																1									
	Caeculus sp.																						2			
Anystidae	*Anystis baccarum*													4			1		3	2		1		1		
	Chausseria sp.																				1					
Adamystidae	*Adamystis sp.*																									
Stigmaeidae	*Agistemus africanus*													4				1								
	Ledermuelleria sp.																					10		7	4	
	Storchia robusta								3			3	1													
	Eustigmaeus sp.													6												
Tetranychidae	*Tetranychus urticae*			3		1														1			2	1	4	
	Bryobia praetiosa																						7		1	
Eriophyidae	(diversi)													1				3								
Erythraeidae	*Abrolophus sp.*																			1		6	7		4	
	Leptus sp.													1					4							
	Erythraeus sp.																									
	Balaustium sp.																									
Smarididae	*Smaris sp.*																									
Trombidiidae	*Allothrombium sp.*																					3			5	
	Thrombidium sp.													1					4							

	Trombiculidae	*Trombiculus larva*																									
CRYPTO-STIG-MATA	(Oppioidea)	*sp 1*																									
	Oppiidae	*Brachioppia sp.*												2						13	1	4		9	1
		Multioppia sp.												3			1	4	4	2	1		2		4
	Oribatulidae	*Zygoribatula sp. 1*			5						11			1		3	1		1						
		Zygoribatula sp. 2			1			8																	
	Scheloribatidae	*Scheloribates sp. 1*	1	1	1		1	1	1		1	3		1	4	3		2	1	9	4	7	1	3	1	4
		Scheloribates sp. 2						1		1	1	1		2	5		1	4	1							
		Scheloribates sp. 3												4			1	1	6						
		Scheloribates sp. 4													6										
	Liodoidea	*cf Liodes*												2											
	Zetomotrichidae	*Floritrichus louisbothai*																							
		Saltatrichus sp. 1												1				3							
		Saltatrichus sp. 2																							
		Zetomotrichus sp.													3			1							
	Scutoverticidae	*Ethiovertex sp.*		2				4			4			13			10			1	30	6	14	24	10
	Tectocepheidae	*Tectocepheus sp.*						1																	
	Otocepheiae	*Pseudotocepheus sp.*												4			7								
	Cepheidae	*cf Sadocepheus sp.*													4				3						
	Ceratozetidae	*Hypozetes sp.*	1		1	1		1	3	1		2	1	1	3				7	3			4			3
	Plateremaeidae	*Pedrocortesella parva*												2											
	Gymnodamaeidae	*cf Jacotella sp.*												4			1			13	1	30	2	14	27
		Gymnodameus sp.												4				6	7						
	Eremulidae	*Austroeremulus sp. 1*												1											
		Austroeremulus sp. 2												7				5							
	Galumnidae	*Galumna sp.*												1						8	1		4	1	4
	Phenopelopidae	*Eupelops sp.*															1		4	1		4	4		8
	Microzetidae	*Microzetes sp.*												1				4							
		(Berlesezetes sp.)																							
	Phthiracaridae	*Atropacarus sp.*												8			1								
	Epilohmanniidae	*Epilohmania sp.*												2	3	4			1		1		3	1	4
	Lohmanniidae	*Cryptacarus sp.*												1			3	4	14	1	4		5	6	6
	(Hypochthonioidea)	*sp 1*												14			10		3						
	Cosmochthoniidae	*Cosmochthonius sp.*												15			31		19	30	1	7	2	19	1
		Brachythonius sp.												31	4		3		61						
	Sphaerochthoniidae	*Sphaerochochthonius sp.*																		4				1	5
	Unidentified	juveniles																1	4						

MESO-STIG-MATA	Laelapidae	*Hypoaspis sp. 1*																										
		sp. 2																										
		Cosmolaelaps sp.																										
		Leptolaelaps sp.	3	1		1		4	4		1	4	17		4														
		Pachylaelaps sp.							6											11		3	11	9	2	6	7		
	Rhodacaridae	*Gamasellus sp.*																										
		Rhodacarus sp.	13		6		6	9	7		11	7	4	3			14												
		Rhodacarellus sp.		1	1		4		6		2	3						1			4								
	Ascidae	*Protogamasellus sp.*	1		2	1			24		4	46	1	3	8		23			9		4		4	7	4	18		
		Proctolaelaps sp.													17			11	7	9									
		Asca sp.							2		4		1				17												
		Lasioseius sp.													3						1			4			1		
	Veigaiaidae	*Veigaia sp.*																										
	Eviphididae	*Eviphus sp.*													7						4								
		Copriphis? sp.																										
	Digamasellidae	*Digamasellus sp.*																										
	Macrochelidae	*Glypthlaspis sp.*																										
		Macrocheles sp.																						2		2			
	Phytoseiidae	*Typhlodromus sp.*													17	11		3	9								11		
	Parastidae	*Pergamasus sp.*										1			1						4	3	11		7		8		
		Parasitus sp.																											
	Uropodidae	*Cilliba? sp.*																			2								
ASTIG-MATA	Acaridae	*Caloglyphus sp.*																3							5				
		Rhizoglyphus echinopus							5																				
		Tyrophagus putrescentidae										3				4								7					
		Hypopi																							4				
		Glycyphagus sp. 1																											
METASTIG-	Ixodidae	juveniles																				1	1			2			
ARANEAE	Lycosidae	*Lycosa sp. 1*																											
		Lycosa sp. 2																											
	Salticidae	Morphospecies 1																											
		Morphospecies 2																											
		Morphospecies 3																											
PSEUDOSCORPIONIDAE																													
SCORPIONIDAE																													

MARCH 200 6			Site 5						Site 6						Site 7					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
PROSTIG-MATA	Nanorchestidae	*Speleorchestes meyeri*	3	1	7	6	4	10	2	4	1	2	4	5						4
		Speleorchestes potchensis							11					16	7	10	1	6	17	10
		Nanorchestes globosus	17	21	5	35	20	66	2	1	4	2	4	6	8	4	2	2	5	7
		Nanorchestes usitatus		2	3				19		2	1		25	2	4	7	5	3	9
		Nanorchestes excertus				2		3							1		4	7		9
	Alicorhagiidae	*Alicorhagia usitata*	6		6	1	4	7	7		1	1		8	2		2	8		10
		Stigmalychus veretrum	2		2	1									2	4		1	5	
	Alycidae	*Alycus acaciae*	4		4	3	1	1	4					6	3	11		9		1
		Bimichaelia sp.													1		2	3	4	
		Petralycus longicornis							6					10						
	Terpnacaridae	*Terpnacarus glebulentus*			2	2	1					4	7							
		Alycosmesis sp.							4					6						
	Oescherchestidae	*Lordalychus sp.*							2			4		16	3			4		1
	Micropsammidae	*Micropsammus sp nova*							11		1			8				2		
	Hybalycidae	*Hybalicus sp.*	6		17	15	19	7	6		2	1	2	4	4	7			2	
	Sphaerolichidae	*Sphaerolichus sp.*			1				4		1			4		3		2	1	
	Iolinidae	*Pronematus ubiquitus*	17	7	16	11	9	21	21	7	9	44	31	30		3		7		9
	Tydeidae	*Coccotydaeolus sp.*	80	5	67	112	56	48	40	10	1	64	11	33	6	66	2		16	
		Coccotydaeus sp.														6		6	12	17
		Tydeus grabouwi			6	7		9	7	1		1		17						
		Tydeus munsteri	1		1	4			1					4		3				2
		Brachytydeus sp.			2			3		2				4						
		Genus indet																		
	Paratydeidae	*Tanytydeus sp.*	4		17	11	9	16	7		3	2	1	8					8	
		Sacotydeus sp.																		
	Rhagidiidae	*Rhagidia sp.*	2		3	4	7	2	9		3	1		7	2	3	3	1	2	4
		Coccorhagia sp.			3		3									3		5	6	
	Eupodidae	*Eupodes parafusifer*	20	11	61	50	33	40	34	4	3	1	4	21	27	19	6	7		3
		sp. 2			6												2			
		Linopodes sp.	3		3	3	4		7					4	5		8		6	2
		Proteroneutes sp.			1		7	4	3					4						
TARSO-NEMINI	Tarsonemidae	*Tarsonemus sp.*	4		12		3	1	19			2		14	16	6		3		1
	Scutacaridae	*Scutacarus sp.*																3	3	
		Imparipes sp.	2		2		1	1	4					6						
	Pygmephoridae	*Bakerdania sp.*			2		4		3					2	11		4	6	4	1

	Siteropsis sp.		12		5	7	1						3						
	Pygmephores sp.																		
Pyemotidae	*Pyemotes sp.*	16		16	7	4	9												
Tarsochelidae	*Hoplocheylus aethiopicus*	2		7	1		1	4					6	4			4		1
Nematalycidae	*Nematalycus sp.*																		
Cunaxidae	*Cunaxa sp. 1*	12	5	11	9	17	6	7		1	1		9		1		3	2	1
	sp. 2				2											2		2	
Bdellidae	*Cyta sp.*	4		1		1		3	2	1	1	1	4	2	1				1
	Biscurus sp.							2					4						
	Bdella sp.	2		1		1		1					1	2					
	Bdellodes hessei							1						2		1		4	
	Spinibdella thori	7		8	3	17	11	16	2	3		1	8	10	3	11	5	6	8
	Hexabdella sp.															2			
Cheyletidae	*Cheyletus sp.*																		
Pseudocheylidae	*Neocheylus sp.*	2		2	4		4	4				1	2		3		3		1
	Anoplocheylus sp.	2		3									2			2			
Linotetranidae	*Linotetranus sp.*		2		17		29	13				2	12		12	1	4		9
Caeculidae	*Microcaeculus sp.*	2			1			2					1	2	2		3		
	Caeculus sp.				3		1	1					3						
Anystidae	*Anystis baccarum*	4		2	3	1	2	4		1	1		4		3		4	2	2
	Chausseria sp.				1	2								2					
Adamystidae	*Adamystis sp.*							4					6		2				
Stigmaeidae	*Agistemus africanus*	2		4		4	7	4					2		2			2	1
	Ledermuelleria sp.																1		
	Storchia robusta		1		4														
	Eustigmaeus sp.			19	3	2		4		1			17						
Tetranychidae	*Tetranychus urticae*											2			2	1		3	1
	Bryobia praetiosa							2					1						
Eriopyidae	(diversi)																		
Erythraeidae	*Abrolophus sp.*			2		2	1					1	2	3		1	1		4
	Leptus sp.	1		4	3		1					1							
	Erythraeus sp.			2				4				2	2				2	2	
	Balaustium sp.												4		2				
Smarididae	*Smaris sp.*				4			2					4				2		1
Trombidiidae	*Allothrombium sp.*				2		1			1			3						
	Thrombidium sp.	3						3					2						
Trombiculidae	*Trombiculus larva*																		

