

Collections Conservation Practices and Possibilities of Contamination by Hazardous Pesticides: Towards a Non-Pesticide Approach of Conserving Organic Collections at the Natural History Museum of Zimbabwe.

A thesis submitted in partial fulfilment of the requirements for a PhD in Heritage and Museum Studies

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School of the Arts

by

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Chapter 1

Introduction

1.0 Introduction

The study investigates the possible contamination of organic collections¹ from pesticide use at the Natural History Museum of Zimbabwe. Organic collections include biological collections such as bird and mammal specimens and objects from indigenous and world cultures, made from leather and textiles. This study is located within the framework of conservation in museums, particularly on pest control. Key debates on pest control in museums have addressed issues such as the type of pests and their destructive habits on museum collections (Strang and Kigawa 2009; National Park Service 1998); the application of pesticides in museums (Dawson 1992); and integrated pest management techniques in museums (McCrea and Disalvo 2001; Strang and Kigawa 2009; National Park Service, 2014, 2016). Critically, the study interrogates the extent to which organic collections at the Natural History Museum of Zimbabwe may be exposed to hazardous pesticide contamination resulting from past and current preservation methods. Finally, the study intends to suggest a non-pesticide approach to pest control in African museums, particularly at the Natural History Museum. The proposed approach should holistically be friendly to the collections themselves, the environment, the museum staff who handle collections, researchers and visitors.

The Natural History Museum of Zimbabwe has been particularly chosen for this study because it has the largest bird skins collection in Africa and the fourth biggest in the world after the British Museum, The Museum of Central Africa in Belgium and the American Museum of Natural History. It is one of the largest museums with natural history collections in Africa. (Natural History Museum of Zimbabwe n.d). The Natural History Museum of Zimbabwe is one of the five national museums administered by the National Museums and Monuments of Zimbabwe (NMMZ) board of trustees. It is located in the western region of the five museological regions under NMMZ. Other museums include the Zimbabwe Museum of Human Sciences in the northern region, Mutare Museum in the eastern region, Great Zimbabwe Site Museum in the southern region and Zimbabwe Military Museum in the central region

¹ The word collection(s) denotes the same meaning as specimen(s), artefact(s) or object(s). They are used interchangeably in the study.

(NMMZ n.d). Apart from these museums, there are two major galleries, namely the National Gallery of Zimbabwe in Harare and the National Gallery of Zimbabwe in Bulawayo. Although these are national museums, they are not under the jurisdiction of NMMZ, they are administered by the National Galleries board (National Gallery of Zimbabwe Act 1980).

All national museums in Zimbabwe are products of colonialism. They were established by European settlers who colonised the country in 1896. Most of the collections in these museums were acquired through expeditions within Zimbabwe and abroad by white settlers. The treatment history of these collections against pest attack from their places of origin as well as in the museums is not known as there are no individual records of their treatment. In the early 19th century there was an upsurge in the number of exploring expeditions which resulted in the collection of natural specimens. Equipped with arsenic and mercury salts to preserve the natural collections in the field during subsequent processing, these explorers certainly used them on cultural materials as well (Goldberg 1996). It is likely that similar treatments were applied to objects from indigenous and world cultures at other institutions. In some collections particularly the natural sciences, the use of these chemicals persisted until well into the second half of the 20th century. It is unlikely that anyone believed that these were not poisons, they were used in ways that were deemed to be appropriate and they were thought to be beneficial rather than harmful (Hawks 2001). With this in mind, there is a probability that collections in Zimbabwe's national museums, particularly the Natural History Museum were contaminated with pesticides which were used for their treatment of pest attack. Scientific analyses on pesticide contamination in these collections will confirm whether these collections are contaminated with pesticides.

Existing literature (Hawks and William 1986; Hawks 2001; Schmidt 2001; Sirois 2001; Palmer 2001; Nason 2001b; National Park Service 2001; Sirois and Sansoucy 2001; Odegard and Sadonge 2001; Collas and Lazar 2003; Ormsby *et al* 2006; Behrooz *et al* 2009; Shugar and Sirois 2012; Tedone and Grayburn 2020) demonstrates that collections face the threat of contamination from pesticide use. Pesticides can cause metal corrosion on iron, brass and other light colour metals. They also result in the deterioration of paper and proteins such as fur, feathers, leather, wool and horsehair. In pigments and dyes, they cause colour change and also result in the shrinking, stiffening or softening of plastics. Further, they cause staining from the surface and vapour contact with collections. The contamination of objects and specimens may

affect analysis and research, such as DNA sampling (Dawson 1992; National Park Service 1998, 2014).

Different application methods of chemicals lead to the contamination of organic specimens in museums. Some pesticides were applied directly on organic specimens as part of their initial preservation against pest attack. The application involved injection of solutions of mercury or arsenic salts onto collections; rubbing of mercuric chloride or soap mixed with arsenic and corrosive sublimate on the inside of bird or animal skins; sponging, dipping or spraying the exterior of collections with mercuric chloride or solutions of mercuric chloride and arsenic on collections; as well as rubbing of powdered chalk or petroleum jelly and arsenic on collections. Additionally, pesticides are applied in museums to create a pest-free environment conducive to the conservation of collections. Some of these pesticides affect organic specimens through cross-contamination via air movement or chemical vapours (Hawks and Williams 1986; US Department of Interior (DOI) 2006).

Apart from conservation challenges resulting from pesticide contamination on museum collections, existing literature (Conserve O Gram 2000; Goldsmith 2001; Kearney 2001; Makos 2001; National Park Service 2001; Odegaard 2001; Kaminitz 2001); demonstrates that contaminated collections pose a danger to the safety of humans. Museum staff, researchers, volunteers and community members who need to access the collections on a regular basis are at risk when handling collections as analysis has confirmed that the hazardous substances in contaminated collections such as arsenic, mercury or lead can enter the human body through touch, inhalation and ingestion. Repeated exposure to contaminated collections in storage or on display exposes staff, researchers and visitors to the risk of diseases such as cancer, heart, liver and kidney failure, neurological damage, hormonal change, allergies and asthma among other ailments (Hawks and Williams 1986; Dawson 1992; Conserve O Gram 2000; National Park Service 2001, 2003; Nason 2001a; Sirois 2001).

The existing corpus of literature on pest control and pesticide contamination of collections in museums mainly focuses on global north case studies. Thus, there is a dearth of literature on these issues in the global south, particularly in Zimbabwe. This study responds to this lacuna by exploring collections preservation strategies at the Natural History Museum of Zimbabwe. The important contribution of the study lies in shedding light on toxic aspects and levels of contamination resulting from the use of hazardous pesticides in conserving collections. In light

of this, the study hopes to recommend safety measures for accessing, handling and use of contaminated collections. Such measures will encompass careful management of contaminated collections for the safety of museum staff, researchers and visitors.

1.1 Background of the Problem Under Investigation

1.1.2 Inadequate Documentation of Pesticide use in Museums and the need for Testing of Collections to Determine Chemical Contamination

Hazardous material in museum collections is a well-known problem and historically many hazardous chemicals were incorporated into collections as pest prevention systems (Goodall *et al*, 2013, Purewal 2001). These activities were probably considered part of the general care of the collections and did not warrant special documentation, thus specific techniques, the specific chemicals, and a record of the specific items that were treated were rarely recorded (Pool *et al* 2005). The historical documentation of these processes is sparse and incomplete and, in some cases, non-existent (Nason 2001b), Purewall 2001). Typically, we do not know what pesticide was applied, how it was applied, when it was applied, and how many times it was applied to collections because complete documents of potential pesticide treatments were not kept for each artefact (Shugar and Sirois 2012). Further, in the circumstance of contaminated collections, it may be difficult to accurately identify a pesticide contaminant based on the availability and accuracy of the records of the collector or museum. Collections may have been preserved in the field before reaching a museum and this information may not be recorded (Kearney 2001). For instance, Sirois (2001) highlights that scientific tests conducted by the Canadian Conservation Institute showed that five Ornithology specimens which came from the Democratic Republic of Congo in 1938 had high arsenic concentrations but there were no treatment records accompanying the specimens. Sirois argues that the high arsenic concentrations in these specimens collected around the 1920s-1930s suggest that specimens from this time should be treated with caution.

With specific reference to Zimbabwean national museums, records of chemical treatment of each artefact against pest attack since their time of establishment during the colonial era from the period 1902-1974 are rarely found. However, Zimbabwean museums were part of the South African Museums Association (SAMA) in the early days of the organisation's establishment. The South African Museums Association Bulletin (SAMAB) (1968) published some lectures by Mr Rau and Mr Schneider that indicated the adoption of EULAN® SPA 01 (permethrin) in the treatment of textiles as well as the lecture by Coffin Grey on the use of commercial chrome

and synthetic tanning on natural history specimens to conserve them against pest attack in 1968. It is not known whether such pesticides were also used by Zimbabwean museums, particularly at the Natural History Museum. Documentation of pesticide use in the museums from the 1970s up to recent times in post-independence Zimbabwe is not detailed. This phenomenon is aptly highlighted by Hawks and Williams (1986) and Nason (2001b), who argue that museum records for pesticide use for earlier periods do not exist, and oral history data on pesticide use in museums has been unreliable (Nason 2001b), therefore testing collections for the presence of pesticides is necessary (Hawks and Williams 1986). Arsenic and other toxic chemicals may be fairly common in natural history collections, and the major problem with them is the lack of treatment and preparation records for older specimens, thus there is a need for testing (Hawks 2001; Palmer 2001; Sirois 2001; Hawks and Williams 1986). Without adequate documentation of the treatment history of artefacts, the question of whether they are contaminated with toxic chemical pesticides will still remain unanswered.