CRYPTO-STIG-MATA	(Oppioidea)	*sp 1*	2		4		4	1			1			2	2		3			
	Oppiidae	*Brachioppia sp.*				3	1		3					3				1		1
		Multioppia sp.	2		1	4	2	1						2		1				
	Oribatulidae	*Zygoribatula sp. 1*	4	1	4	3	2	4	4		1			9	1	4		2		3
		Zygoribatula sp. 2			2		1		3			1	1	4	1		2	1	1	2
	Scheloribatidae	*Scheloribates sp. 1*	4	4	7	2	2	4	2	2	1			4	3		2	1	1	2
		Scheloribates sp. 2			2			3							1	5		2	1	
		Scheloribates sp. 3			1				3					1			2			
		Scheloribates sp. 4	4	2	1	2		1	4					4	2	1	1	1	2	
	Liodoidea	*cf Liodes*																		
	Zetomotrichidae	*Floritrichus louisbothai*	1		2		1		2		1	1	2	4		8		7		3
		Saltatrichus sp. 1	4			2										1		2	3	
		Saltatrichus sp. 2	1			1			3					2	3	1		2	1	1
		Zetomotrichus sp.					3		2					1		1				
	Scutoverticidae	*Ethiovertex sp.*	1		23	2		4	3	2	1		1	5		2	1		2	
	Tectocepheidae	*Tectocepheus sp.*	4		7	6	1		2					4	2		3	1		4
	Otocepheiae	*Pseudotocepheus sp.*			1		2		2		1	3		4	4		3		1	
	Cepheidae	*cf Sadocepheus sp.*													2	1		2		
	Ceratozetidae	*Hypozetes sp.*	2		1		4	1								2			3	2
	Plateremaeidae	*Pedrocortesella parva*		2		1	3		2		2			3						
	Gymnodamaeidae	*cf Jacotella sp.*	20		2	3	13	1	27	3	1	5		30		6		7	1	4
		Gymnodameus sp.							2					3	3		2			1
	Eremulidae	*Austroeremulus sp. 1*							4		1			4	1	1			2	
		Austroeremulus sp. 2			1				1							8		6		2
	Galumnidae	*Galumna sp.*	4		3	3	12	3	11		2			6		1			2	1
	Phenopelopidae	*Eupelops sp.*			2	2	3		4				1	3		1			2	1
	Microzetidae	*Microzetes sp.*	3	1	1	4		1	2			1		3	3		1			2
	Phthiracaridae	*Atropacarus sp.*	1		2	4	1	2							2					2
	Epilohmanniidae	*Epilohmania sp.*	3			17	4	1	14		1	1	1	11	9			8	1	9
	Lohmanniidae	*Cryptacarus sp.*	1		9	3	4	1	3			1		2	4	12	5		6	7
	(Hypochthonioidea)	*sp 1*	14		1	30	3	16	19		1	4		9		3	1	2		1
	Cosmochthoniidae	*Cosmochthonius sp.*	17	2	14	4	8	17	40		6	1	4	24	1		2	7		4
		Brachythonius sp.			3		1	2												
	Sphaerochthoniidae	*Sphaerochochthonius sp.*			4		1		4		1		1	8		4		2		1
	Unidentified	juveniles																		
MESOSTIG-MATA	Laelapidae	*Hypoaspis sp. 1*	3	4		21	4		4		1	1		4	3	4	1	2	1	
		sp. 2	2					1	2										1	

		Cosmolaelaps sp.							4			1		6	9	2	4		1	
		Leptolaelaps sp.	1		7	4		2	8					7	4			1	2	7
		Pachylaelaps sp.							2		2		1	4						
	Rhodacaridae	*Gamasellus sp.*							4					3		3			4	
		Rhodacarus sp.	4	7	12	18	7	6	14					12	11	9	7		2	
		Rhodacarellus sp.		2			3		9					1	5		8			4
	Ascidae	*Protogamasellus sp.*	19	7	31	23	4	16	20			4		17	4	3	6		2	4
		Proctolaelaps sp.			2	3	1		13		1		1	4		2		1		4
		Asca sp.	3		4	2	4	6	10		1			12	4		6		2	4
		Lasioseius sp.			3		4		2		1		1							
	Veigaiaidae	*Veigaia sp.*																		
	Eviphididae	*Eviphus sp.*	2		1	4		1	1		1		1	4		3				
		Copriphis? sp.				2														
	Digamasellidae	*Digamasellus sp.*	1			3	1	4						8		3			6	
	Macrochelidae	*Glypthlaspis sp.*	2		3	3		1												
		Macrocheles sp.	3			3	1		6		2			4						
	Phytoseiidae	*Typhlodromus sp.*			2			1	2					7			4		2	
	Parastidae	*Pergamasus sp.*	4		6	1	2		1					4	2					
		Parasitus sp.																		
	Uropodidae	*Cilliba? sp.*				1	2					1		18	3			4		
ASTIGMATA	Acaridae	*Caloglyphus sp.*		6		4			4		1			7			2		2	
		Rhizoglyphus echinopus																5		
		Tyrophagus putrescentidae	1		3		4	1								7				
		Hypopi							7	1	2			8	16					
		Glycyphagus sp. 1																		
METASTIG-	Ixodidae	juveniles									2									
ARANEAE	Lycosidae	*Lycosa sp. 1*		2	1	1	3		2		1		1	2	1	1		2		2
		Lycosa sp. 2		1		1					2		2	2			1			
	Salticidae	Morphospecies 1		2		1						1	2	1						
		Morphospecies 2																		
		Morphospecies 3				1														
PSEUDOSCORPIONIDAE			4		6	7	4	4	5	1	2	1	1	6	5	6	2	1	9	5
SCORPIONIDAE																				

MARCH 2006			Site 1						Site 2						Site 3						Site 4					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
COLLEMBOLA	Poduridae	sp. 1																								
		sp. 2								2		3														
	Isotomidae								1		3	4	15	11	12		9									
	Entomobryidae	sp. 1													11		19		17	11	18	7	21	3	7	17
		sp. 2							1		4	5	1	7			11									
		sp. 3													2		9		4	21						
	Tomoceridae	sp. 1																								
		sp. 2																								
	Sminthuridae	sp. 1		2	31	67	3	34	10		7	2			19	3		4	16	27	10	3	4	7		17
		sp. 2			3																				2	
	Neelidae	sp. 1																								
		sp. 2																								
COLEOPTERA	Staphylinidae			3		1		1																		
	Elateridae				1			2	1			2	1		1			3		4			2			1
HYMENOPTERA	Formicidae	*Anaplolepis sp.*													2										1	
		Plagiolepis sp.										1												2		1
		Pheidole sp.										1											1			
		Tetramonium sp.																			1					
		Monomonium sp.																								
		Technomyrmex sp																								
		Cerapachys sp.																								
	Vespidae	sp.1																								
		sp.2																								
PSOCOPTERA	Psocidae	sp.							3	4		4		1							7	6	8	1	1	4
ISOPTERA	Hodotermitidae	sp.															5									
	Termitidae	sp.																			1					
THYSANOPTERA	Thripidae								4	3		4	11	4	7		7		1	9	8	4	4	7	6	11
	Aelothripidae																									
HEMIPTERA	Nymphs		1			2		4			2				13	7		14	1	4		1	1	2	1	2
DIPTERA	Muscidae														1			3								
	Cecidomyiidae																									
	Diverse larvae														1				4							
LEPIDOPTERA	Geometridae	larvae																								
PROTURA															2					1		1			2	
DIPLURA															1				2		2		1		3	1

CHILOPODA	Scolopendromorpha																										
	Lithobiomorpha																						4			1	
	Geophilomorpha														2	4			4	1	2	4	1	6	1	4
SYMPHYLA																											
PAUROPODA																											
DIPLOPODA		*Polixenus sp.*													1												
CRUSTACEA	Isopoda																										
NEMATODA		Criconema													4		3			7		2			2		
		Xiphinema								4																	
		Longidoridae																									
ANNELIDA		Oligochaeta													2				2	1	1						

MARCH 2006			Site 5						Site 6						Site 7					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
COLLEMBOLA	Poduridae	sp. 1	7		6	5	1	4	90	4	7	8	15	13	3	18	14	20	1	11
		sp. 2				2			4	1			10	9						
	Isotomidae								19	7	4	40	14	17	40	13	21	29	7	12
	Entomobryidae	sp. 1	97	3	40	80	116	37	20	24	14	37	16	44	2	3	1	2	6	4
		sp. 2				3		2		2	4								2	
		sp. 3																		
	Tomoceridae	sp. 1				1														
		sp. 2																		
	Sminthuridae	sp. 1	20	2		1			1					2	10	12		33	4	2
		sp. 2																		
	Neelidae	sp. 1							1					2				1	1	2
		sp. 2														2	2			
COLEOPTERA	Staphylinidae				4			1						2	2			1		2
	Elateridae																			
HYMENOPTERA	Formicidae	*Anaplolepis sp.*			4		4	1	6											
		Plagiolepis sp.	2		2				8					113						
		Pheidole sp.																		
		Tetramonium sp.																		
		Monomonium sp.						7												
		Technomyrmex sp																		
		Cerapachys sp.																		
	Vespidae	sp.1							1					1						
		sp.2																		
PSOCOPTERA	Psocidae	sp.	7	3	9	10	1	3	7		1	1		8	7	5	1	6	5	4
ISOPTERA	Hodotermitidae	sp.														3			2	
	Termitidae	sp.					4				2				3					
THYSANOPTERA	Thripidae			7	4	1	6		8	10	9	14	2	7	7	2	1	3	2	4
	Aelothripidae								2											
HEMIPTERA	Nymphs								3		3		1	2			1		2	
DIPTERA	Muscidae		3			1										3		1		2
	Cecidomyiidae			2		2		1												
	Diverse larvae																		2	
LEPIDOPTERA	Geometridae	larvae		3		4	1		4			1		1						
PROTURA																3	2		2	1
DIPLURA			2		3		1		2		1	2				1		2	2	1

CHILOPODA	Scolopendromorpha				1															
	Lithobiomorpha																			
	Geophilomorpha			1	6		4	1				2		1	4	7	14	3	4	2
SYMPHYLA			6	6	17	11	10	27	12	11	6	7	5	12	10	12	9	8	9	14
PAUROPODA																				
DIPLOPODA		*Polixenus sp.*																		
CRUSTACEA	Isopoda						2								1					
NEMATODA		Criconema	2			1			1					1						
		Xiphinema																		
		Longidoridae			3		1		2											
ANNELIDA		Oligochaeta																		

MAY 2006			Site 1						Site 2						Site 3						Site 4					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
PROSTIG-MATA	Nanorchestidae	*Speleorchestes meyeri*	17	27	4	9	35	11	45	18	13	17	12	26	7		41	35	55	40	7	9	11	14		3
		Speleorchestes potchensis																								
		Nanorchestes globosus													5				4							
		Nanorchestes usitatus																			17	4	1	27	3	9
		Nanorchestes excertus																								
	Alicorhagiidae	*Alicorhagia usitata*																								
		Stigmalychus veretrum																								
	Alycidae	*Alycus acaciae*														1			4	3	3		2	1		14
		Bimichaelia sp.																								
		Petralycus longicornis																								
	Terpnacaridae	*Terpnacarus glebulentus*																								
		Alycosmesis sp.																								
	Oescherchestidae	*Lordalychus sp.*														3					3	1	4	1	6	7
	Micropsammidae	*Micropsammus sp nova*																								
	Hybalycidae	*Hybalicus sp.*																								
	Sphaerolichidae	*Sphaerolichus sp.*																								
	Iolinidae	*Pronematus ubiquitus*							39	3		51	10	2	1			4								
	Tydeidae	*Coccotydaeolus sp.*	60		8	54	53	46	41	49	13	60	71	87	80		77	31	15	79	16	9	34	9		30
		Coccotydaeus sp.				21										18										
		Tydeus grabouwi										7				29	40	15	10	16						
		Tydeus munsteri							4		1			3	1	45	5	10	1	8						
		Brachytydeus sp.																								
		Genus indet													4		2	1								
	Paratydeidae	*Tanytydeus sp.*													14		11		6	19	21	1	5	9	2	8
		Sacotydeus sp.																								
	Rhagidiidae	*Rhagidia sp.*													2		3		1	1	3			1	1	5
		Coccorhagia sp.																	4	21		3	4			
	Eupodidae	*Eupodes parafusifer*													30	4	5	5	70	15	9	1	111		30	41
		sp. 2														7			6			1	1	2		
		Linopodes sp.																				3			4	1
		Proteroneutes sp.													1			3	4							
TARSO-NEMINI	Tarsonemidae	*Tarsonemus sp.*													4				17	5	6		11		9	
	Scutacaridae	*Scutacarus sp.*																								
		Imparipes sp.													3											
	Pygmephoridae	*Bakerdania sp.*	3		4		7	1	8				9	9												