This is also the case with Mammalogy and Ornithology specimens at the Natural History Museum of Zimbabwe. It has very old collections that have been collected both locally and abroad, some of which date back to the 19th Century. Records that document the treatment history of the collections are rarely found at the museum. Chemicals that have been historically used to treat the specimens against pest attack are not known. This study is significant in that it seeks to answer the question of whether organic collections at the museum are contaminated with toxic chemical pesticides through scientific analyses of the specimens. It is also significant in that it is probably one of the few, if not the first of its kind in the global south to scientifically test museum collections for toxic pesticide contaminants and to recommend safety measures for their display, storage, handling and use. The study emphasises the need for preventive care of collections against pest attack, rather than the status quo whereby there is an overreliance on toxic chemicals in the control of pests in some museums in the global south.

Chemical analysis represents one of the few reliable means for determining whether an artefact has been contaminated by pesticides and obtaining qualitative and quantitative assessments of the contamination. Although such analyses have been performed in various collections, only a few references and case studies on these analyses are reported in the literature (Kearney 2001; Palmer 2001). Likewise, such analyses have not been done in Zimbabwe's museums, thereby exposing collections to deterioration from possible contamination by pesticides and putting human health at risk through handling possibly contaminated collections.

Because museums kept incomplete and inconsistent records documenting the specific application of pesticides; because pesticides were also known to have been applied to collections by field collectors and dealers before they arrived at the museum, because personal recipes of mixed pesticides were concocted and applied to collections; and because collections were commonly moved from location to location (sold, donated, loaned, re-housed within the museum), no assumption about the pesticide content of any specific item can be made without testing (Davis *et al*, 2001). The study covers this gap through chemical analysis of the collections to determine whether they have been contaminated. Such analysis would pave way for the establishment of conservation and safety measures by the study which helps to save collections from further deterioration owing to possible pesticide contamination as well as ensure their safety and that of humans who access these collections.

1.2 Significance of the Study

This study is very important within the Zimbabwean context as it will have a socio-economic impact on museums and the public. Zimbabwe is experiencing devastating economic and social challenges that have crippled the operations of many industries and social services, many of which are operating below capacity. Public health, education and national museums are suffering from underfunding and a lack of prioritisation by the government in budget allocation. This gloomy outlook for these sectors has been exacerbated by the COVID-19 pandemic that has swept across the globe crippling economies and straining the health systems of many countries. Zimbabwe has also been heavily affected by this global pandemic which has left public institutions in dire need of funding. The deepening economic crisis, rampant corruption in the government and the Covid-19 pandemic will incapacitate national museums on collections conservation projects, including pest control initiatives. Prior to the Covid-19 pandemic, collections conservation in these museums was already suffering due to a lack of funding.

Therefore, this study is of great importance to Zimbabwe's national museums as it focuses on key collections conservation issues that have not been addressed by the museums due to lack of funding. Discovery of pesticide contamination in collections in museums is an expensive undertaking that requires specialised equipment such as an X-ray Fluorescence Spectrometer and laboratory facilities for gas chromatography-mass spectrometry (GCMS) analysis of chemical elements in collections. National museums in Zimbabwe lack the equipment and

facilities for conducting such a study. This study capacitates the Natural History Museum by conducting this vital collection conservation exercise which the museum is not able to do owing to the harsh economic conditions in which it is operating. However, there are implications for this study. If specimens are heavily contaminated, the museum may need to change its collections on display as well as its display cases. It may also need to improve ventilation in galleries and storage rooms. The museum will have to meet the costs of revamping its displays and storage areas. Considering the harsh economic conditions that are being experienced in Zimbabwe, the museum may not be in a position to embark on such an undertaking. The museum may need to consider searching for funding from donors to assist it in this revamping exercise.

Further, this study lays the foundation for Zimbabwe's museums to review their pest control programmes, some of which have been outsourced to pest control companies at a cost to the museums. It emphasises the need for non-toxic alternatives for the control of pest attack on collections in museums. These include freezing of collections to kill pests, a pest trapping programme, prohibition of food in museum storage and display cases and housekeeping among others. These measures are cost-effective compared to outsourcing pest control from commercial companies whereby the museum pays these companies for pest control services. In the long run outsourcing pest control services is expensive to the museum and the museum will be better off saving the money and investing it in non-pesticide control initiatives which are safe for both humans and collections.

This study also has a critical socio-impact in supporting the educational role of museums as well as public health in museums. Museum collections are a critical educational tool for primary, secondary and tertiary education in Zimbabwe. These collections are used in subjects such as history, heritage and biological and natural sciences. It is possible that some collections in these museums could have been contaminated by pesticides and are not suitable for use to support the educational role of museums as they endanger the health of pupils, students, teachers, museum staff and researchers. This study provides safety measures for use of possibly contaminated collections to support the educational role of the museums in the country.

The general members of the public that visit these museums and access the collections are also at risk from using contaminated collections. Research has shown that short-term exposure to pesticides during or after their application or getting into contact with treated materials can

result in mild poisoning which shows the following symptoms: headache, fatigue, dizziness, nausea, vomiting, general weakness, blurred vision, abnormal sweating and salivation, stomach cramps or diarrhoea, tightness in the chest, generalised aching and muscle twitching (Dawson 1992). Further prolonged exposure to pesticides contaminants such as arsenic, mercury and lead can cause many ailments such as heart failure, kidney failure, respiratory failure, paralysis, liver and lung infections, birth defects as well as various types of cancers (Dawson 1992; Boyer *et al.* 2005; National Park Service 2016). Zimbabwe's health system has almost collapsed with no basic facilities in public hospitals and private hospitals are beyond the reach of many. Medical doctors and nurses in public hospitals are constantly on industrial action demanding a better living wage and facilities to support their work. Besides that, most of the private hospitals are not specialised to deal with the above-mentioned ailments. The Covid-19 pandemic has stretched the resources of many of these hospitals and they are incapacitated to deal with many of the ailments caused by these pesticide contaminants. People who suffer from these ailments in Zimbabwe are forced to seek treatment abroad. This is an expensive undertaking that the majority of people cannot afford. This study is vital as it ensures that the safety and health of staff, visitors, researchers, pupils, students and teachers who access these possibly contaminated collections is guaranteed through the adoption of precautionary measures in their handling and use of these collections in the museums. Such precautionary measures will involve the use of personal protective equipment and cautionary labelling of contaminated collections to warn people about the dangers of accessing and using such collections. These precautionary measures will prevent people from contracting these chronic ailments.

The study is also in line with the *Our Collections Matter Project* of the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), whose goal is to accelerate, increase, and amplify activity in support of sustainable development through the use, development and conservation of heritage collections. ICCROM's worldwide mission and commitment is to promote the conservation and sustainable use of collections for the benefit of present and future generations. Collections and their conservation have a critical role to play in sustainable development. They are an effective way of safeguarding and transmitting cultural and natural heritage and they also provide the basis for enabling a wide range of activities and programmes in museums. These activities and programmes include learning, education, participation and research, creative industries, sustainable tourism and peacebuilding (ICCROM 2020). Additionally, the study is also aligned with the United Nations Decade of

Action to deliver Sustainable Development Goals by 2030, as it is underpinned by the realisation that collections and conservation work are an anchor for sustainable development in museums.

1.3 Problem Statement

Scientific research has shown that significant levels of pesticides exist in particular collections as well as in museum working environments and that according to medical literature these pesticides are harmful to human health, and they also react with collections resulting in deterioration. Testing continues to be conducted to identify various contaminants and appropriate handling of hazardous collections (Hawks 2001). While testing is being done for chemical contamination on collections in museums, significant studies in this area have been mainly conducted in the global north. Examples are publications by Odegaard and Sadongei (2001) whose study focused on testing collections at the Arizona State Museum for repatriation to the Native Indian Americans; Caldararo *et al* (2001) whose study focused on pesticide testing of repatriated regalia of the Hoopa Tribe of the Native American Indians; Purewal (2001) whose study focused on the identification of hazardous residues present on historic plant collections housed within the National Museum and Galleries of Wales in the UK; Schmidt (2001) whose study focused on insecticide contamination of collections at the National Museum of Denmark; Sirois (2001) whose study focused on the analysis of museum collections for the presence of arsenic and mercury at the Canadian Conservation Institute; and Goodall *et al* (2013) whose study focused on test for chemical contamination on collections in the Museum Victoria State Collection in Australia.

However, there is a dearth of studies focusing on scientific analysis for the discovery of pesticide contamination in museum collections as well as their conservation against the contaminants in Africa, particularly in Zimbabwe. A review of literature on museums in Zimbabwe shows that the debates focus on issues such as historiography of museums (Thondhlana 2015); community museums and empowerment of communities (Chikozho 2015; Chipangura and Chipangura 2020); impact of digital exhibitions on visitor numbers and demographics in museums (Chiwara and Chipangura 2019); social inclusion in museums (Chitima 2017; Chiwara 2017b), decolonisation of museums (Chaterera and Nyawo 2013, Chipangura 2018); ethics of keeping human remains in museums (Mubaya 2015); repatriation and restitution of collections in museums (Mubaya and Mawere 2015; Chiwara *et al.* 2022); collections documentation and security in museums (Chaterera 2017; Chiwara 2019); the use

of museum collections and exhibitions for informal education for school pupils and adults (Mawere and Sigauke 2015; Chipangura 2019); museum governance (Mawere and Mubaya 2015; sustainable museums (Chitima 2015); funding, management and participation of indigenous people in African museums (Mawere 2015), and public culture in Zimbabwe's museums (Chipangura 2015).

Conservation studies on museum collections, particularly scientific testing for pesticide contaminants are rare in Africa. Where conservation issues are addressed in Zimbabwe, discussions are on preventive conservation with a particular focus on storage, lack of environmental control and housekeeping (Chiwara 2017); durability of materials used in the making of art (Chiwara and Mudariki 2016); interdisciplinary collaboration in the conservation of biological matter in museum exhibitions (Chiwara 2022); and conservation of immovable cultural property such as the restoration of Great Zimbabwe World Heritage Site and Khami World Heritage Site (Ndoro 2005; Sinamai 2013; Makuvaza and Makuvaza 2017). However, the aspect of scientific analysis of artefacts for the presence of toxic residues and their effect on collections conservation and the health of people who are exposed to them is lacking in conservation studies in Zimbabwean museums. A study conducted by Chiwara (2018) showed that national museums in Zimbabwe currently use pesticides for pest control and in some cases, they outsource this vital conservation activity to private pest control companies without the input of trained conservators. Regarding the issue of whether the collections in the museums have been contaminated by pesticides, the study results are inconclusive as no scientific tests have been conducted on the collections.

Very little is known regarding the historical use of chemicals in controlling pest attack on collections in the museum. Further, no analyses have been done to determine the effects of possible pesticide contaminants on the conservation of the collections and the safety of humans who access these collections in the museum. This study located in Africa covers this gap by scientifically testing collections for pesticide contamination using the case of the Natural History Museum of Zimbabwe. The study will recommend a non-pesticide approach to conserve collections from pest attack. The approach rooted in the realities of the African context intends to limit overreliance on pesticides at the Natural History Museum of Zimbabwe and to prevent future contamination of the collections and their eventual deterioration through the reapplication of pesticides. The approach also provides measures for the safe handling and

use of contaminated collections and their storage without endangering the health of staff, visitors and researchers.

1.4 Purpose of the Study

To investigate the nature and extent of toxic pesticide residues in Mammalogy and Ornithology organic collections at the Natural History Museum of Zimbabwe. This investigation involves scientific analysis of the collections to bring out a clear picture of pesticide contaminants on them, which is largely missing and sparsely documented in collections records and archives at the museum. The study intends to recommend safe pest control measures for collections at the museum as well as safety measures for the display, storage, handling and use of contaminated collections.

1.5 Area of the Study

The study will be conducted at the Natural History Museum of Zimbabwe located in Bulawayo with a particular focus on Mammalogy and Ornithology specimens. The Natural History Museum has been specifically chosen for this study because it is the largest and oldest museum in the country having been established in 1902. It is also one of the largest museums with natural history collections in Africa and the eighth largest in the world, with over 100 000 of mammal collections and the largest bird skins collection in Africa and the fourth biggest in the world after the British Museum, The Museum of Central Africa in Belgium and the American Museum of Natural History. The bird collection comprises about 100 000 study skins, 2 000 skeletons, 8 000 egg clutches, nests, an anatomical collection as well as 40 specimen types (Natural History Museum of Zimbabwe n.d). Its date of establishment coincided with the use of harmful heavy metal compound pesticides that have been widely used in natural history collections across the globe. There is a probability that the collections could have been contaminated by these harmful pesticides.

1.6 Aim

The aim of this study is to evaluate the extent of pesticide residue contaminants on specimens and propose measures to handle, store and use collections without harming people working with them or the public viewing them. The study also aims evaluate any detrimental effect on the collections and suggest remedial action, and lastly to propose a non-toxic pest control approach that does not endanger the safety of collections as well as the health of human beings at the Natural History Museum.

1.7 Objectives

- To investigate chemical residues on collections that could be indicative of pesticide residues of heavy metal and organic compounds on the collections at the Natural History Museum of Zimbabwe.
- To analyse the state of conservation of organic collections that have been contaminated with pesticides at the Natural History Museum of Zimbabwe. This will be done through visual assessments of changes in the appearance of the collections owing to possible reactions with pesticides. The analysis will also focus on the fabric of the materials and the form of degradation that may be happening due to possible reactions with pesticide contaminants.
- To appraise pest control practices at the Natural History Museum of Zimbabwe in order to develop protocols that minimise the use of harmful pesticides and ensure the safety of museum staff and visitors from the use of contaminated collections.
- To assess possible health risks to museum staff, researchers and visitors from accessing contaminated collections and environments in the museum.

1.8 Research Questions

1. What are the chemical residues on organic collections at the Natural History Museum of Zimbabwe?
2. How have pesticide contaminants reacted with organic collections at the Natural History Museum of Zimbabwe and what is the state of conservation of the contaminated organic collections at the Natural History Museum of Zimbabwe?
3. Which pest control practices are used at the Natural History Museum of Zimbabwe?
4. What are the possible health risks to museum staff, researchers and visitors who access contaminated collections and environments in the Natural History Museum of Zimbabwe?

1.9 Ethical Considerations

Ethical considerations towards collections and participants were observed in the study. International Council of Museums (ICOM) (2017) Code of Ethics, Article 2.18 on collection

continuity stipulates that museums should establish policies that ensure that collections are available for current use and will be passed on to future generations in as good and safe a condition as practicable. Further, article 2.23 specifies that preventive conservation is an important element of museum policy and collections care. It is an essential responsibility of members of the museum profession to create and maintain a protective environment for the collections in their care. To ensure that the mammalogy and ornithology collections at the Natural History Museum of Zimbabwe are passed on to future generations in a good and safe condition as well as promote their preventive conservation, the study used non-destructive analytical methods for determining chemical contamination in the collections. This included the use of X-ray Fluorescence Spectroscopy (XRF) and Gas Chromatography-Mass Spectrometry (GCMS) in the analysis of the collections. These methods are non-destructive and promote the conservation of artefacts. We also ensured that the collections were handled and used in an environment that protected them against damage. This included the use of gloves and other necessary support equipment in the handling and movement of collections during the study. Compliance with these ethical issues promoted the principle of authenticity in the conservation of cultural property.

To safeguard research participants, as the principal researcher in the study, the researcher obtained ethical clearance from the University of Pretoria's Ethical Committee (See Appendix 1). Further, permission was granted by the director of the Natural History Museum of Zimbabwe to use the museum's collections in this study (See Appendix 2). Permission was also granted by the research participants at the museum to interview them by signing letters of informed consent to participate in the interviews (See Appendices 3-6). Other research participants agreed to take part in the research but did not sign the consent forms as they indicated that this was not necessary for them to do that because the museum had already permitted me to do my research. The researcher respected their wishes and allowed them to participate in the study. The anonymity of all the research participants was guaranteed in the study by not revealing their names and the information that they gave was used for research purposes only, and the notes written from their responses were stored securely and anonymously. The research participants were allowed to withdraw from the interviews at any time without coercing or threatening them if they felt uncomfortable continuing with the interview.

1.10 Limitations of the Study

Running costs for conducting gas chromatography-mass spectrometry are high due to the chemicals and consumables that are required for testing. The Department of Chemistry at the University of Pretoria charges R1000 per sample if it is collaborative work and R1500 for non-collaborative work. It was not feasible to analyse all 300 specimens, whose condition was assessed as a precursor to scientific analysis, as the costs were beyond the funding of this study. To reduce costs, 20 samples were selected to represent the collections for the study. These specimens were specifically chosen because they were in excellent condition, but no inorganic pesticide residues could be observed by XRF analyses. Some loose powders in the drawers were also samples. Of the 20 samples that were selected only 6 were analysed and the remaining 14 were not analysed due to a breakdown of the gas chromatography mass-spectrometry equipment. We hope to have these analysed in future and report more complete data. The University of Pretoria's Tangible Heritage Conservation programme owns a handheld XRF spectrometer so in February Maggi Loubser travelled with the spectrometer to Zimbabwe and we analysed as many samples as we could possibly fit into a week. 218 Specimens were analysed in total in Mammalogy and Ornithology departments.

1.11 Definition of Key Terms

Carcinogen: substance or physical agent that may cause cancer in animals or humans (National Park Service 2001).

Contaminant: any chemical or biological material found on museum items that pose a potential hazard to those who use or care for them. The contaminant may be inherent, such as heavy metals that occur in pigments, it may have been acquired later inadvertently, or through treatments such as chemical preservatives and pesticide application (The U.S. Department of Interior 2006).

Fumigant: a toxic, gas-phase, chemical agent that is lethal to pests, insects and or micro-organisms (Hawley 1987, cited in Derrick *et al*, 1990).

Fumigation: the use of toxic gas or vapour to kill an organism (Strang and Kigawa 2009).

Hazardous Material: chemical or mixture of chemicals that are toxic, highly toxic, irritant, corrosive, a strong oxidiser, combustible, flammable, extremely flammable, dangerously

reactive, the pressure generating, or otherwise may cause substantial personal injury or substantial illness during or as a direct result of any customary or reasonable foreseeable handling or use (National Park Service 2001).

Mammalogy: the study of mammals (Natural History Museum of Zimbabwe n.d).

Organic Collections: materials that are prone to bio-deterioration such as feathers, furs, leather, hides, cotton, wool, linen, hemp, paper, horn, wood and baleen (Dawson 1992).

Ornithology: the study of birds (Natural History Museum of Zimbabwe. n.d)

Pesticide: a solid, liquid or gaseous chemical intended to eliminate a living organism (Strang and Kigawa 2009).

1.12 Chapter Outline

Chapter 1 provided an overview of the study by discussing the background of the problem showing how pesticide use on collections began and highlighting the challenge of pesticide contamination of artefacts in museums across the globe and the need for testing to ensure their conservation and the safety of people who access and use them. It also discussed the ethical issues addressed in the study concerning data collection and the protection of research participants.

Chapter 2 reviews the literature on the study which will include a discussion on the theoretical frameworks underpinning the study. It will also review the literature on the chemical treatment of artefacts in museums by tracing the history of treatment across the globe; discussing the effects of the chemical contaminants on the conservation of artefacts and human health and safety; safety protocols for the conservation, access and handling and use of the artefacts.

Chapter 3 discusses the repatriation of possibly contaminated artefacts from museums in the global north to museums in the global south and the weaknesses of legislations in safeguarding recipients of the collections.

Chapter 4 outlines the methodology used in the study which will involve the quantitative and qualitative methods and the safety issues addressed in the study.

Chapter 5 presents, interprets and discusses the research findings in light of the objectives of the study which include investigating chemical residues on collections that could be indicative of pesticide residues of heavy metal and organic compounds on the collections at the Natural History Museum of Zimbabwe; assess the state of conservation of organic collections that have reacted with pesticide contaminants at the Natural History Museum of Zimbabwe to assess possible health risks to museum staff, researchers and visitors from accessing contaminated collections and environments in the museum.