		Siteropsis sp.													87											
		Pygmephores sp.												3			4		111							
	Pyemotidae	*Pyemotes sp.*												3				5	3							
	Tarsochelidae	*Hoplocheylus aethiopicus*															3			2			3			
	Nematalycidae	*Nematalycus sp.*	14				3	11																		
	Cunaxidae	*Cunaxa sp. 1*												7		13	41	18	9	8		7		11	1	
		sp. 2													2											
	Bdellidae	*Cyta sp.*												1		3		4	1		2	1	4			
		Biscurus sp.																								
		Bdella sp.																								
		Bdellodes hessei																								
		Spinibdella thori												10			7		9	6		4	4	1	2	
		Hexabdella sp.																								
	Cheyletidae	*Cheyletus sp.*												17		1	4	11								
	Pseudocheylidae	*Neocheylus sp.*													2											
		Anoplocheylus sp.									7	7						7	1		7					3
	Linotetranidae	*Linotetranus sp.*												7			7		5	11	4	1	1	3		
	Caeculidae	*Microcaeculus sp.*												2				1					3			
		Caeculus sp.																		1	1					
	Anystidae	*Anystis baccarum*												1			3		4	2	4		1	1	1	
		Chausseria sp.												1				1								
	Adamystidae	*Adamystis sp.*																								
	Stigmaeidae	*Agistemus africanus*												1				3								
		Ledermuelleria sp.																		3		3				
		Storchia robusta						4	1			2	1													
		Eustigmaeus sp.												16				11		4			17		30	
	Tetranychidae	*Tetranychus urticae*	1		1		2	4												3		4		1		
		Bryobia praetiosa																			4		4			
	Eriopyidae	(diversi)															4		1							
	Erythraeidae	*Abrolophus sp.*																			4		1	6	1	
		Leptus sp.												1		3		2								
		Erythraeus sp.																								
		Balaustium sp.																								
	Smarididae	*Smaris sp.*																		3		7	1	4	1	
	Trombidiidae	*Allothrombium sp.*																								
		Thrombidium sp.												1					3		2					
	Trombiculidae	*Trombiculus larva*													8											

CRYPTO-STIG-MATA	(Oppioidea)	*sp 1*																								
	Oppiidae	*Brachioppia sp.*												3			4		1							
		Multioppia sp.													2	4										
	Oribatulidae	*Zygoribatula sp. 1*												13			3		17	5	3			4	7	
		Zygoribatula sp. 2													1			4								
	Scheloribatidae	*Scheloribates sp. 1*	1	1		1			1		1	1	1	1	1	2	4	1	3	14	9			11	1	17	
		Scheloribates sp. 2			1	1		1	1	1	1			1			2	4		11						
		Scheloribates sp. 3												7			1	1		4						
		Scheloribates sp. 4												1					1		1		5			
	Liodoidea	*cf Liodes*																								
	Zetomotrichidae	*Floritrichus louisbothai*												2			4									
		Saltatrichus sp. 1																								
		Saltatrichus sp. 2																								
		Zetomotrichus sp.												4				3								
	Scutoverticidae	*Ethiovertex sp.*													6	21		40		21	6	3	17	18	11	
	Tectocepheidae	*Tectocepheus sp.*												4				16								
	Otocepheiae	*Pseudotocepheus sp.*												7			3									
	Cepheidae	*cf Sadocepheus sp.*																2								
	Ceratozetidae	*Hypozetes sp.*	12	3	9	13	3	10	1	1	1			1		3		4		6	2	1			1	4
	Plateremaeidae	*Pedrocortesella parva*														1		3								
	Gymnodamaeidae	*cf Jacotella sp.*																		17	29	11	2	10	3	
		Gymnodameus sp.												10			12		11							
	Eremulidae	*Austroeremulus sp. 1*													3											
		Austroeremulus sp. 2												4			6		9							
	Galumnidae	*Galumna sp.*																		7	6	6	1		5	
	Phenopelopidae	*Eupelops sp.*												6												
	Microzetidae	*Microzetes sp.*																1								
	Phthiracaridae	*Atropacarus sp.*												4		7		14								
	Epilohmanniidae	*Epilohmania sp.*												10		7		15	1	4	1	4		7	1	
	Lohmanniidae	*Cryptacarus sp.*												3		3		5	1	7	7	2	4	2	4	
	(Hypochthonioidea)	*sp 1*																								
	Cosmochthoniidae	*Cosmochthonius sp.*												1		4		63	14	6	7	17	4	24	7	
		Brachythonius sp.												70				17								
	Sphaerochthoniidae	*Sphaerochochthonius sp.*																								
	Unidentified	juveniles												2		2										
MESOSTIG-MATA	Laelapidae	*Hypoaspis sp. 1*																								
		sp. 2																								

		Cosmolaelaps sp.													3		2			13							
		Leptolaelaps sp.	4		1	4		6	17	3		15	15	27													
		Pachylaelaps sp.										6			7		17	11	9	1	7	7	11		14	9
	Rhodacaridae	*Gamasellus sp.*													13											
		Rhodacarus sp.	38	2	11		7	1	5		2	7	6	1	17		21	13	6	11						
		Rhodacarellus sp.					4	6							3					8						
	Ascidae	*Protogamasellus sp.*		4		4		6	14	11	4	1	8	1	41	11		13		3	30	17	9	16	4	21
		Proctolaelaps sp.														7										
		Asca sp.							2		1	1									14		5	5	1	6
		Lasioseius sp.															4				1		3	7	6	
	Veigaiaidae	*Veigaia sp.*																								
	Eviphididae	*Eviphus sp.*																	3				4			
		Copriphis? sp.																			2					
	Digamasellidae	*Digamasellus sp.*													1					2	7			8		9
	Macrochelidae	*Glypthlaspis sp.*																								
		Macrocheles sp.														5			4	4	4		1		1	
	Phytoseiidae	*Typhlodromus sp.*													1		4	13	17		14		1	1	5	6
	Parastidae	*Pergamasus sp.*																								
		Parasitus sp.																								
	Uropodidae	*Cilliba? sp.*																	3		2					3
ASTIGMATA	Acaridae	*Caloglyphus sp.*													14						5					
		Rhizoglyphus echinopus																								
		Tyrophagus putrescentidae													11			27								
		Hypopi															13						9			
		Glycyphagus sp. 1																								
METASTIG-	Ixodidae	juveniles													1							2				
ARANEAE	Lycosidae	*Lycosa sp. 1*													1										2	
		Lycosa sp. 2																							3	
	Salticidae	Morphospecies 1																								
		Morphospecies 2																								
		Morphospecies 3																								
PSEUDOSCORPIONIDAE																										
SCORPIONIDAE																										

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			Site 5						Site 6						Site 7					
			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
PROSTIG-MATA	Nanorchestidae	*Speleorchestes meyeri*	33	17	10	3		11	7	9		14	3	4						
		Speleorchestes potchensis		2					2	7		2	2	4	7	6	33	4		2
		Nanorchestes globosus	47	10	21	16	12	18				2		4						
		Nanorchestes usitatus							22	14	4	17	9	13	22	4	10	11	2	
		Nanorchestes excertus	1	3		4	7		4				2		3			7	6	5
	Alicorhagiidae	*Alicorhagia usitata*	2		16		8		4	10	11	2	1	2	17	6	3		1	4
		Stigmalychus veretrum	3	17	11	8		3							3	2		3	2	
	Alycidae	*Alycus acaciae*	4	7	6	7	11	6	10	3	4	3	7	9	4	7	1	12	13	6
		Bimichaelia sp.		1		2									4		7	8		2
		Petralycus longicornis							8		14	16		7	2		3		4	
	Terpnacaridae	*Terpnacarus glebulentus*	4	7		6	3	1	18		17	6	21	9						
		Alycosmesis sp.							7	9	16	1	7	10						
	Oescherchestidae	*Lordalychus sp.*							3	7	13		4	7	2		6	3		1
	Micropsammidae	*Micropsammus sp nova*							60	16		7		10	7	1		4	4	3
	Hybalycidae	*Hybalicus sp.*	7		16	21	3		7	6	1	2	4	9	8		1		2	
	Sphaerolichidae	*Sphaerolichus sp.*	3		3				7	2	3	4	6	8	4	1	4		2	
	Iolinidae	*Pronematus ubiquitus*	17	5	12	3	4	16	14	102	70	39	13	15	20	7	10	114	14	10
	Tydeidae	*Coccotydaeolus sp.*	119	70	30	16	89	71	117	70	16	6	30	10	17		18	1	4	16
		Coccotydaeus sp.														4	9	4		7
		Tydeus grabouwi		5		7	9		12	1	6	6	6	4	9		6		5	
		Tydeus munsteri	3	5	7	18	6	1				4			4					
		Brachytydeus sp.		3		4					4	1	4						6	
		Genus indet																		
	Paratydeidae	*Tanytydeus sp.*	2		19	11	6	1	1		6	5	5	4	1		4	2		
		Sacotydeus sp.																		
	Rhagidiidae	*Rhagidia sp.*	13	4	7	18	23		8	3	1	1	4	1	7	2	1	1	4	2
		Coccorhagia sp.							3		2		1		2		9		8	
	Eupodidae	*Eupodes parafusifer*	84	67	19	28	70	16	19	90	4	14	23	27	21	3	6		25	17
		sp. 2		6		6		1	2	1		2			4		1	3		
		Linopodes sp.	16	10	11	1	2	14	4	1	1		4	5	4	1	1	4	2	
		Proteroneutes sp.	1	2	1	2				2	2		3	1				1	3	7
TARSO-NEMINI	Tarsonemidae	*Tarsonemus sp.*	17		15	3		1	11	4	2	17	16	9	14				16	
	Scutacaridae	*Scutacarus sp.*														6		2		
		Imparipes sp.	3		4		1				4									4
	Pygmephoridae	*Bakerdania sp.*	23	1	14	7		1	3			4		14	10	9	7	6	4	4

	Siteropsis sp.	11	9			7						3	4								6
	Pygmephores sp.							3	1	5		1				2			5		1
Pyemotidae	*Pyemotes sp.*	4		7			9	2				3							3		1
Tarsochelidae	*Hoplocheylus aethiopicus*		4	6	7	1	2		4		7	1		2		1					
Nematalycidae	*Nematalycus sp.*																				
Cunaxidae	*Cunaxa sp. 1*	9	7	18	9	4	1	7	8	5	3	6	1	4	7	8	1	4	4		
	sp. 2		1							4								2			
Bdellidae	*Cyta sp.*				2			2		3	4	1	1			2					
	Biscurus sp.		2								2	2		4		3				3	
	Bdella sp.								1		1	4		2							
	Bdellodes hessei														4		1			1	
	Spinibdella thori	17	1	13	16	1	9	8	14	11	9	7	16	11	13		7	2		9	
	Hexabdella sp.													3							
Cheyletidae	*Cheyletus sp.*																				
Pseudocheylidae	*Neocheylus sp.*	3		7		1		3		4	2		2	4		2		4			
	Anoplocheylus sp.			3	1		4			2				1	2			2	1		
Linotetranidae	*Linotetranus sp.*	16		7		3			15					27		16		5	1		
Caeculidae	*Microcaeculus sp.*				3					4				1	2		1	2			
	Caeculus sp.		4	1		2	1				2	2				2					
Anystidae	*Anystis baccarum*	2	3			4		3	7		2	1		4		1	2		1		
	Chausseria sp.		1				3	2				2			2			2			
Adamystidae	*Adamystis sp.*	2				6			1		5	4					2		1		
Stigmaeidae	*Agistemus africanus*	4	4	2	1	3	1	4				4		4		1	6	1	9		
	Ledermuelleria sp.			2		1		4	6	1		4	2		2		2	1	1		
	Storchia robusta	2													4		2	4			
	Eustigmaeus sp.		12		3	25		16	2	10	11	4	9	10	17		7		9		
Tetranychidae	*Tetranychus urticae*		9	1	4	7											8	4	2		
	Bryobia praetiosa																				
Eriopyidae	(diversi)																				
Erythraeidae	*Abrolophus sp.*	2		1	4	7	4	2						2	2		3	1	1		
	Leptus sp.		3		4				2		1						2	1			
	Erythraeus sp.										2	1	4	2		1		4	1		
	Balaustium sp.								4						1						
Smarididae	*Smaris sp.*				1		2	1		2					2		1		2		
Trombidiidae	*Allothrombium sp.*	3		1		4		1	2		1	1		1		2					
	Thrombidium sp.		1			1	2					2	1					2			
Trombiculidae	*Trombiculus larva*																				