Chapter 6 summarises, concludes and gives recommendations on the way forward regarding pest control and the protocols that need to be taken for accessing contaminated artefacts and ensuring human safety at the Natural History Museum of Zimbabwe.

Chapter 2

Literature Review

2.0 Introduction

This chapter reviews the literature which will include a discussion on the theoretical framework underpinning the study. It will also discuss the chemical treatment of artefacts in museums by tracing the history of treatment across the globe; the effects of the chemical contaminants on the conservation of artefacts and human health and safety and safety protocols for the conservation, access, handling and use of the artefacts in museums.

2.1 Theoretical Lens: Weiss's Concept of “The Planetary Trust: Conservation and Intergenerational Equity” and the concept of “Integrated Pest Management”.

This study is theoretically guided by the contemporary theory of conservation. The contemporary theory of conservation is not a single framework but a multi-dimensional knowledge corpus, which includes articles, book chapters and international conventions and charters (Salvador 2002). This study is specifically informed by theoretical strands from Weiss' (1984) concept of “The Planetary Trust: Conservation and Intergenerational Equity” as well as the concept of “Integrated Pest Management” which falls under the contemporary theory of conservation. These two concepts have been particularly chosen because they uphold sustainable practices in the conservation of cultural and natural heritage. Weiss (1984) highlights that our cultural heritage – the intellectual, artistic, social and historic record is important because it represents our contribution as a species to the planet. It is the source of ideas, knowledge, and skills that future generations may use in their efforts to provide for their own well-being. The purpose for which we hold the earth's resources among other things is to sustain a healthy and decent environment. Weiss (1984) further argues that we act as trustees for future generations and that we have a fiduciary obligation to conserve this heritage for them. Thus our fiduciary obligation consists of two duties which are: to conserve options by conserving the diversity of the natural and cultural resource base; and to conserve the quality of the trust's corpus by leaving the planet in no worse condition than we receive it.

Weiss (1984) avers that there are challenges of toxic chemicals that are released into the environment and that our capacity to harm the environment globally forces us to be concerned at a global level with the survival of the natural and cultural heritage that we pass to future generations. Likewise, toxic chemicals from pesticide use have contaminated collections and museum environments leading to the deterioration of some collections and endangering the

health of museum staff and visitors. Weiss' concern about the effect of toxic chemicals on natural and cultural heritage forms the foundation of this study. This study is anchored on the need to ensure that collections at the Natural History Museum of Zimbabwe are safeguarded from possible deterioration owing to contamination by toxic chemicals from pesticides. It also explores feasible ways of ensuring that the museum environment is safe for humans through prioritising non-pesticide methods in the control of pests.

Weiss (1984) challenges the current generation to ensure that it conserves cultural heritage for posterity. Weiss argues that we must be concerned with both human and natural degradation of art objects and other cultural properties and that new causes of degradation must be guarded against. Further, Weiss contends that our fiduciary obligation as trustees of the planetary trust can be inferred from the nearly universal recognition and acceptance among peoples of an obligation to protect the natural and cultural heritage for future generations. Under the principle of conservation of quality, Weiss (1984) also challenges people to pass on their heritage to future generations in no worse condition than they found it. In cases, where one generation fails to meet this obligation and passes the heritage in worse condition than it received it, the inheriting generation has an obligation to ensure that the planet does not deteriorate further. For instance, the principle states that if a past generation has disposed of hazardous substances in such a way that their ill effects are felt by the present generation, the present generation is responsible to take whatever measures are necessary to ensure that the substances do not harm future generations (Weiss 1984). This principle is in line with the thrust of this study which seeks to discover contaminated objects from past and present pesticide use at the Natural History Museum and institute preventive conservation strategies on pest control which safeguard its objects and ensure the safety of current and future generations of museum staff, researchers and visitors.

Weiss' (1984) concept also proposes that among other strategies, there be the promotion of scientific research and development to analyse the impact of human activities on the environment. This may yield new information about the impact of human activities on the diversity and quality of our natural and cultural heritage, thus helping us to assess with greater precision the risk that our activities pose to them. Weiss' call for scientific research on the impact of human activities on the quality of cultural heritage resonates well with the methodological approach of this study which uses scientific research methods such as XRF spectrometry and gas chromatography-mass spectrometry to unearth possible toxic pesticide

contaminants on collections at the Natural History Museum of Zimbabwe. Some chemical contaminants cannot be seen by the naked eye and only scientific analysis using these research methods will expose such kind of contamination on objects caused by past and current human activities in the control of pests in museums. This will help in determining the level of risk that staff, researchers and visitors face when working with possibly contaminated collections at the Natural History Museum.

However, Weiss' concept's principles such as the preservation of the quality of trust assets can only be used as general guidelines in the conservation of collections in museums. The principles are not specific in terms of the actual conservation measures that need to be adopted to prevent the contamination of collections and museum environments by toxic chemicals from pesticides. This lack of specificity on the actual conservation measures that need to be adopted will be dealt with through the use of strands from the concept of Integrated Pest Management (IPM). Integrated Pest Management is a decision-making process that coordinates knowledge of pest biology, the environment, and available technology to prevent unacceptable levels of pest damage by cost-effective means while posing the least possible risk to people, resources and the environment (National Park Service Management Policies (2006) cited in National Park Service 2014). IPM uses various techniques to prevent and solve pest problems using knowledge of a pest's habits, ecology, and the environment in which it thrives and survives. These include preventive maintenance, adherence to an established housekeeping plan, rigorous exclusion, sanitation and a pest-trapping programme. IPM is site-specific, adaptable to any museum setting, and protects the museum and its collections from museum pests with minimal pesticide use. It discourages reliance on chemical treatments and provides safer alternatives (National Park Service 2014). Alternatively, integrated pest management involves methods and techniques used to prevent pests in museums and how to take appropriate pest control measures to mitigate the problems (Pool *et al* 2005).

The United States Department of Interior (USDOI 1993) cited in Tsosie (2001:25) asserts that traditionally, museum practices focused on controlling pests through the use of dangerous chemicals for the preservation of objects. However, current museum policy acknowledges that contemporary studies have demonstrated that these chemicals can damage the artefacts and pose health risks to staff. This has motivated museums to adopt the contemporary practice of integrated pest management (IPM). This is an ecosystem approach to pest control that use a variety of approaches to eliminate pest problems in the most efficient and ecologically friendly

manner. The policy shift acknowledges that museums have a duty to preserve the collection in their care and to safeguard the health of their staff members (Tsosie 2001).

This Integrated Pest Management concept is specific to preventive conservation measures on pest control in museums. Thus this concept is in harmony with this study as it is advocating for non-pesticide control of pests in museums to prevent the contamination of collections and museum environments. Some of the elements of IPM involve monitoring, inspection and pest identification to determine the most appropriate, effective and low-risk treatment methods (National Park Service 2014). These elements are in line with the objectives of this study and they will be used as guidelines for establishing protocols that limit the use of pesticides at the Natural History Museum thereby preventing contamination of collections and ensuring the safety of staff, visitors and researchers. However, IPM has a limitation in this study as it only focuses on the detection and control of pests in museums. It does not have provisions for the detection of toxic pesticide contaminants in museum collections and museum environments. This limitation will be addressed through the adoption of the principle of scientific research and development in Weiss' (1984) "Planetary Trust: Conservation and Intergenerational Equity" concept. The principle supports the use of scientific methods in the discovery of toxic pesticide contaminants in collections and museum environments.

The other limitation of IPM is that some of its provisions are expensive and are beyond the reach of many museums in the global south, particularly Zimbabwean museums. For instance, it calls for appropriate facility design and construction practices with the help of architects as a way of preventing museum pest infestation (properly sealing the building envelope; routine maintenance of and upgrades to structures housing collections. It is also labour-intensive as it requires constant monitoring of pest activity in the museum as well as thorough housekeeping. Despite IPM's shortcomings, it is environmentally friendly and it is safe for humans and collections compared to pesticides. This study will adopt strands from the IPM concept that focus on pest control aspects that can be afforded by museums in the global south. This will form the basis of non-pesticide approaches in the control of pests which the museum can build on and then adopt other expensive non-pesticide methods if funding becomes available.

However, the call for scientific research and development in analysing the impact of human activities on the natural environment by this concept is not specific to the realities of the socio-economic conditions experienced in countries in the global south, particularly in Zimbabwe

where there is rampant poverty, corruption and a non-performing economy. It would be difficult to implement in Zimbabwe as museums do not have the capacity to embark on such projects. For instance, scientific research methods for determining toxic pesticide contaminants in museum environments and on collections, such as XRF spectrometry and GC-MS spectrometry are very expensive to undertake and they are beyond the reach of many museums globally. In the global north, most museums form consortiums to acquire these technologies or partner with a scientific institution or a large museum that has these analytical capabilities. In the global south, one of the challenges is that there are not nearly as many institutions to partner with local museums to conduct this kind of research. The XRF spectrometry alone costs around R750 000. Chromatography needs a well-equipped laboratory for it to be conducted and consumables and chemicals needed for the study are very expensive. Unlike some museums in the global north which are well equipped with conservation resources, conservation of collections in museums in many museums in Africa is yet to develop and many museums including the Natural History of Zimbabwe do not have laboratories and equipment to undertake this kind of research. This is only achievable through partnerships and funding from international organisations. To deal with this challenge, this study is being carried out with the support of the University of Pretoria which is providing the equipment and laboratory facilities for the analysis of the collections.

Despite a few limitations highlighted on the use of these two concepts as theoretical frameworks for this study, their principles on the discovery of toxic chemical contaminants in collections and the use of non-pesticide methods on pest control in museums respectively are very relevant to this study. The conservation principles found in these concepts challenge us to think critically about conservation decisions we make as they have an impact on the environment, collections and the health and well-being of humans currently and in the future. These concepts remind us to be conscious about the use of toxic chemicals on cultural heritage and consider their impact on the ability of future generations to utilise this heritage in almost perfect condition without causing harm to them and the environment. They call for the sustainable conservation of objects in museums for the benefit of future generations. The concepts promote cultural sustainability, which refers to the adaptability of conservation objects for future use (Salvador 2002). Both concepts advance principles of responsible conservation which do not harm the environment where we live as human beings as well as the collections that we use in museums.