CRYPTO-STIG-MATA	(Oppioidea)	*sp 1*	2		4	1	1	2	2	1		2		2	1		2	1	1	
	Oppiidae	*Brachioppia sp.*	3									3	1		2				1	2
		Multioppia sp.	1	2		4	1		2	1	2									
	Oribatulidae	*Zygoribatula sp. 1*	4	7		8	1	2	4	5	1	4	1	4	4		2	3		2
		Zygoribatula sp. 2		1	2				1	2		1	1		3	1	2		2	1
	Scheloribatidae	*Scheloribates sp. 1*	2	7	4	5	1	7	4	15	9	7	11	9	3	9		2	6	1
		Scheloribates sp. 2		3		3				2		3			3	4	1	2		1
		Scheloribates sp. 3	4				7	1	1	2	1	4	1							
		Scheloribates sp. 4	3		4				4	3	1	1	4	3	2	4	3	2		1
	Liodoidea	*cf Liodes*																		
	Zetomotrichidae	*Floritrichus louisbothai*	2	2	3	1	3	1	2	1		1		2	2	4		7		1
		Saltatrichus sp. 1		2	7		1		2	1										
		Saltatrichus sp. 2		1										2	1		2		2	2
		Zetomotrichus sp.	2			1			1	2			2	1	4		2	1		
	Scutoverticidae	*Ethiovertex sp.*	21	16	4	1	7	4	3	1	4	2	1	2	2		3	1		4
	Tectocepheidae	*Tectocepheus sp.*	3		4	7			3		4	1	4	1	2		2	3		
	Otocepheiae	*Pseudotocepheus sp.*	3				1	4	2	1	1	2	4	3	2		1		1	
	Cepheidae	*cf Sadocepheus sp.*		3					2					2		1		2		1
	Ceratozetidae	*Hypozetes sp.*	2		4		1		1	3		2	1	2	3	4		1	2	3
	Plateremaeidae	*Pedrocortesella parva*	1	2		1		4		1				4		2				1
	Gymnodamaeidae	*cf Jacotella sp.*	3	4	1		13	1	15	4	11	1	4	5	4	2		17		6
		Gymnodameus sp.							2							2	2		2	
	Eremulidae	*Austroeremulus sp. 1*			2		4		4		1		1	3	2			3		
		Austroeremulus sp. 2					4				3				5		4		1	
	Galumnidae	*Galumna sp.*				3		1	2		1	1		3	4			4		3
	Phenopelopidae	*Eupelops sp.*	2	1	2	3	1	4	6		2		1	4	2	1	3			1
	Microzetidae	*Microzetes sp.*	7	1	4	1	2		2	1		2		4		2		1		2
	Phthiracaridae	*Atropacarus sp.*	2		4		3	4		2			1	2	1		2	1	1	
	Epilohmanniidae	*Epilohmania sp.*	16	10		11	7	3	12	16	3	4	11	15	21		7		6	4
	Lohmanniidae	*Cryptacarus sp.*		17		22				2		3	2	4	7	11	1	4	2	9
	(Hypochthonioidea)	*sp 1*	21	16	10	1	30	12	40	14	27	16	30	18	4	2		1	1	4
	Cosmochthoniidae	*Cosmochthonius sp.*	4		14	4	10	1	21	13			14	17	16		22	3		7
		Brachythonius sp.																		
	Sphaerochthoniidae	*Sphaerochochthonius sp.*	4		1	4	10	1		4		5	1	4	4		4	2		4
	Unidentified	juveniles																		
MESOSTIG-MATA	Laelapidae	*Hypoaspis sp. 1*	4	1	7		3		3		5	1		4	7		3	2	4	2
		sp. 2			2		4		3						2	2				

		Cosmolaelaps sp.		1			1		4		7	1	4	1	2		3		6	1
		Leptolaelaps sp.			2				7	3		2			7		1			3
		Pachylaelaps sp.	2		4		1	1		2		4		4	3				9	
	Rhodacaridae	*Gamasellus sp.*							7	8		1	4	1	4			3		
		Rhodacarus sp.	17	4	11	8	13	3	6	4		4	10	13	12		3		9	4
		Rhodacarellus sp.	1		2			1	7	1		2	1		9		4	6	1	
	Ascidae	*Protogamasellus sp.*	21	31	19	6	33	4	25	19	10	7	17	13	2		3		4	
		Proctolaelaps sp.	4		1		6		4		3	5	1		3			4		6
		Asca sp.	1		1		8	2	1	7	4	12		2	3	4		1	2	
		Lasioseius sp.	1		2							2								
	Veigaiaidae	*Veigaia sp.*																		
	Eviphididae	*Eviphus sp.*	1		4		2		4					3		2		1		
		Copriphis? sp.		3					1										3	
	Digamasellidae	*Digamasellus sp.*	1		4	2	4	1	5		4		1	7	8		4	7		1
	Macrochelidae	*Glypthlaspis sp.*	1		4		7		2						3		4			
		Macrocheles sp.	3	4		1	2	4	6	4	4	2	1	7			4		1	
	Phytoseiidae	*Typhlodromus sp.*	3	2	4	1	7	1		1			2	5		2			3	
	Parastidae	*Pergamasus sp.*	4	1	3	1	1	1	4											
		Parasitus sp.																		
	Uropodidae	*Cilliba? sp.*		2		1			2		12					2				
ASTIGMATA	Acaridae	*Caloglyphus sp.*		8			16	1	4			1		7	4			2		
		Rhizoglyphus echinopus		4			1		2			1		4		4		9		
		Tyrophagus putrescentidae	1	4	3		1	1							3				6	
		Hypopi																		
		Glycyphagus sp. 1																		
METASTIG-	Ixodidae	juveniles				2	1		2			1			2					
ARANEAE	Lycosidae	*Lycosa sp. 1*	3		1	4	2	1	4	1	2	2	2	3	1		2		1	
		Lycosa sp. 2		1	1					2	1		1	2						1
	Salticidae	Morphospecies 1	2	1			4		2			1	1	1						1
		Morphospecies 2					1													
		Morphospecies 3																		
PSEUDOSCORPIONIDAE			7	7	4	3	3	13	4	11	4	5	1	7	6	6	4	9	9	2
SCORPIONIDAE							1													

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			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
COLLEMBOLA	Poduridae	sp. 1													70	4	14	1		3						
		sp. 2																								
	Isotomidae								11	8	1	4		17	7	1	14	3	70	1						
	Entomobryidae	sp. 1													13		44	30	3	13	8	3	44	6	10	12
		sp. 2							4	6	1		1	12							3		1	1	4	
		sp. 3														1										
	Tomoceridae	sp. 1													4			7								
		sp. 2																	3							
	Sminthuridae	sp. 1	80	11	9	4	1	1		4	4	13	7	17	13		17	11	22	9	14		1	19	7	27
		sp. 2			1		2								4											
	Neelidae	sp. 1																								
		sp. 2																								
COLEOPTERA	Staphylinidae			1		4	1	1										2								
	Elateridae				1		1				2			1	6		1		1	3	2		2		3	4
HYMENOPTERA	Formicidae	*Anaplolepis sp.*																						4	1	
		Plagiolepis sp.																					3			
		Pheidole sp.																								
		Tetramonium sp.																								
		Monomonium sp.																						5		
		Technomyrmex sp																								
		Cerapachys sp.																								
	Vespidae	sp.1														1				2						
		sp.2																								
PSOCOPTERA	Psocidae	sp.							6	1		2	1	4							8	8	2	4	5	1
ISOPTERA	Hodotermitidae	sp.													1											
	Termitidae	sp.																								
THYSANOPTERA	Thripidae								3	7		7	10	6	5		1	13	1	31	14	2	7	1	7	6
	Aelothripidae																									
HEMIPTERA	Nymphs			1		4		1		1	1			2	7		6	10		15	7		8	4	3	1
DIPTERA	Muscidae																3									
	Cecidomyiidae														1				4							
	Diverse larvae																									
LEPIDOPTERA	Geometridae	larvae																								
PROTURA																1			2	4			4		1	4
DIPLURA															3	1		1		2	4		1	2	1	2

CHILOPODA	Scolopendromorpha																										
	Lithobiomorpha																										
	Geophilomorpha														4	1		3		3	7	2	1	4	5	4
SYMPHYLA																											
PAUROPODA																											
DIPLOPODA		*Polixenus sp.*																									
CRUSTACEA	Isopoda														3	4		4		1							
NEMATODA		Criconema														4						1		4		1
		Xiphinema						2			1		1														
		Longidoridae																									
ANNELIDA		Oligochaeta													3			4		1							

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			A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
COLLEMBOLA	Poduridae	sp. 1							17	14	6	9	14	10	13	9	21	9	16	11
		sp. 2																		
	Isotomidae								6	10	9	30	33	20	12	17	12	14	33	12
	Entomobryidae	sp. 1	107	69	15	16	112	41	17	22	9	41	24	14	2			4	7	5
		sp. 2		3			4		3						3		4			
		sp. 3																		
	Tomoceridae	sp. 1				1	3		2			2		4	7	9	6		2	
		sp. 2			2	4				1	2				3		4			
	Sminthuridae	sp. 1	20	7	9		17	6	27	14	10	30	9	2	16	6	21	29	20	3
		sp. 2								2			2		4					
	Neelidae	sp. 1							1		2				2		2	2		
		sp. 2										2	1							
COLEOPTERA	Staphylinidae		1		2		1	4	2		1	1		3		1		4		1
	Elateridae		1	2					1	2		1	1	2	3		1	2	1	
HYMENOPTERA	Formicidae	*Anaplolepis sp.*		7			11													
		Plagiolepis sp.					4													
		Pheidole sp.								3										
		Tetramonium sp.																		
		Monomonium sp.																		
		Technomyrmex sp																		
		Cerapachys sp.											32							
	Vespidae	sp.1							2		2	1								
		sp.2																		
PSOCOPTERA	Psocidae	sp.	3	4			7	2	7	8	4	1	4	5	7	3	4	4	2	5
ISOPTERA	Hodotermitidae	sp.							3							2				
	Termitidae	sp.						2			2		1							
THYSANOPTERA	Thripidae		2	1	4	1	17	2	3	8	8	13	6	9	17	4	2	1	4	6
	Aelothripidae								4			2								
HEMIPTERA	Nymphs									1	2		2		2			3		1
DIPTERA	Muscidae						3									2		1		
	Cecidomyiidae		4																	
	Diverse larvae														2		2			1
LEPIDOPTERA	Geometridae	larvae	1		2		3		2		1		2							
PROTURA							2		2	1	4			4	2	4	3	2	1	2
DIPLURA							2		3		1		4	1	4		3	2		2

CHILOPODA	Scolopendromorpha						2	1					1			1				
	Lithobiomorpha																			
	Geophilomorpha				3		1	1	2	3	2	1	1	2	14	8	9	10	9	4
SYMPHYLA			7	13	11		13	9	4	6	6	7	8	9	12	21	17	9	7	16
PAUROPODA					2										2					1
DIPLOPODA		*Polixenus sp.*																		
CRUSTACEA	Isopoda					2														
NEMATODA		Criconema					2		2		4		2			2			2	
		Xiphinema					1	1		2		2		1				1	2	1
		Longidoridae		2			2		2	1		1			2					
ANNELIDA		Oligochaeta	1				2						1						1	

Appendix 2:

Complete list of species within each functional group along with abbreviations used for each species in some of the graphs.