2.2 History of Chemical Treatment of Organic Collections in Museums

Historical information concerning the use of pesticides and fumigants is important in understanding and evaluating the care and treatment museum collections have received in the past. A wide variety of chemicals including herbicides, fungicides and other various substances have been used consistently over a century ago to prevent, destroy, repel or mitigate pests in order to preserve museum collections (See Table 1 for a summary of the pesticides that have been used in museums). These chemicals are basically in three types namely; botanical, inorganic and organic pesticides. They were applied in many ways through spraying, aerosol bombing, fogging, dusting, painting, dipping or fumigation techniques as fumigant gases (Goldberg 1996; Loma' Omvaya 2001; Nason 2001c; Pool *et al* 2005). Application techniques of the hazardous pesticides on collections differed depending on the type of the artefact. Fragile objects were sprayed, small specimens were dipped and larger objects were painted (Loma' Omvaya 2001).

Table 1 Chronology of historical use of pesticides in museums (Osorio 2001)

Years	Chemicals used
Early 1800s	Compounds containing inorganic arsenic & compounds containing inorganic mercury
Mid -1800s	Continued use of arsenic and mercuric compounds, tobacco, sulphur, camphor & heat
Late 1800s & early 1900s	Continued use of arsenic & mercuric compounds, strychnine, carbolic acid, naphthalene, wax/solvents & carbon disulfide
Mid-1900s	Dichlorobenzene, hydrocyanide, gas, aluminium silicate, DDT, ethylene dichloride, carbon tetrachloride, ethylene dibromide, dichlorvos, sulfuryl fluoride & freezing

During the eighteenth century, European naturalists and collectors possessed large quantities of specimens sent back from Africa, Asia, and the New World by explorers, colonists and professional naturalist collectors. In the preparation of taxidermy for ornithology specimens in the eighteenth century, the danger of the destruction of collections by pests remained. Written records of naturalists such as Turgot, Kuckahn, Mauduyt and Becoeur suggest in the eighteenth-century chemicals such as alum and camphor and mixtures that included a liquid varnish made of raw turpentine, camphor and the spirit of turpentine; a dry compound made of corrosive sublimate, saltpetre, alum, sulphur, musk, pepper and ground tobacco; and powdered

white arsenic, soap, salt of tar, camphor and powdered lime were used for preserving bird skins. Some were sprinkled inside bird skins (Farber 1977).

Museum and expedition records suggest that during the late 19th century and early 20th centuries, both field collectors and museum professionals also applied chemical preparations for pest control, following instructions published by the curators of larger museums such as the American Museum of Natural History and the Smithsonian Institution (Goldberg 1996; Pool *et al* 2005). With regards to natural history collections, the physical preparation of study skins was done by both amateurs and professionals within the field and in the museum and they travelled in and out of and within countries. The methods they used have allowed specimens to survive into the 21st Century (Lewis 2012). Early evidence suggests that 19th-century collectors applied poison to their anthropological and biological specimens during collecting trips to reduce pest damage while in transit. With regards to the Smithsonian's National Museum of Natural History, some records of the 19th century indicate that pests were a menace to the museum's anthropological collections, and chemicals such as arsenic (arsenic powder, soap, paste, chalk, vaseline, potassium arsenite or water-soluble arsenic acid), mercury compounds (mercuric chloride or corrosive sublimate) benzene, alcohol, fumigating tobacco, camphor, flour of sulphur, were purchased for use during field collecting and in the museum to aid in the preservation of specimens. The records indicated that it was a standard procedure that collections were poisoned before they entered the museum to ensure that eggs and larvae of insects were destroyed while preserving the colour, softness and texture of the specimens (Goldberg 1996; Austin *et al* 2005; Sirois *et al* 2008).

By 1830, arsenic had become the standard preservative of ornithology specimens against pest attack, because firstly it was effective and secondly because it was popularised by the preparators at the Museum National d'Histoire Naturelle (Farber 1977). Arsenic compounds (arsenic trioxide, arsenous acid, sodium arsenite, potassium arsenite), mercury compounds (mercuric acid solution, mercuric chloride, boric acid and dichloro-diphenyl-trichloroethane (DDT) are common pesticides that have been historically used in museums. These chemicals were used in preparing taxidermy animal specimens as well as protecting materials prone to pest attack such as feathers, skins, hair, fur, fabrics, wood and baskets. By nature, arsenic pesticides are very persistent compounds that reside in treated specimens sometimes appearing as fine white dust (Dawson 1992; Goldberg 1996; Loma' Omvaya 2001; Kearney 2001; Nason 2001c; Pool *et al* 2005). Arsenic and mercury compounds have long been used by natural

scientists who valued their preservative properties for natural history specimens. They were rubbed inside the skins to prevent them from deteriorating. Other naturalists used both arsenic and mercury compounds on the same specimen (Hawks 1986; Kearney 2001:44-45; Sirois *et al* 2008;176; Lewis 2012: 133-134). Further, Early collection records also showed that crystalline mercuric chloride was scattered over objects such as textiles as well as in drawers of objects as a way of protecting them against pest attack (Goldberg 1996).

Published accounts and manuals suggest that natural scientists of all disciplines practised similar preservation techniques for biological specimens and ethnological specimens (Goldberg 1996). Documents shared by naturalists, museums and related institutions across countries such as Britain, France, Germany and the United States in the 18th and 19th centuries indicate acceptance and widespread use of arsenic and mercury compounds in preventing pest attack on natural history collections. The Royal Society in London, the Museum National d'Histoire Naturelle in Paris, the Museum of Natural History in Paris, the Smithsonian Institution in the United States and the National Museum of Canada are some of the institutions that have historically used arsenic and mercury compounds in the control of pests (Hawks and Williams 1986, Sirois *et al* 2008). It is likely that similar chemicals were applied to objects from indigenous and world cultures at other institutions. While their use in anthropological collections seems to have ceased about 100 years ago, in some collections, particularly in the natural sciences, the use of these chemicals persisted until well into the second half of the 20th century. It is unlikely that anyone believed that these were not poisons, it was simply that they were used in ways that were deemed to be appropriate. They were thought to be beneficial rather than harmful (Hawks 2001).

Naphthalene, paradichlorobenzene, tar camphor, hydrocyanic acid, fluorosilicate compounds, strychnine in arsenical solutions, thymol, salicylic acid and chlorinated hydrocarbons are also other chemicals that were used for pest control in the late 19th century and the greater part of the early 20th century respectively. Naphthalene and paradichlorobenzene have both been used in museums for much of the 1900s, and are still used in some museums today. These chemicals were used as volatile preservatives or fumigants in closed cases. (Hawks 2001; Austin *et al* 2005; Pool *et al* 2005). As additional pesticides from the agricultural developments of the mid-20th century were introduced, museums utilised a greater variety of chemical pesticide products (Pool *et al*, 2005). More chemicals such as carbon disulfide, ethylene dichloride, ethylene dibromide, carbon tetrachloride, hydrocyanic acid gas, larvex, entol, hydrogen

cyanide, chloropicrin, tar camphor, carbon disulphide, hydrocyanic acid, fluorosilicate compounds, dowfume G, dowfume 75, methyl bromide were used in the 20th century. By the mid-1940s new organic pesticides were adopted for use and among the most persistent were DDT (dichloro-diphenyl trichloroethane), dieldrin, chlordane, lindane and methoxychlor which can remain effective on treated surfaces for decades. They were used for pest control in exhibit cases through fogging of all object surfaces. These objects included materials such as textiles, felts, furs, feathers, leather, mummies and whalebone (Goldberg 1996; Kearney 2001; Nason 2001c, Pool *et al* 2005, Sirois *et al* 2008). During the second half of the 20th century, these chemicals were later replaced by less toxic organophosphates such as vapon strips and DDVP which were often used in closed exhibit and storage cases. Other chemicals that were also used during this period include organic phosphates such as parathion, malathion, diazinon and DDVP (dichlorvos), dimethyl formamide, and methyl bromide, (Nason 2001c; Sirois *et al* 2008).

Sirois *et al* (2008) assert that in a survey carried out on museums in New York City in 1982, it was discovered that 27 museums used a variety of pesticides and fumigants which included ethylene oxide, para-dichlorobenzene, pyrethrins, thymol, naphthalene, methoxychlor, ethyl alcohol, dursban (chlorpyrifos), methyl bromide, formaldehyde, chlordane and bendiocarb. On the other hand, in the first half of the 20th century National Museums of Canada which consisted of the National Gallery of Canada, the National Museum of Man and the National Museum of Natural Sciences used a mixture of three parts ethylene dichloride with one part of carbon tetrachloride as well as carbon disulphide, hydrocyanic acid gas, chloropicrin, naphthalene and para-dichlorobenzene. Other chemicals used include sodium fluoride and a solution of mercuric chloride in alcohol (Leechman 1931 cited in Sirois *et al* 2008:177).

Also, a mixture of ethylene dichloride, carbon tetrachloride and ethylene dibromide was used in the fumatorium (fumigation) chambers to treat objects affected by insects (Goldberg 1996, Nason 2001c). For a while in the later 20th century, the use of pressurised fumigation chambers in museums was considered safer, faster and more effective in controlling insect pests. Examples of the fumigants used included ethylene oxide, methyl bromide and sulfuryl fluoride (Pool *et al*. 2005; Sirois *et al* 2008). They were mainly used between the 1960s and 1980s. However, their use was stopped due to health concerns. Carboxide, (a mixture of Ethylene oxide 90% and carbon dioxide 10%) as well as ethylene oxide on its own, propylene oxide, vikane (sulfuryl fluoride), and methyl bromide were/are also used for fumigation purposes.

These are all toxic to humans and react with artefacts (Goldberg 1996; Nason 2001c; Kigawa *et al* 2011). These chemicals are of course just the highlights of a selected few chemical agents and are by no means more than a sampling of what has been used (Nason 2001c).

Many institutions with natural history collections have similar histories of pesticide and fumigant use (Goldberg 1996). It is important to note that in a great many cases donated objects were clearly treated by the collectors, not the museum. Similarly, some objects received from other institutions through exchanges or by purchase from dealers may be contaminated. We cannot assume that the source did not treat objects with pesticides. The use of pesticides has been considered a professional standard to prevent insect damage from the 1800s until only recently, and museums have used successive waves of chemical agents to achieve this goal. Many dangerous pesticides used from the 19th century are as toxic now as they ever were and have remained as residues on and in artefacts. According to historic documents, museum records, interview evidence from museum employees, and the few available test results, it can be assumed that most if not all museum collections or organic materials have been treated with pesticides and other hazardous chemicals (Davis *et al* 2001).

The widespread use of these chemicals in museums across the globe could be indicative of their presence in collections at the Natural History Museum of Zimbabwe. Although there is no specific information about the possible presence of these chemicals in collections in museums in the global south, particularly in Zimbabwe, it is likely that the collections may be contaminated as the application of chemicals was universal across museums. As shown in chapter one, the Natural History Museum of Zimbabwe is a product of colonial white settler communities who came into the country to explore economic wealth. These European explorers travelled around the world collecting treasures such as artefacts and treating them against pest attack. These artefacts were then deposited in museums.

The Natural History Museum of Zimbabwe is home to thousands of specimens that have been collected across the globe. A preliminary survey of ornithology and mammalogy artefacts conducted by the researcher at the museum showed that the museum has collections from the 19th and 20th centuries which have been collected abroad including countries such as the United States, Mexico, Australia, Britain, Denmark, Philippines, India, Afghanistan, Kenya, Mozambique, South Africa and Tanzania amongst others. The treatment history of these collections from their source countries is not known. Some artefacts in this museum originated

from big institutions such as the Smithsonian Institution in the United States and the British Museum, which are known to have treated their artefacts with harmful chemicals such as arsenic and mercury. It is likely that these artefacts could have been treated with these chemicals. Therefore, no chances should be taken with these collections as they may be contaminated with harmful chemicals that are hazardous to human health and also affect the conservation of collections that react with these chemicals.

What we do not know precisely is which chemicals were applied to the in objects. This study endeavours to cover this gap by examining the collections and the storage places to identify the chemicals that could have possibly been used for pest control and establish the potential danger of the chemicals to humans. This is vital as it will pave way for the establishment of safety protocols for accessing, handling, use and conservation of the collections at the museum.

Some of the chemicals highlighted above, including arsenic and mercury, are not only very persistent, but they can also leave residues that represent a real toxic risk to humans as they are carcinogenic as well as poisonous. All specimens collected before 1970 should be examined for evidence of these pesticides before being handled (Nason 2001c). The researcher concurs with Nason's call for the examination of all specimens collected before 1970. The Natural History Museum of Zimbabwe was established much earlier than 1970 and a huge number of its artefacts were collected outside Zimbabwe where their treatment history is not known. Finding out which chemical was actually used in a museum may be difficult as not all museums have kept records about what was used to treat objects. Further, many donated objects were treated by the collectors, not the museum, and some objects received from other institutions through exchanges or by purchase from dealers may be contaminated (Nason 2001c). There is a possibility that some of the artefacts at the Natural History Museum of Zimbabwe are contaminated with harmful pesticides. Therefore, this research covers this gap by analysing the specimens at the museum to ascertain the toxic chemicals that have contaminated them.

2.3 Effects of Pesticides on the Conservation of Museum Collections

The role played by pesticides in combating pests in museums cannot be overemphasised. Most museums in Africa rely on pesticides in protecting collections against pest attack. However, overreliance on pesticides causes unwanted damage to collections and museums in Africa should address this issue to safeguard collections from deterioration. The literature reviewed

below demonstrates that indeed pesticides lead to chemical reactions with museum collections resulting in their eventual deterioration. Yet there is a lack of empirical studies to highlight this conservation problem on collections in museums in Africa. This study covers this gap by analysing the effects of pesticides on organic collections at the Natural History Museum of Zimbabwe.

Information on pesticide and fumigant use in museum collections is vital to the understanding of past methods of care, historical treatments and chemical alterations (Pool *et al* 2005). Professional conservators have long been concerned that the use of chemicals in museums may cause unpredictable, disfiguring, and irreversible changes to the artefacts treated (Odegaard and Sadongei 2001). Many items exhibit stains, tide lines, or areas of white and crystalline bloom (Goldberg 1996). With regards to the anthropological collections at the Smithsonian's National Museum of Natural History, observations indicate that objects have treatment-specific characteristics such as increased embrittlement, salt efflorescence and significant colour change (Austin *et al* 2005). A chemical known as Maynard's Dermal Preservative was used by ornithologists in the mid-1880s to protect bird skins against insects as well as safeguard staff's hands from arsenic poisoning. Despite claims that the chemical was totally harmless, by the end of the 19th century it had discoloured plumages, was discredited and no longer appeared in the bird preservation literature. Borax which was used as a natural soap and mild insect repellent for many decades has been stopped because it was discovered that it accelerated colour changes to plumage (Lewis 2012). Elsewhere methyl bromide has been banned for use in countries in the global north due to its adverse effects on museum collections. However, in some developing countries methyl bromide is still being used until such a time it is completely phased out of use (Kigawa *et al* 2011).

Pesticides also result in chemical reactions with objects which cannot be observed by the naked eye. Some chemicals have an adverse effect on the DNA of natural history specimens. For instance, fumigants such as methyl bromide, methyl iodine, ethylene oxide and propylene oxide make DNA molecules in natural history specimens fragile and subsequent DNA analysis is difficult. DNA analysis of natural history specimens is very important in modern taxonomic studies and therefore it is vital to ensure that this DNA is not disturbed by chemicals (Kigawa *et al* 2011).

Kigawa *et al* (2011) carried out a study on the effects of fumigants on proteinaceous materials in museums which included muscle specimens, animal glue and silk textiles. There are many kinds of proteinaceous components found in natural history collections such as muscles, furs, feathers, leathers or ethnology collections such as animal glue, casein and albumin used in paintings; wool and silk in textiles; and gelatin in photographic materials. The results of the study showed that the freeze-dried muscle specimen did not show significant changes visually, however, when soluble proteins were extracted for sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE), large fractions of soluble proteins were absent from treatments using methyl bromide, methyl iodine and sulfuryl fluoride, indicating possible alterations with more significant changes in samples treated with higher concentrations of these chemicals. Thus the chemicals led to the denaturation of proteins in muscle specimens. The study also showed that there was some modification of protein-based collection that was fumigated with pure-grade vikane (sulfuryl fluoride, greater than 99.8%). These results demonstrate that the muscle protein samples fumigated with methyl bromide, methyl iodine and sulfuryl fluoride had undergone conformational changes that cause a loss of the original properties of the muscle by the fumigation treatment (Kigawa *et al* 2011). It has also been observed that when sulphuryl fluoride condenses during atmospheric fumigation it damages wallpaper and corrodes brass collections (Dawson 1992).

Kigawa *et al* (2011) also showed that fumigation left chemical residues on artefacts. Bromine and iodine residues were clearly observed through the use of XRF. These residues were from treatments that were done using methyl bromide and methyl iodine respectively more than 5 years earlier. Similarly, bromine or iodine was also found on the piles of several glues or polyethylene sheets and residual bromine was detected with several layers of silk textiles and glue beads. Elsewhere, in a study carried out in 1982 by the Carpet and Rug Institute with the National Pest Control Association and the United Pesticide Formulators and Distributors Association, it was discovered that dichlorvos produced an unacceptable colour change on acid red used in carpets. The study also showed that dichlorvos causes discolouration of textiles; it is corrosive to mild steel and black iron; and it tarnishes copper, silver and brass collections (Dawson 1992).

Organophosphates have also been found to react with red dyes in carpets when applied under conditions of high relative humidity. They also cause staining of museum collections. Examples include chlorpyrifos and diazinon. Apart from affecting red dyes on carpets, the

former corrode brass and copper collections, whereas the latter causes deterioration of collections when it mixes with solvents. Another organophosphate is malathion and tests carried out demonstrated that it is corrosive to iron, steel, tin plate, lead and copper materials. Tests also showed that it affects carpets containing acid red, disperse red, or telon red dyes (Dawson 1992).

Naphthalene is also another chemical that reacts with museum collections. Under uncontrolled environments, it can recrystallise on specimens, and in the presence of moisture, it produces a reddish-brown discolouration in wool. Naphthalene can also cause fats in biological specimens such as stuffed animals to dissolve resulting in damage (Dawson 1992). Another chemical that reacts with museum collections is paradichlorobenzene. It causes discolouration of ultramarine, yellowing of paper, and fading of ink and can also affect zinc white, lithopone and scarlet pigments. It alters some cellulose acetate dyes and also causes excessive shrinking of polystyrene forms. Apart from the above-mentioned chemicals, phosphine is also another chemical that is dangerous to museum collections as it is spontaneously flammable and reacts violently with oxygen, nitrates and halogens (Dawson 1992).

There are also carbamates that have been used for pest control in museums, such as bendiocarb, carbaryl and propoxur. Bendiocarb has caused no significant staining on carpets with red dyes, whereas carbaryl has been found to be non-corrosive. However, due to the residual nature of carbaryl, care should be taken to prevent contact with collections. Regarding propoxur, manufacturers have cautioned about its use on carpets, drapes, wallpaper or similar materials that may be stained. When using it near collections, they must be covered with protective polyethylene (Dawson 1992).