			Sp name	Abbrev.
MP	PROSTIGMATA	Alicorhagiidae	*Alicorhagia usitata*	*Ali_usi*
			Stigmalychus veretrum	*Sti_ver*
		Alycidae	*Alycus acaciae*	*Aly_aca*
			Bimichaelia sp.	*Bim_sp*
			Petralycus longicornis	*Pet_lon*
		Terpnacaridae	*Terpnacarus glebulentus*	*Ter_gle*
			Alycosmesis sp.	*Aly_sp*
		Oescherchestidae	*Lordalychus sp.*	*Lor_sp*
		Micropsammidae	*Micropsammus sp nova*	*Mic_sp*
		Hybalycidae	*Hybalicus sp.*	*Hyb_sp*
		Sphaerolichidae	*Sphaerolichus sp.*	*Sph_sp*
		Eupodidae	*Linopodes sp.*	*Lin_sp*
		Tarsonemidae	*Tarsonemus sp.*	*Tar_sp*
		Scutacaridae	*Scutacarus sp.*	*Scu_sp*
			Imparipes sp.	*Imp_sp*
		Pygmephoridae	*Bakerdania sp.*	*Bak_sp*
			Siteropsis sp.	*Sit_sp*
			Pygmephorus sp.	*Pyg_sp*
	CRYPTO-STIG-MATA	(Oppioidea)	*Genus indet sp 1*	Oppioide
		Oppiidae	*Brachioppia sp.*	*Bra_sp*
			Multioppia sp.	*Mul_sp*
		Oribatulidae	*Zygoribatula sp. 1*	*Zyg_sp1*
			Zygoribatula sp. 2	*Zyg_sp2*
		Scheloribatidae	*Scheloribates sp. 1*	*Sch_sp1*
			Scheloribates sp. 2	*Sch_sp2*
			Scheloribates sp. 3	*Sch_sp3*
			Scheloribates sp. 4	*Sch_sp4*
		Liodoidea	*Liodes? sp*	*Liod_sp*
		Zetomotrichidae	*Floritrichus louisbothai*	*Flo_lou*
			Saltatrichus sp. 1	*Sal_sp1*
			Saltatrichus sp. 2	*Sal_sp2*
			Zetomotrichus sp.	*Zet_sp*
		Scutoverticidae	*Ethiovertex sp.*	*Ethi_sp*
		Tectocepheidae	*Tectocepheus sp.*	*Tec_sp*
		Otocepheiae	*Pseudotocepheus sp.*	*Pse_sp*
		Cepheidae	*Sadocepheus? sp.*	*Sado_sp*
		Ceratozetidae	*Hypozetes sp.*	*Hyp_sp*
		Plateremaeidae	*Pedrocortisella parva*	*Ped_par*
		Gymnodamaeidae	*Jacotella? sp.*	*Jaco_sp*
			Gymnodameus sp.	*Gym_sp*
		Eremulidae	*Austroeremulus sp. 1*	*Aus_sp1*
			Austroeremulus sp. 2	*Aus_sp2*
		Galumnidae	*Galumna sp.*	*Gal_sp*
		Phenopelopidae	*Eupelops sp.*	*Eupe_sp*
		Microzetidae	*Microzetes sp.*	*Micz_sp*
		Phthiracaridae	*Atropacarus sp.*	*Atrp_sp*
		Epilohmanniidae	*Epilohmania sp.*	*Epi_sp*
		Lohmanniidae	*Cryptacarus sp.*	*Cryp_sp*
		(Hypochthonioidea)	*Genus indet sp. 1*	*Hypochth*
		Cosmochthoniidae	*Cosmochthonius sp.*	*Cost_sp*

			Brachythonius sp.	*Brac_sp*
		Sphaerochthoniidae	*Sphaerochochthonius sp.*	*Spha_sp*
		Unidentified	juveniles	Juvn
	MESOSTIGMATA	Uropodidae	*Cilliba sp.*	Cil_sp
	COLLEM-	Poduridae	*sp. 1*	Pod_sp1
	BOLA		*sp. 2*	Pod_sp2
		Isotomidae	*sp. 1*	Isotom
		Entomobryidae	*sp. 1*	Ento_sp1
			sp. 2	Ento_sp2
			sp. 3	Ento_sp3
		Tomoceridae	*sp. 1*	Tomo_sp1
			sp. 2	Tomo_sp2
		Sminthuridae	*sp. 1*	Smin_sp1
			sp. 2	Smin_sp2
		Neelidae	*sp. 1*	Neel_sp1
			sp. 2	Neel_sp2
	PSOCOPTERA	Psocidae	*sp.*	Psoc_sp
	PAUROPODA			PAURO
MBM	PROSTIG-	Nanorchestidae	*Speleorchestes meyeri*	*Spe_mey*
	MATA		*Speleorchestes potchefstroomensis*	*Spe_pot*
			Nanorchestes globosus	*Nan_glo*
			Nanorchestes usualis	*Nan_usi*
			Nanorchestes exsertus	*Nan_exc*
		Tydeidae	*Coccotydaeolus sp.*	*Cocc_sp*
			Coccotydaeus sp.	*Coc_sp*
		Eupodidae	*Eupodes parafusifer*	*Eup_par*
			Eupodes sp. 2	*Eup_sp2*
			Proteroneutes sp.	*Prot_sp*
		Nematalycidae	*Nematalycus sp.*	*Nem_sp*
Pred	PROSTIG-	Iolinidae	*Pronematus ubiquitus*	*Pro_ubi*
	MATA	Tydeidae	*Tydeus grabouwi*	*Tyd_gra*
			Tydeus munsteri	*Tyd_mun*
			Brachytydeus sp.	*Brat_sp*
			Genus indet sp.	*Gen_ind*
			Tanytydeus sp.	*Tan_sp*
			Sacotydeus sp.	*Sac_sp*
		Rhagidiidae	*Rhagidia sp.*	*Rha_sp*
			Coccorhagia sp.	*Cgia_sp*
		Pyemotidae	*Pyemotes sp.*	*Pye_sp*
		Tarsochelidae	*Hoplocheylus aethiopicus*	*Hop_aet*
		Cunaxidae	*Cunaxa sp. 1*	*Cun_sp1*
			Cunaxa sp. 2	*Cun_sp2*
		Bdellidae	*Cyta sp.*	*Cyt_sp*
			Biscurus sp.	*Bis_sp*
			Bdella sp.	*Bde_sp*
			Bdellodes hessei	*Bde_hes*

		Spinibdella thori	*Spi_tho*
		Hexabdella sp.	*Hex_sp*
	Cheyletidae	*Cheyletus sp.*	*Che_sp*
	Pseudocheylidae	*Neocheylus sp.*	*Neoc_sp*
		Anoplocheylus sp.	*Ano_sp*
	Caeculidae	*Microcaeculus sp.*	*Micr_sp*
		Caeculus sp.	*Cae_sp*
	Anystidae	*Anystis baccarum*	*Any_bac*
		Chausseria sp.	*Cha_sp*
	Adamystidae	*Adamystis sp.*	*Ada_sp*
	Stigmaeidae	*Agistemus africanus*	*Agi_afr*
		Ledermuelleria sp.	*Led_sp*
		Storchia robusta	*Sto_rob*
		Eustigmaeus sp.	*Eus_sp*
	Erythraeidae	*Abrolophus sp.*	*Abr_sp*
		Leptus sp.	*Lep_sp*
		Erythraeus sp.	*Ery_sp*
		Balaustium sp.	*Bal_sp*
	Smarididae	*Smaris sp.*	*Sma_sp*
	Trombidiidae	*Allothrombium sp.*	*Allo_sp*
		Thrombidium sp.	*Thr_sp*
	Trombiculidae	*Trombiculus larva*	*Tro_lar*
MESOSTIG-MATA	Laelapidae	*Hypoaspis sp. 1*	*Hyp_sp1*
		Hypoaspis sp. 2	*Hyp_sp2*
		Cosmolaelaps sp.	*Cosm_sp*
		Leptolaelaps sp.	*Lept_sp*
		Pachylaelaps sp.	*Pach_sp*
	Rhodacaridae	*Gamasellus sp.*	*Gam_sp*
		Rhodacarus sp.	*Rho_sp*
		Rhodacarellus sp.	*Rhoc_sp*
	Ascidae	*Protogamasellus sp.*	*Protg_sp*
		Proctolaelaps sp.	*Proc_sp*
		Asca sp.	*Asca_sp*
		Lasioseius sp.	*Las_sp*
	Veigaiaidae	*Veigaia sp.*	*Vei_sp*
	Eviphididae	*Eviphus sp.*	*Evi_sp*
		Copriphis? sp.	*Cop_sp*
	Digamasellidae	*Digamasellus sp.*	*Dig_sp*
	Macrochelidae	*Glypthlaspis sp.*	*Gly_sp*
		Macrocheles sp.	*Macls_sp*
	Phytoseiidae	*Typhlodromus sp.*	*Typ_sp*
	Parastidae	*Pergamasus sp.*	*Perg_sp*
		Parasitus sp.	*Para_sp*
ARANEAE	Lycosidae	*Lycosa sp. 1*	*Lyco_sp1*
		Lycosa sp. 2	*Lyco_sp2*
	Salticidae	*Morphospecies 1*	*Sal_Morp1*
		Morphospecies 2	*Sal_Morp2*
		Morphospecies 3	*Sal_Morp3*
PSEUDOSCORPIONIDAE			PSCD
SCORPIONIDAE			SCD
COLEOPTERA	Staphylinidae		Staph
	Elateridae		Elater

	HYMENOPTERA	Formicidae	*Anaplolepis sp.*	*Anapl_sp*
			Plagiolepis sp.	*Plagi_sp*
			Pheidole sp.	*Pheid_sp*
			Tetramorium sp.	*Tetra_sp*
			Monomonium sp.	*Monom_sp*
			Technomyrmex sp	*Techn_sp*
			Cerapachys sp.	*Cerap_sp*
		Vespidae	*sp.1*	*Vesp_sp1*
			sp.2	*Vesp_sp2*
	CHILOPODA	Scolopendromorpha		Scolop
		Lithobiomorpha		Lithob
		Geophilomorpha		Geoph
	METASTIGMATA	Ixodidae	juveniles	Juvn_M
Ppar	PROSTIGMATA	Linotetranidae	*Linotetranus sp.*	*Lino_sp*
		Tetranychidae	*Tetranychus urticae*	*Tet_urt*
			Bryobia praetiosa	*Bry_pra*
		Eriophyidae	(diversi)	Eriophyi
	THYSANOPTERA	Thripidae		Thrip_sp
		Aelothripidae		Aelo_sp
	ISOPTERA	Hodotermitidae	*sp.*	Hodot_sp
		Termitidae	*sp.*	Termi_sp
	HEMIPTERA	Nymphs		HEMI_nym
	LEPIDOPTERA	Geometridae	larvae	Geom_lar
	DIPLURA			DIPLU
	SYMPHYLA			SYMPH
	DIPLOPODA		*Polixenus sp.*	*Poli_sp*
SO	ASTIGMATA	Acaridae	*Caloglyphus sp.*	*Cal_sp*
			Rhizoglyphus echinopus	*Rhi_ech*
			Tyrophagus putrescentiae	*Tyr_put*
			Hypopi	Hypopi
			Glycyphagus sp. 1	*Glyc_sp1*
	DIPTERA	Muscidae		Musci
		Cecidomyiidae		Cecid
		Diverse larvae		DIPT_div
	PROTURA			PROT
	CRUSTACEA	Isopoda		Isopo
	NEMATODA		*Criconema sp.*	*Crico*
			Xiphinema sp.	*Xiphi*
		Longidoridae		Longid
	ANNELIDA	Oligochaeta		Oligo

Appendix 3:

Raw data showing concentrations of all metals analysed from the soil samples ($\mu g.g^{-1}$) which were collected at increasing distances away from the tailings dam over a period of one year during different months (n=6)