Botanic insecticides are also used for pest control. They consist of organic insecticides that are derived from plants as well as synthetic botanicals, also known as synthetic pyrethrins or pyrethroids. The latter is more stable and toxic to insects than the former. Botanicals and synthetic pyrethroids should be assessed individually since some are more toxic than others. An example is pyrethrum and its reactivity with collections in museums is unknown, though there is a possibility of solvent effects. Collections should not be allowed to come in contact with insecticides containing pyrethrins or pyrethroids (Dawson 1992).

The effects of pesticides on museum artefacts have been demonstrated, and they include colour distortion, alteration of DNA of organic specimens and deposition of chemical residues on artefacts. Thus they affect the integrity and authenticity of artefacts, yet their use is widespread in museums in the global south. The Nara document on authenticity (1994), section 9 on values and authenticity, specifies that the conservation of cultural heritage in all its forms and historical periods is rooted in the values attributed to the heritage. Museum artefacts have research, social and aesthetic values which should be safeguarded. Section 10 further states that the understanding of authenticity plays an important role in scientific studies of cultural heritage and in conservation and restoration planning. Section 13 specifies that authenticity judgements of cultural heritage may be linked to a variety of sources of information, particularly form and design, and materials and substance which are relevant to this study. These sources permit elaboration of the specific artistic, historic, social and scientific dimensions of the cultural heritage being examined.

However, as demonstrated above, pesticide contaminants alter the DNA, colour and appearance of the artefacts. This, in turn, affects the form and design, and materials and substance of the artefacts. Therefore, chemical pesticides affect the authenticity of artefacts by interfering with their research, and social and aesthetic values. It is very likely that artefacts at the Natural History Museum are experiencing gradual deterioration owing to possible pesticide use, which may not be noticed currently, but may become full-blown and uncontrollable in decades to come. Therefore, this study is a necessity to assess the effects of pesticides on the collections and to establish and institute preventive conservation measures that stop the deterioration of collections caused by pesticides.

2.4 Health Hazards of Pesticides Contaminants in Museum Collections

At the end of the 20th century, the use of pesticides in museums became undesirable. In museums, there has been greater awareness of the effect of pesticides on the safety of museum workers and the adverse effect on artefact appearance (Pool *et al* 2005). There are several reasons why the historic use of pesticides to prevent insect damage to objects is now an increasingly important subject that needs attention. The most important of these reasons is that many of those very dangerous pesticides used from the 19th century are as toxic now as they ever were and have remained as residues on and in objects. The other reason is that some of these chemical compounds such as arsenic and mercury, and those that followed are variously explosive, flammable, carcinogenic and mutagenic as well as being just plain poisonous (Nason

2001c). Chemicals now known to be carcinogenic were routinely used in museums with no safeguards for staff who applied them to collections (Hawks 2001). Many of the pesticides used in fumigation chambers and forging have been taken off the market for environmental or human health reasons (Pool *et al* 2005).

The potential for pesticide residue remaining on collection objects is very high. Collections with such residues are a health hazard to curatorial staff and the public who come into physical contact with them (Kaminitz 2001; National Park Service 2001). Scientific research has shown that substantial levels of pesticides exist in specific collections as well as in museum working environments and that according to medical literature these pesticides are harmful to human health (Davis *et al*, 2001). Insecticides can cause mild and severe poisoning (Dawson 1992). There are suspicions that link pesticides with cancer, hormonal change, neurological damage, and increased rates of allergies and asthma in human populations, with associated environmental and health costs estimated at \$8 billion per year range in the United States in 1990 (Nason 2001a).

The following are the health effects of some of the chemicals that have been used or are still in use in some museums. Inorganic pesticides such as arsenic and mercury, they were among the first insecticides used in museums in the preservation of animal and bird skins in taxidermy specimens. They are usually very persistent and slow-acting and remain toxic long after treatment to those who handle treated items and care should be taken to prevent ingestion (Dawson 1992; Goldberg 1996; Boyer *et al* 2005). Pesticides containing arsenic and mercury have been used ubiquitously and for a long time on leather and feather-containing artefacts in museums, and generally in amounts that are capable of harming humans. They are environmentally permanent and create hazards of air, soil, and groundwater contamination (Boyer *et al* 2005). Arsenic insecticides appear in treated specimens as fine white dust. They enter the human body through inhalation, skin absorption or ingestion. Their signs and symptoms include loss of appetite, cramps, nausea, headache, itching of the skin and dizziness. Arsenic causes health effects on the kidneys, lungs, liver, and nervous system and it has been linked with cancers of the skin, pulmonary, mouth, oesophagus, larynx, bladder, and paranasal sinus (Dawson 1992; Osorio 2001). Arsenic caused depressive effects as well as physical ailments on staff who prepared study skins in the late 19th Century. Such physical ailments included rendering hands painful and immobile (Lewis 2012). This is a major concern for the health of people who work with museum collections and steps should be taken for the

protection of staff and other users of the collection (Nason 2001c). People with diseases of the skin, blood, hair, liver, kidney or central nervous system should avoid any risk or exposure to arsenic (Kaminitz 2001).

On the other hand, mercury (Hg) (mercuric chloride) is a neurotoxin (nerve poison) that can be absorbed into the body through direct contact, ingestion or inhalation of mercury vapour. It can accumulate in the kidneys and the brain resulting in mental and physical symptoms. Inorganic mercury in the blood of a pregnant woman can also enter the developing foetus (Canadian Conservation Institute 2002). It is associated with symptoms such as irritations to the skin, eyes, nose, throat and lungs and possible shortness of breath and coughing. Very high exposure to mercury causes gingivitis, tremor, proteinuria (loss of protein in the urine indicating renal damage), and neuropsychiatric manifestations (changes in personality, sensations, and motor coordination) (Osorio 2001). Artefacts with open surfaces of mercury or damaged objects where mercury has spilt present a risk. Mercury compounds can be absorbed easily into the body, even extremely small amounts absorbed over time can cause chronic effects (Canadian Conservation Institute 2002).

Another inorganic chemical that is used in the treatment of artefacts in museums is amorphous silica gel (silicon dioxide), also known as amorphous hydrated silica, silica aerogel or silica gel. It enters the human body through inhalation or ingestion and it affects the respiratory system and causes skin irritation. Silica gel in its pure, unaltered form is considered non-toxic. However, it may contain other crystalline varieties of silica that cause fibrosis (Dawson 1992, 20). Silica which has been used in combination with other active ingredients in some pesticides has been shown to cause pulmonary cancer, whereas ethylene dibromide which is a known genotoxic agent causes reproductive effects (Osorio 2001).

Dichlorvos (2,2-dichlorovinyl dimethyl phosphate) also known as DDVP, dichlorvos or vaponal has also been used for pest control in museums. It is very toxic and is easily absorbed through the skin. It is a persistent chemical that tends to be moderate to high in toxicity, but it breaks down with time. Potentially, dichlorvos can cause neurological effects and can result in excessive secretions, heart rhythm disturbance, coma, seizures and death. Due to its hazardous effects on humans, its use in museums should be considered as a stop-gap measure (Dawson 1992; Osorio 2001, Boyer *et al.* 2005). Another chemical is methyl bromide

(Bromomethane), it is very toxic to humans and museums should use it only as the last option if there is a major infestation of pests (Dawson 1992).

Naphthalene also affects human health through inhalation of vapour or dust, skin absorption and skin and eye contact. It affects the eyes, blood, liver, kidney, skin, red blood cells and the central nervous system. Upon surface contact, it causes cataracts, ocular irritation, skin irritation, severe dermatitis and systematic poisoning in infants. Inhalation or ingestion of high concentrations of naphthalene causes headache, confusion, excitement, nausea, vomiting, extensive sweating, dysuria, acute haemolytic anaemia, abdominal pain, bladder irritation, jaundice, haematuria and haemoglobinuria, and kidney failure. Naphthalene also causes dermatitis. High levels of exposure in children cause hemolysis and renal damage. Extensive use of naphthalene in museums should be avoided because of health risks (Dawson 1992; Osorio 2001). However, the use of naphthalene for pest control in museums in the global south is widespread as the museums are over-reliant on it in solving pest problems. This exposes museum staff, researchers and members of the public to serious health problems. The other chemicals that have been widely used in museums are organochlorines, which include DDT, dieldrin and chlordane. DDT is persistent in the environment and it causes gastrointestinal disturbances, central nervous system effects of hyperexcitability, suspect fetotoxicity, possible liver and kidney damage, nausea/vomiting, coma, seizures and death (Osorio 2001; Boyer *et al* 2005).

Paradichlorobenzene has also been commonly used in museums. It affects humans through inhalation, ingestion and eye and skin contact. It causes headaches, eye irritation, periorbital swelling, profuse rhinitis, anorexia, numbness, clumsiness, kidney damage, and haemolytic anaemia. It is very volatile and leads to rapid loss of vapour from museum cases leading to the extensive concentration of vapour in the surrounding air, which poses a health hazard through inhalation. Another pesticide that has been used in museums is phosphine (hydrogen phosphide) also known as phostoxin, or delicia gastoxin. It enters the human body through inhalation and affects the respiratory system, brain, kidneys, liver and heart. It also causes headache, enlarged pupils, vertigo, thirst, loss of appetite, diarrhoea, vomiting, lassitude, immobility, ataxia, pallor, epileptiform, convulsions, apnea and cardiac arrest. There is also sulphuryl (vikane or sulphuric oxyfluoride) which is absorbed in the body through inhalation, and skin and eye contact. It affects the eyes, respiratory system, central nervous system and

kidneys. Its signs and symptoms include nausea, vomiting, abdominal pains (cramps), itching, pruritus, conjunctivitis, and rhinitis (hay fever) (Dawson 1992).