Aug '05	Al	As	Ba	Be	B	Cd	Ca	Cr
Site1	5,290.00	0.43	13.14	0.02	3.114	0.025	2,661.00	43.07
	5,245.00	0.425	13.51	0.012	2.752	0.045	2,913.00	42.31
	2,247.00	0.214	7.327	0.009	2.832	0.045	1,162.00	23.35
	4,932.00	0.224	12.05	0.011	2.094	0.039	2,952.00	34.09
	4,220.00	0.336	12.31	0.013	4.245	0.039	2,221.00	41.06
	3,329.00	0.266	8.927	0.01	2.408	0.089	1,761.00	32.62
Site2	4,243.00	0.412	11.88	0.017	2.962	0.053	2,853.00	31.62
	4,593.00	0.38	12.1	0.009	2.896	0.067	2,616.00	35.6
	2,080.00	0.268	7.197	0.012	2.877	0.031	1,128.00	21.41
	3,540.00	0.294	10.51	0.013	2.105	0.056	2,237.00	31.05
	3,016.00	0.323	10.39	0.014	3.429	0.095	1,857.00	39.3
	2,365.00	0.237	9.266	0.015	2.364	0.036	1,408.00	27.45
Site3	9,790.00	0.419	29.14	0.038	2.923	0.036	6,608.00	58.13
	4,936.00	0.313	43.77	0.093	2.516	0.053	6,851.00	28.09
	4,736.00	0.302	53.66	0.121	2.558	0.042	5,606.00	20.42
	5,663.00	0.362	66.62	0.151	2.102	0.058	7,391.00	20.94
	5,249.00	0.302	55.35	0.125	3.092	0.061	13,350.00	24.52
	7,042.00	0.237	32.92	0.046	2.681	0.047	32,420.00	49.81
Site4	5,707.00	0.505	91.67	0.193	2.982	0.078	7,305.00	14.52
	6,012.00	0.464	75.21	0.186	2.504	0.058	9,191.00	18.87
	4,383.00	0.378	58.11	0.16	2.444	0.064	10,620.00	11.57
	6,165.00	0.359	77.09	0.122	2.023	0.036	9,876.00	66.64
	3,233.00	0.255	11.69	0.008	3.271	0.022	2,505.00	77.83
	7,698.00	0.349	122.5	0.247	2.473	0.053	9,148.00	18.95
Site5	6,538.00	0.435	95.9	0.226	2.612	0.039	7,057.00	11.14
	4,722.00	0.469	61.51	0.189	3.93	0.039	5,718.00	8.679
	6,152.00	0.393	96.26	0.202	2.57	0.033	6,363.00	11.03
	5,978.00	0.362	99	0.208	2.557	0.05	7,539.00	9.765
	5,367.00	0.438	90.73	0.181	3.019	0.047	6,245.00	12.64
	6,822.00	0.331	102	0.209	2.217	0.045	10,580.00	11.93
Site6	4,478.00	0.404	58.49	0.159	3.038	0.017	4,567.00	7.1
	5,064.00	0.474	71.94	0.187	2.813	0.047	5,461.00	7.845
	5,271.00	0.318	67.96	0.198	2.447	0.036	5,579.00	7.66
	5,840.00	0.305	83.55	0.197	2.57	0.039	8,545.00	9.516
	3,599.00	0.3	46.96	0.129	3.001	0.025	7,611.00	6.219
	6,758.00	0.305	97.04	0.249	2.221	0.047	7,076.00	9.701
Site7	6,576.00	0.557	94.34	0.266	2.561	0.167	16,060.00	11.16
	6,687.00	0.471	110.6	0.263	2.124	0.064	12,200.00	11.99
	4,944.00	0.354	73.35	0.208	2.496	0.042	4,878.00	8.294
	6,474.00	0.453	131.3	0.262	2.037	0.047	8,530.00	10.7
	6,386.00	0.477	129.7	0.268	3.33	0.103	7,413.00	11.57
	6,378.00	0.461	122.1	0.263	2.271	0.045	6,300.00	10.73

Aug '05	Co	Cu	Fe	Pb	Mg	Mn	Ni	K
Site1	5.473	93.09	4,023.00	3.929	3,828.00	61.73	100.1	306.8
	6.127	95.91	4,256.00	3.936	4,209.00	59.03	111.1	318.2
	3.471	67.11	2,369.00	2.794	2,341.00	33.23	64.48	125.4
	5.118	79.99	3,846.00	3.694	3,740.00	51.94	100.7	386.9
	6.06	85.59	4,162.00	4.123	3,798.00	54.91	104.5	246.8
	5.192	69.61	3,907.00	3.664	3,183.00	50.89	90.43	161.1
Site2	5.509	105	3,977.00	3.305	4,522.00	53.25	95.1	289
	5.671	108.6	4,077.00	3.635	3,851.00	58.34	99.22	342.1
	3.722	74.78	2,430.00	2.633	2,171.00	34.88	66.65	121.6
	5.792	110.9	3,526.00	3.568	3,381.00	50.55	112.3	318.6
	5.337	192.2	3,208.00	4.542	2,704.00	147.3	95.25	319.9
	4.686	66.59	2,958.00	3.493	2,557.00	47.04	72.74	261.7
Site3	9.391	99.53	5,864.00	6.194	5,989.00	150.3	152	690
	11.66	77.62	3,006.00	5.113	3,233.00	427.7	57.95	896.5
	13.15	32.32	2,260.00	4.421	2,419.00	543.5	40.28	724
	15.85	43.1	2,504.00	5.069	3,482.00	668.6	44.17	942.2
	13.69	36.78	2,782.00	5.288	4,287.00	515.5	46.03	594.3
	11.18	253.6	4,864.00	3.816	6,010.00	267.4	75.6	457.6
Site4	23.72	62.44	2,097.00	4.929	2,897.00	997.6	47.84	1,087.00
	14.08	55.41	1,950.00	5.505	3,115.00	568.3	37.35	709.9
	16.41	34.98	1,646.00	4.94	1,675.00	768.4	29.77	669.8
	16.26	67.07	4,074.00	5.232	4,012.00	689.6	85.74	589.8
	9.867	69.01	4,854.00	3.526	3,619.00	55.73	81.02	333.4
	26.91	26.88	3,007.00	6.19	2,676.00	1,261.00	45.98	639.4
Site5	18.46	62.61	1,885.00	5.817	3,318.00	885	26.93	592.4
	16.88	39.46	1,425.00	4.627	1,814.00	742.9	24.73	715.2
	18.68	28.43	1,841.00	5.334	2,062.00	862.1	26.57	532.5
	22.57	21.08	1,835.00	5.282	2,062.00	1,159.00	32.99	778.7
	17.39	21.12	1,758.00	6.391	2,176.00	853.5	34.09	985.1
	16.72	21.14	2,014.00	6.151	2,201.00	814.5	27.79	554.9
Site6	14.65	34.77	1,295.00	4.156	1,888.00	692.4	22.26	416.4
	16.54	35.15	1,511.00	4.708	2,220.00	795.7	27.1	443.7
	17.34	21.85	1,507.00	4.443	2,013.00	822.3	25.04	492.9
	17.28	19.61	1,636.00	5.204	2,365.00	804.1	26.57	490.4
	14.51	217.4	1,130.00	4.648	1,551.00	1,052.00	21.55	301.1
	17.87	14.26	2,023.00	5.327	2,456.00	809.4	26.95	351.2
Site7	20.67	41.27	1,987.00	5.732	3,005.00	952.7	30.76	420.3
	24.27	24.31	2,182.00	6.457	2,668.00	1,120.00	34.7	527.2
	22.53	23.48	1,558.00	5.487	2,057.00	1,054.00	30.37	422
	25.35	138.4	2,018.00	6.653	2,453.00	1,191.00	34.68	539.7
	27.08	44.87	2,121.00	8.477	4,667.00	1,251.00	37.36	679.3
	26.27	17.82	2,083.00	7.264	2,600.00	1,216.00	36.52	734.7

Aug '05	Se	Na	Tl	V	Zn
Site1	1.962	619.6	0.08	2.299	21.42
	1.592	740.2	0.103	2.378	24.52
	0.889	292	0.104	1.248	12.88
	0.963	671.2	0.095	1.829	16.71
	1.444	507.4	0.095	2.174	15.2
	1.592	401.1	0.056	1.599	8.528
Site2	2.11	875.3	0.088	1.978	29.28
	1.629	813.3	0.113	2.18	26.48
	1.333	233.8	0.079	1.298	12.31
	1.962	680.5	0.101	1.771	18.95
	1.555	441.1	0.118	1.549	190.8
	0.852	239.1	0.056	1.371	18.31
Site3	1.555	991.8	0.099	4.685	23.52
	2.554	321.5	0.119	7.766	24.8
	1.629	119.9	0.103	8.683	16.27
	2.258	597.7	0.115	12.44	27.33
	2.999	709.6	0.072	9.823	19.02
	1.518	635.2	0.057	4.618	19.15
Site4	1.851	236.7	0.142	13.33	31.85
	1.777	337	0.12	10.44	27.98
	1.481	65.76	0.112	8.791	17.05
	2.369	434.6	0.116	10.28	13.99
	1.444	398.6	0.072	2.432	13.58
	2.147	91.65	0.074	19.84	46.49
Site5	1.814	632.1	0.102	13.75	38.34
	2.073	81.41	0.124	9.762	76.72
	2.11	71.62	0.108	13.71	15.04
	1.629	67.48	0.116	17.52	13.01
	1.407	178.1	0.084	13.8	13.86
	1.592	66.02	0.062	15.24	12.74
Site6	2.554	116.6	0.082	9.142	21.25
	2.073	209.3	0.109	11.22	20.81
	1.777	51.72	0.113	10.54	13.41
	1.74	85.67	0.101	12.88	16.89
	1.407	48.09	0.078	8.03	14.22
	1.888	72.08	0.068	17.95	12.22
Site7	1.777	229.1	0.116	16.55	26.58
	2.036	52.63	0.118	16.8	15.99
	1.407	56.53	0.113	9.989	15.05
	2.332	54.19	0.098	17.03	14.99
	2.258	1,191.00	0.104	16.23	45.81
	1.777	52.68	0.074	14.4	12.98

Dec '05	Al	As	Ba	Be	B	Cd	Ca	Cr
Site1	2,914.00	0.214	11.69	0.014	3.797	0.047	1,494.00	29.27
	2,824.00	0.227	8.684	0.009	2.569	0.053	1,670.00	26.3
	3,792.00	0.287	42.52	0.081	1.835	0.081	9,590.00	19.87
	4,903.00	0.326	21.68	0.025	2.279	0.033	4,866.00	76.12
	3,660.00	0.227	58.28	0.136	1.797	0.056	4,026.00	9.197
	4,573.00	0.242	66.25	0.161	1.94	0.042	5,146.00	7.524
Site2	1,728.00	0.164	5.591	0.007	3.104	0.042	821.3	19.5
	2,993.00	0.195	9.348	0.01	2.602	0.031	1,873.00	26.83
	2,082.00	0.227	10.11	0.015	2.528	0.05	1,542.00	19.32
	2,622.00	0.203	9.107	0.009	2.321	0.028	1,636.00	42.36
	3,899.00	0.292	63.53	0.14	1.713	0.097	6,698.00	8.144
	4,990.00	0.333	85.63	0.231	1.731	0.075	5,157.00	9.726
Site3	2,164.00	0.208	8.049	0.011	3.2	0.117	1,121.00	23.56
	2,025.00	0.206	6.697	0.008	2.434	0.042	1,201.00	20.27
	4,388.00	0.214	37.6	0.075	2.042	0.045	8,997.00	35.4
	2,254.00	0.242	10.73	0.012	2.204	0.047	1,665.00	36.92
	5,572.00	0.289	91.59	0.199	2.032	0.047	5,809.00	8.075
	5,417.00	0.289	109.5	0.237	1.885	0.039	5,730.00	9.819
Site4	2,652.00	0.279	7.33	0.011	2.748	0.075	1,373.00	22.44
	1,280.00	0.19	5.656	0.009	2.509	0.019	817.8	12.97
	2,515.00	0.208	27.47	0.066	1.976	0.092	10,700.00	16.03
	8,243.00	0.474	119.3	0.258	2.714	0.058	15,060.00	13.15
	4,003.00	0.279	47.86	0.153	2.114	0.045	4,906.00	6.328
	3,768.00	0.294	54.17	0.18	1.935	0.036	3,899.00	7.078
Site5	2,929.00	0.229	9.589	0.008	2.954	0.086	1,684.00	30.89
	1,547.00	0.237	5.47	0.008	2.493	0.033	934.8	15.39
	5,798.00	0.185	64.05	0.195	1.87	0.047	12,990.00	10.65
	3,585.00	0.247	56.46	0.124	1.718	0.045	4,247.00	8.423
	4,688.00	0.289	62.03	0.173	1.921	0.036	5,584.00	7.394
	5,257.00	0.401	114.4	0.218	1.877	0.031	5,532.00	9.918
Site6	1,167.00	0.102	3.584	0.007	2.57	0.028	838.3	13.04
	7,413.00	0.336	82.7	0.16	2.927	0.081	9,681.00	38.05
	2,663.00	0.201	35.05	0.093	2.155	0.019	5,283.00	6.75
	5,804.00	0.346	97.76	0.196	2.067	0.047	6,210.00	10.97
	3,922.00	0.242	51.58	0.142	1.627	0.028	4,330.00	6.503
	4,704.00	0.362	89.39	0.23	1.763	0.053	4,884.00	8.901
Site7	1,705.00	0.19	6.661	0.007	2.681	0.036	855.2	16.6
	4,498.00	0.318	51.41	0.122	2.24	0.031	8,453.00	19.78
	5,013.00	0.419	74.93	0.164	2.226	0.064	8,111.00	16.03
	2,791.00	0.206	48.89	0.114	2.187	0.056	3,670.00	7.019
	3,891.00	0.271	51.89	0.128	1.528	0.033	4,941.00	6.654
	5,582.00	0.344	116.3	0.23	1.936	0.045	7,649.00	10.24

Dec '05	Co	Cu	Fe	Pb	Mg	Mn	Ni	K
Site1	4.9	80.13	3,188.00	2.681	2,914.00	41.74	97.97	158.2
	4.837	87.59	3,399.00	2.992	2,806.00	44.56	90.8	168.4
	11.44	1,838.00	2,268.00	5.079	2,474.00	449.6	49.86	737.4
	8.781	89.16	5,064.00	6.363	4,213.00	81.88	130.3	440.3
	12.87	15.74	1,264.00	4.804	1,318.00	773.2	22.24	461.4
	15.79	11.97	1,426.00	5.02	1,806.00	732	23.64	436.3
Site2	2.991	52.72	2,038.00	2.081	1,867.00	26.4	57.07	112.5
	4.704	67.69	3,368.00	3.376	3,102.00	44.62	90.36	174
	4.649	51.94	2,549.00	3.041	2,346.00	68.07	65.44	294.5
	5.413	60.24	3,155.00	4.076	2,384.00	41.92	75.24	283
	14.64	23.64	1,308.00	4.806	1,444.00	655.5	20.92	473.8
	24.73	14.9	1,652.00	7.341	2,188.00	1,125.00	32.13	590.3
Site3	3.535	45.69	2,285.00	3.843	1,908.00	39.21	66.08	149.8
	3.319	60.62	2,165.00	2.408	1,919.00	32.66	65.04	115.2
	10.65	41.17	2,674.00	5.238	2,973.00	358.2	53.3	394.9
	5.786	55.4	2,823.00	3.387	2,167.00	43.26	68.67	259.9
	16.84	15.51	1,662.00	5.799	2,282.00	808.8	25.34	636.9
	26.78	12.78	2,111.00	6.413	2,152.00	1,335.00	42.09	336.1
Site4	3.531	58.11	2,481.00	2.727	2,234.00	33.45	69.22	150.5
	2.549	46.18	1,432.00	2.383	1,171.00	26.67	43.42	101.6
	7.658	31.61	1,746.00	3.179	1,821.00	273.2	34.54	427
	24.09	24.08	2,355.00	7.87	2,998.00	1,171.00	33.6	757.4
	14.27	15.91	1,320.00	3.812	1,583.00	605.8	19.24	266.1
	20.86	14.4	1,319.00	5.22	1,679.00	1,018.00	29.47	382.3
Site5	5.162	79.89	3,290.00	2.96	2,975.00	42.89	101.1	256.3
	2.883	55.66	1,679.00	2.696	1,434.00	26.38	53.6	107
	12.35	21.27	1,921.00	4.282	2,899.00	426.8	16.05	375.5
	12.14	14.61	1,224.00	4.577	1,350.00	582.8	21.29	433.7
	14.65	11.47	1,448.00	4.826	1,831.00	697.2	21.97	384.4
	23.43	14.2	1,793.00	7.233	2,025.00	1,125.00	33.51	600.7
Site6	2.171	35.29	1,380.00	2.053	1,457.00	19.94	42.71	118.5
	20.84	48.6	4,062.00	8.37	4,340.00	793.8	79.73	1,262.00
	9.867	13.61	1,013.00	2.916	1,403.00	409.1	19.53	290.6
	17.94	15.47	1,792.00	6.075	1,923.00	882.2	27.88	657.7
	13.28	13.71	1,267.00	4.294	1,585.00	648.9	21.21	377.3
	21.6	15.74	1,525.00	6.516	2,016.00	983	29.25	556.7
Site7	3.455	56.72	2,100.00	2.653	1,744.00	37.6	59.26	126.4
	14.19	28.86	2,392.00	4.505	2,508.00	500	41.53	656
	23.57	42.93	1,762.00	5.53	2,812.00	1,176.00	51.61	701.6
	9.842	19.72	985.1	5.357	1,236.00	461.3	20.8	602.9
	16.31	12.52	1,308.00	4.313	1,616.00	844.7	29.17	478.4
	25.87	16.15	1,997.00	6.453	2,114.00	1,177.00	36.49	448.3

Dec '05	Se	Na	Tl	V	Zn
Site1	1.777	306	0.049	1.487	34.17
	1.629	282.7	0.043	1.399	16.04
	1.296	151	0.043	5.328	21.48
	1.814	650.8	0.058	3.295	19.08
	1.74	47.57	0.036	7.006	16.54
	2.073	43.9	0.039	9.586	12.79
Site2	1.407	192	0.04	0.905	25.04
	1.333	554.1	0.044	1.434	20.12
	1.592	209.9	0.038	1.825	13.32
	2.666	290.5	0.044	1.543	16.55
	1.111	236.3	0.036	8.269	24.5
	2.11	55.26	0.046	9.717	11.77
Site3	1.407	236.4	0.035	1.286	14.95
	1.222	225.6	0.038	1.126	13.38
	1.629	334	0.046	5.048	26.47
	1.037	304.7	0.047	1.613	15.03
	2.332	295.9	0.047	12.55	19.73
	1.37	65	0.071	14.86	15.18
Site4	1.629	358.1	0.043	1.153	10.74
	1.518	150.9	0.037	0.778	16.72
	1.629	71.82	0.033	4.877	23.08
	2.851	339.3	0.06	16.64	18.18
	2.221	45.13	0.049	9.442	22.64
	1.222	43.59	0.044	8.185	12.45
Site5	1.629	304.7	0.048	1.5	9.882
	1.555	170.8	0.043	0.946	13.12
	1.629	334.7	0.045	9.947	22.78
	1.74	46.04	0.03	7.352	17
	1.518	41.76	0.036	9.151	14.18
	1.666	41.92	0.05	13.59	12.1
Site6	1.074	224.3	0.025	0.641	13.77
	1.962	500	0.05	13	35.26
	1.962	191.4	0.03	4.891	17.96
	1.37	73.06	0.044	12.32	20.66
	1.444	42.57	0.043	7.915	15.55
	1.259	58.67	0.039	9.409	20.87
Site7	1.481	187.1	0.041	1.047	14.31
	1.888	134.8	0.04	9.112	22.21
	1.37	356	0.103	9.414	45.27
	1.925	308.5	0.035	5.78	18.18
	1.222	39.42	0.051	9.06	13.55
	1.444	42.12	0.066	14.6	20.31

Mar '06	Be	B	Al	V	Cr	Mn	Fe	Co
Site1	0.014	1.208	1,716.987	0.776	13.439	14.657	1,126.771	1.458
	0.009	0.950	1,367.987	0.649	10.949	11.247	874.071	1.090
	0.006	0.789	1,296.987	0.671	11.429	13.557	1,021.771	1.396
	0.007	0.715	888.487	0.439	7.872	9.003	705.071	1.006
	0.007	0.606	950.587	0.432	8.201	8.184	635.971	0.789
	0.009	0.559	1,344.987	0.610	10.239	11.117	844.971	1.130
Site2	0.006	0.495	1,122.987	0.525	8.556	10.287	782.871	1.025
	0.005	0.474	999.287	0.495	8.061	10.327	807.971	1.018
	0.006	0.452	903.787	0.434	7.422	9.346	699.571	0.942
	0.003	0.404	963.987	0.449	7.265	9.992	725.471	1.008
	0.005	0.345	812.687	0.406	6.606	9.271	598.171	0.826
	0.003	0.324	859.087	0.405	6.404	8.387	568.271	0.776
Site3	0.009	0.306	875.687	0.685	7.163	19.197	664.371	1.156
	0.029	0.287	838.587	1.826	3.245	74.667	433.371	2.024
	0.039	0.300	891.587	2.372	3.068	96.647	396.171	2.455
	0.028	0.244	1,084.987	2.119	6.107	84.657	586.771	2.376
	0.008	0.233	922.987	0.852	8.329	33.217	768.271	1.728
	0.016	0.232	855.387	1.138	6.756	32.297	585.271	1.539
Site4	0.039	0.230	882.387	2.130	2.693	154.197	357.471	3.640
	0.042	0.214	806.787	2.025	2.626	98.007	347.471	2.353
	0.036	0.231	799.687	2.012	2.407	99.827	342.971	2.328
	0.050	0.203	959.287	1.966	2.701	119.197	318.571	2.734
	0.041	0.180	817.687	1.874	2.607	78.817	419.271	2.244
	0.033	0.197	752.587	2.576	2.668	166.397	324.171	2.516
Site5	0.048	0.169	1,039.987	2.768	2.168	222.097	385.071	4.326
	0.041	0.151	1,034.987	2.501	2.277	134.297	370.671	3.402
	0.046	0.186	999.987	2.704	2.618	166.497	423.871	3.996
	0.039	0.138	927.087	2.372	1.940	122.397	322.471	2.697
	0.038	0.149	775.187	1.939	2.165	93.767	296.571	2.208
	0.051	0.143	908.187	2.184	1.975	105.197	321.971	2.434
Site6	0.046	0.146	791.587	2.066	1.713	93.567	277.271	2.179
	0.045	0.153	791.487	2.074	1.462	82.907	271.471	1.941
	0.035	0.127	757.587	1.897	1.461	78.637	266.271	1.877
	0.049	0.151	880.387	2.430	1.550	111.797	313.471	2.598
	0.043	0.147	840.287	2.117	1.560	107.997	296.671	2.502
	0.046	0.142	835.287	2.173	1.668	101.397	290.371	2.348
Site7	0.047	0.180	712.987	1.869	1.777	140.097	278.971	3.313
	0.051	0.166	802.087	2.495	1.895	126.997	331.071	3.002
	0.054	0.137	862.787	2.399	1.962	160.697	346.671	3.783
	0.053	0.154	758.887	2.028	1.744	119.597	299.171	2.754
	0.052	0.165	801.087	2.326	2.226	120.597	477.971	2.921
	0.048	0.183	807.787	2.250	1.928	134.097	312.871	3.136

Mar '06	Ni	Cu	Zn	As	Se	Cd	Ba	Tl
Site1	32.357	17.632	3.004	0.122	0.384	0.013	3.734	0.077
	22.617	11.232	1.468	0.093	0.298	0.010	3.259	0.062
	29.347	17.482	1.886	0.110	0.278	0.012	3.388	0.049
	21.857	12.442	1.532	0.072	0.318	0.004	2.262	0.039
	16.327	11.962	1.110	0.056	0.384	0.006	2.437	0.033
	23.507	14.192	2.676	0.080	0.304	0.009	3.348	0.031
Site2	21.957	12.392	1.948	0.078	0.411	0.011	2.653	0.025
	20.867	13.662	2.288	0.054	0.364	0.004	2.434	0.020
	19.187	12.012	2.248	0.061	0.331	0.004	2.295	0.015
	19.777	11.962	9.287	0.064	0.265	0.006	2.416	0.016
	15.457	11.842	2.868	0.067	0.298	0.006	2.422	0.014
	15.257	9.943	2.079	0.052	0.284	0.003	2.350	0.013
Site3	16.447	9.245	2.406	0.044	0.245	0.002	3.431	0.010
	6.289	2.515	2.387	0.050	0.311	0.005	9.969	0.009
	6.177	3.775	1.966	0.049	0.218	0.007	13.189	0.009
	8.737	3.867	1.995	0.045	0.251	0.007	11.789	0.007
	13.307	19.072	26.721	0.037	0.178	0.006	4.484	0.007
	10.517	6.094	1.744	0.043	0.231	0.005	5.436	0.007
Site4	7.458	2.355	1.900	0.042	0.271	0.005	14.819	0.011
	5.514	2.348	2.148	0.047	0.218	0.006	14.299	0.011
	5.588	3.350	2.856	0.045	0.298	0.011	14.339	0.006
	6.927	1.845	3.639	0.029	0.218	0.009	17.579	0.010
	6.630	1.707	1.434	0.045	0.291	0.005	13.619	0.008
	7.615	2.113	3.487	0.052	0.311	0.011	36.119	0.009
Site5	8.258	1.663	2.508	0.056	0.185	0.080	20.469	0.009
	5.555	2.105	1.326	0.050	0.271	0.009	19.509	0.008
	7.535	2.800	2.641	0.051	0.298	0.008	19.129	0.009
	4.865	1.894	1.377	0.045	0.298	0.009	17.239	0.007
	5.944	11.762	16.301	0.039	0.211	0.005	14.269	0.006
	4.325	1.621	1.289	0.038	0.211	0.015	16.799	0.005
Site6	3.813	1.188	1.573	0.037	0.178	0.004	14.689	0.006
	3.592	1.265	1.375	0.036	0.231	0.005	13.779	0.006
	3.432	1.176	1.573	0.027	0.225	0.007	12.779	0.005
	5.013	1.425	1.862	0.037	0.178	0.007	15.859	0.007
	4.585	2.199	3.114	0.044	0.165	0.134	15.959	0.007
	4.541	1.445	1.176	0.031	0.238	0.010	15.689	0.005
Site7	5.125	1.623	1.627	0.050	0.165	0.002	17.949	0.006
	4.646	1.571	5.212	0.042	0.304	0.006	17.109	0.010
	5.796	1.359	1.216	0.045	0.245	0.061	21.149	0.008
	4.822	2.264	1.955	0.042	0.284	0.006	17.289	0.006
	6.463	5.475	11.401	0.039	0.178	0.149	16.179	0.009
	5.029	1.157	1.491	0.039	0.291	0.004	20.659	0.007

Mar '06	Pb
Site1	0.818
	0.598
	0.591
	0.416
	0.461
	0.692
Site2	0.480
	0.627
	0.494
	0.793
	0.550
	0.486
Site3	0.515
	0.601
	0.647
	0.661
	0.455
	0.513
Site4	0.960
	0.704
	0.870
	0.746
	0.615
	0.660
Site5	0.985
	0.998
	0.920
	0.788
	0.755
	0.717
Site6	0.655
	0.688
	0.649
	0.689
	0.890
	0.735
Site7	0.861
	0.808
	1.113
	0.963
	0.949
	0.843

May '06	Be	B	Al	V	Cr	Mn	Fe	Co
Site1	0.012	0.193	2,688.967	1.396	25.309	37.438	2,362.861	3.953
	0.012	0.183	3,770.967	1.701	31.659	51.038	3,075.861	4.541
	0.014	0.242	4,774.967	2.049	36.739	58.098	3,510.861	5.031
	0.011	0.197	4,214.967	1.952	36.159	56.538	3,347.861	5.015
	0.013	0.179	4,476.967	1.853	34.779	53.968	3,239.861	4.439
	0.013	0.279	4,692.967	2.066	35.099	56.208	3,261.861	4.879
Site2	0.016	0.201	4,019.967	1.790	26.099	51.238	2,802.861	4.417
	0.010	0.172	2,815.967	1.529	25.359	40.298	2,689.861	4.236
	0.005	0.165	2,559.967	1.305	22.069	35.158	2,467.861	3.703
	0.013	0.204	3,480.967	1.694	25.349	50.538	2,480.861	4.207
	0.207	0.179	5,860.967	10.160	29.819	584.598	3,074.861	16.000
	0.007	0.207	2,288.967	1.226	18.999	31.428	1,873.861	3.267
Site3	0.020	0.152	2,403.967	1.812	19.499	68.528	2,117.861	4.085
	0.182	0.137	4,213.967	11.620	17.429	546.598	2,001.861	15.720
	0.179	0.140	3,534.967	12.620	9.807	460.098	1,382.861	11.900
	0.131	0.142	3,379.967	8.177	16.979	344.998	1,584.861	9.928
	0.067	0.125	4,526.967	4.892	41.279	263.098	2,715.861	9.937
	0.050	0.166	2,464.967	4.174	40.899	135.398	2,497.861	8.995
Site4	0.169	0.150	3,034.967	6.287	7.511	442.298	909.961	10.620
	0.274	0.150	4,799.967	12.520	12.539	629.998	1,588.861	15.490
	0.174	0.134	3,285.967	10.980	7.348	525.298	1,174.861	12.370
	0.176	0.127	3,526.967	8.800	9.323	545.098	1,156.861	12.960
	0.001	0.121	4.863	0.029	0.096	0.547	14.401	0.015
	0.192	0.122	3,641.967	9.401	10.749	590.998	1,176.861	13.590
Site5	0.199	0.123	3,378.967	9.531	6.338	548.798	915.161	12.460
	0.191	0.123	3,388.967	8.772	6.653	544.098	923.861	12.350
	0.243	0.140	4,044.967	10.220	8.584	624.498	1,064.861	14.290
	0.238	0.121	3,805.967	10.370	6.106	511.298	989.261	11.650
	0.193	0.123	3,736.967	9.904	6.585	547.398	1,003.861	12.280
	0.149	0.121	2,619.967	7.631	4.893	412.298	745.361	9.371
Site6	0.247	0.116	4,380.967	12.360	7.182	672.298	1,211.861	15.480
	0.249	0.115	4,457.967	12.050	6.533	650.398	1,228.861	15.310
	0.207	0.118	3,605.967	9.873	5.515	525.898	999.861	12.460
	0.228	0.114	3,870.967	11.270	6.113	585.498	1,053.861	13.910
	0.175	0.104	2,885.967	9.025	4.716	430.598	793.661	9.821
	0.215	0.125	3,863.967	11.630	6.423	606.598	1,017.861	13.680
Site7	0.263	0.111	4,137.967	13.820	7.606	801.598	1,356.861	18.750
	0.184	0.115	2,586.967	7.899	4.510	511.998	824.861	11.880
	0.275	0.104	4,151.967	13.580	7.117	850.698	1,235.861	19.800
	0.245	0.116	3,629.967	8.743	6.276	641.098	1,105.861	15.330
	0.233	0.111	3,242.967	10.090	5.828	711.598	952.861	16.070
	0.226	0.108	3,096.967	9.588	5.722	628.898	925.961	14.970

May '06	Ni	Cu	Zn	As	Se	Cd	Ba	Tl
Site1	86.399	60.743	3.341	0.142	0.203	0.016	10.390	0.023
	99.979	62.143	3.364	0.172	0.256	0.028	14.580	0.031
	110.399	58.493	4.505	0.165	0.309	0.019	16.780	0.035
	110.299	62.673	3.580	0.179	0.256	0.021	15.510	0.029
	99.999	61.193	3.830	0.167	0.210	0.023	16.120	0.034
	104.099	59.033	3.547	0.165	0.249	0.019	16.060	0.034
Site2	90.379	57.473	3.300	0.146	0.223	0.023	14.800	0.031
	89.729	58.793	2.904	0.134	0.263	0.023	11.300	0.024
	79.189	54.763	2.503	0.163	0.243	0.020	10.330	0.022
	85.599	58.813	4.316	0.159	0.230	0.023	14.040	0.028
	96.109	53.723	5.155	0.245	0.369	0.035	73.600	0.049
	66.969	54.833	3.964	0.125	0.276	0.018	9.658	0.025
Site3	62.709	34.753	3.523	0.105	0.176	0.018	12.880	0.020
	39.189	13.683	5.717	0.158	0.249	0.026	63.600	0.022
	24.879	8.317	3.876	0.114	0.303	0.024	72.540	0.019
	35.749	15.403	4.820	0.131	0.303	0.029	54.990	0.016
	68.099	29.873	6.069	0.128	0.276	0.021	43.550	0.022
	49.719	29.703	4.759	0.112	0.276	0.016	21.340	0.025
Site4	25.069	5.694	3.510	0.124	0.283	0.023	58.890	0.023
	32.139	9.104	4.362	0.167	0.422	0.024	90.530	0.027
	20.819	5.884	3.210	0.116	0.316	0.022	68.950	0.018
	32.039	5.963	3.967	0.175	0.316	0.030	67.660	0.026
	0.113	0.557	0.485	0.022	0.123	0.005	0.087	0.004
	33.329	8.208	4.470	0.171	0.289	0.032	70.150	0.026
Site5	19.389	6.205	3.213	0.144	0.309	0.028	72.340	0.017
	20.189	6.584	3.414	0.129	0.342	0.024	75.140	0.019
	27.929	9.328	4.399	0.167	0.395	0.041	80.430	0.019
	17.729	5.462	3.050	0.143	0.322	0.020	75.840	0.023
	19.129	6.163	3.487	0.125	0.309	0.023	79.200	0.020
	14.519	4.439	2.482	0.099	0.249	0.021	53.760	0.018
Site6	25.689	6.615	4.075	0.165	0.462	0.035	87.270	0.025
	24.459	4.987	3.184	0.165	0.422	0.032	85.210	0.030
	19.169	4.756	2.905	0.128	0.342	0.024	73.120	0.024
	21.599	5.702	3.623	0.147	0.349	0.025	85.080	0.022
	16.599	4.920	3.072	0.109	0.243	0.019	63.320	0.017
	23.969	7.319	3.724	0.176	0.369	0.030	86.690	0.022
Site7	28.559	5.249	3.588	0.196	0.442	0.029	98.730	0.031
	18.569	3.141	2.433	0.118	0.356	0.020	61.530	0.026
	28.569	7.344	3.839	0.184	0.429	0.029	91.190	0.038
	21.799	4.087	3.101	0.138	0.309	0.018	69.310	0.031
	23.639	4.538	3.201	0.147	0.303	0.024	77.980	0.022
	22.189	4.612	3.168	0.139	0.336	0.028	83.600	0.023

May '06	Pb
Site1	2.723
	3.337
	3.746
	3.492
	3.980
	3.323
Site2	2.814
	2.643
	2.464
	2.661
	5.750
	2.256
Site3	2.501
	3.842
	3.133
	3.476
	5.188
	2.440
Site4	3.104
	4.550
	2.971
	3.524
	0.317
	3.815
Site5	3.826
	4.109
	5.597
	3.730
	4.000
	2.938
Site6	4.910
	4.191
	3.880
	4.604
	3.151
	4.517
Site7	5.095
	3.301
	5.335
	4.465
	4.369
	4.561