Other chemicals that affect human health are organophosphates such as diazinon, chlorpyrifos, and malathion. Diazinon (phosphorothioate) affects humans through ingestion, inhalation or skin contact. It affects the respiratory system, skin, central nervous system and cardiovascular system. Its signs and symptoms include; (mild) anorexia and nausea, weakness, dizziness, blurred vision; (moderate) vomiting, abdominal cramps and diarrhoea, salivation, lacrimation, sweating, dyspnea, substernal tightness, slow pulse, tremors of the extremities, muscular cramps, ataxia; (severe) fever, cyanosis, pulmonary edema, areflexia and loss of sphincter control, convulsions, coma, heart block, shock and respiratory failure. Depending on exposure it may cause delayed paralysis, and very high cholinesterase inhibition and people with active kidney or liver diseases should not be exposed to it. There is also chlorpyrifos (phosphorothioate) which can be absorbed into the human body through skin contact, inhalation and ingestion. It affects the respiratory system, skin, central nervous system and cardiovascular system. Exposure to chlorpyrifos can result in a significant decrease in plasma and red blood cell cholinesterase levels and can cause cholinergic symptoms (Dawson 1992).

Malathion (phosphorodithioate) affects humans through inhalation of vapour, skin absorption, ingestion and skin and eye contact, causing health effects on the respiratory system, liver, blood, cholinesterase, central nervous system, cardiovascular system and gastrointestinal system. Its signs and symptoms include increased bronchial secretion, excessive salivation, nausea, vomiting, excessive sweating, miosis, muscular weakness and fasciculation which are induced by the inhibition of functional acetylcholinesterase in the central nervous system. It also causes allergic sensitisation of the skin. Malathion is a potential teratogen and is highly toxic if ingested (Dawson 1992).

There are other pesticides in the form of carbamates which consist of compounds such as bendiocarb, carbaryl and propoxur. Bendiocarb affects humans through inhalation, skin or eye contact, skin absorption and ingestion. It attacks the respiratory system, skin, central nervous system and cardiovascular system. Its signs and symptoms include headache, dizziness, blurred or dark vision, constriction of pupils, salivation, profuse sweating, lassitude, muscle incoordination, nausea, vomiting, diarrhoea, epigastric pain, tightness in the chest, twitching, tremor, incontinence, slow heartbeat and wheezing. Carbaryl (1-naphthyl methylcarbamate)

enters the human body through inhalation, skin or eye contact, skin absorption or ingestion. It affects the respiratory system, skin, central nervous system and cardiovascular system. Its symptoms include (mild) headache, anorexia and nausea, weakness, dizziness, blurred vision, miosis; vomiting, abdominal cramps and diarrhoea, salivation, lacrimation, sweating, dyspnea, substernal tightness, slow pulse, tremors of the extremities, muscular cramps, ataxia; and severe fever, cyanosis, pulmonary edema, areflexia and loss of sphincter control, convulsions, coma, heart block, shock and respiratory failure (Dawson 1992).

Propoxur (2-isopropoxyphenyl methylcarbamate) also enters the human body through inhalation, ingestion, skin or eye contact or skin absorption. It affects the respiratory system, central nervous system and cardiovascular system. Its signs and symptoms include headache, dizziness, blurred or dark vision, constriction of pupils, salivation, profuse sweating, lassitude, muscle incoordination, nausea, vomiting, diarrhoea, epigastric pain, tightness in the chest, twitching, tremor, incontinence, slow heartbeat and wheezing. The signs and symptoms of propoxur are caused by its cholinesterase inhibition. In very large doses it can cause tremors, convulsions and death. People with asthma if exposed to propoxur can experience respiratory problems (Dawson 1992).

Pyrethrum also known as pyrethrins has also been used in museums for pest control. It is one of the most common insecticides that falls under botanicals, which are insecticides derived from plants. Its route of entry into the human body includes inhalation, ingestion, and eye and skin contact. It attacks the respiratory system, skin and central nervous system. Its signs and symptoms include skin irritation and allergic dermatitis, asthmatic breathing, headache, tinnitus, nausea and vomiting, excitement, diarrhoea, incoordination, tremors, convulsions, prostration and anaphylactic reactions (Dawson 1992).

Boric acid (orthoboric acid) also known as boracic acid, borsaure or NC1- C56417) is another chemical that is used for the treatment of artefacts against pest attack. It enters the human body through inhalation, ingestion or skin absorption via damaged skin, cuts or scratches. It affects the central nervous system, skin, gastrointestinal tract, and the developing foetus. Its signs and symptoms include depression of circulation, nausea, persistent vomiting, abdominal pain, diarrhoea, possible headache and weakness, abnormal temperature, red body rash followed by peeling, profound shock and coma (Dawson 1992). Apart from boric acid, diatomaceous earth (also known as siliceous earth, fossil flour or super-cel) was also used as a pesticide in

museums. It affects humans through inhalation or ingestion, and it has a health effect on the respiratory system. Its signs and symptoms include chest pains, cough with little or no spitting out, skin irritation, dyspnea, reduced thoracic excursion, cyanosis or fatigue (Dawson 1992).

Interest in human safety and health hazards from the use of pesticides has long been of concern to natural scientists and museum professionals. Many previously used pesticides and fumigants could potentially have long-term health effects when there is accidental exposure. Museum staff concerned with exposure potential for previously applied pesticides should evaluate each chemical that may have been used in terms of time and method of application, volatility and other physical characteristics. For instance, metal salts such as arsenic or mercury could exist as crystalline residues. Residues for many chemicals may be traced using specific chemical tests (Goldberg 1996). However, little is known regarding human exposure to possible pesticide contaminants in collections and museum environments in the global south, particularly in Zimbabwe. This study covers this gap through the scientific investigation of pesticide residues on organic collections at the Natural History Museum of Zimbabwe. The study will also assess the possible health effects that users of these collections at the Natural History Museum of Zimbabwe could be exposed to.

The general index of acute toxicity for chemicals is LD 50 (Lethal Dose), which is defined as the dose that leads to death in 50% of test animals exposed to it. The smaller the number for the LD 50, the more hazardous the substance. This can be used to provide a general comparative index between substances (Kearney 2001). See Tables 2 and 3 for the pesticide toxicity rating scale and the characteristics and health hazard summary for selected pesticides.

However, the challenge of LD 50 value as an index of toxicity is that it only focuses on a one-time or acute exposure, and does not take into account other factors that influence a patient's susceptibility to toxic effects (such as age, other diseases and medications), assumes that animals can predict effects in humans, and only consider the final effect of death (Kearney 2001). The toxicity levels for arsenic include 1 mg-10g (toxic and fatal); 1-3 mg/kg ingested (potentially fatal). The effects of this type can include hemorrhagic gastroenteritis, chronic renal failure, arrhythmias, paralysis, delirium, and coma. Chronic (cumulative) toxicity by ingested dose is 3-4 mg/day. The effects of this type of exposure can include neuropathy, anaemia, and Mees's lines (white lines that appear in the nails). The skin may show a change, either an increase or a decrease, in pigmentation and hyperkeratosis (thickening). Other effects

of cumulative exposure can be cancers of the lung, liver, kidney and or bladder (Boyer *et al* 2005). With regards to mercury, acute exposure may be evident after ingestion within minutes to hours. The effects of acute toxicity may include corrosion, kidney injury and circulatory collapse. Dermal exposure may lead to systematic toxicity. Chronic toxicity may be evident from weeks to years after exposure. Effects of chronic exposure may include tremors, gastrointestinal effects and kidney damage. Dermal exposure may include neuropathy, kidney injury, pigmentation and mental status changes (Boyer *et al* 2005).

Table 2 Example of toxicity rating scale (Kearney 2001)

Rating	LD 50 (oral)
Extremely toxic	<1 mg/kg
Highly toxic	1-50 mg/kg
Moderately toxic	50-500 mg/kg
Slightly toxic	500-5,000 mg/kg
Practically nontoxic	5000-15,000 mg/kg
Relatively harmless	>15,000 mg/kg

As shown in table 3, the minimum risk level (MRL) for the selected chemicals, acute (1-14 days), intermediate (15-364 days) and chronic (365 days and longer) is a cause for concern particularly to staff that work in museum environments and with collections that are contaminated with pesticide contaminants. Pesticide use in museums in the global south is widespread. Little is known regarding exposure levels to staff and other users in these museums as the focus is on pest control. Studies that determine the exposure levels of staff, as well as researchers and other users of collections in these museums, are rare. This could expose them to the harmful effects of pesticides as they work in potentially contaminated environments and with contaminated collections without knowledge of the effects of these contaminants on their health. This makes this study important to the Natural History Museum of Zimbabwe as it will highlight the exposure of staff and other users to possible pesticide contaminants and safety measures that must be taken to protect them from contaminated environments and collections.

Table 3 Characteristics and health hazard summary for selected pesticides (Kearney 2001)

Pesticide name & category	Chemical & physical characteristics	Sources & use	Potential routes of exposure	Acute & chronic effects by target organ	Minimum risk level (MRL) ¹	Cancer classification
Arsenic <i>Heavy metal pesticide</i>	Silver-gray, shiny, brittle, crystalline metal-loid, darkens to black with moisture. May dissolve in water	Element found in ores & ground water. Used in metallurgy, glass manufacture, pigment, electronics & broad spectrum pesticide & preservatives	All routes; ingestion, intact skin & inhalation	Irritant; cellular poison with multi-organ effects for acute & chronic	Oral, chronic, 0.0003 mg/kg/day	IARC 1 (Skin, liver & respiratory tract cancers)
DDT <i>Organochloride pesticide</i>	Colourless or white to slightly off-white powder with no odour or taste. Poor water solubility for all organochlorine pesticides	Synthetic. Banned in the US due to wildlife & environmental damage. May be used in other parts of the world	All routes; ingestion, intact skin (poorest with DDT) & inhalation	Irritant; nervous system (acute & chronic) & liver (chronic). Bioaccumulation (accumulate in the body with repeated exposures)	Oral, acute, 0.0005 mg/kg/day	IARC 2B EPA Group B
Dieldrin <i>Organochlorine pesticide</i>	Colourless, white to light tan (impurities) powder with mild chemical odour	See DDT above	See DDT above	See DDT above	Oral, acute, 0.00007 mg/kg/day; chronic, 0.00005 mg/kg/day	IARC 3 (Liver & adrenal cancers in animals)
Lindane <i>Organochlorine pesticide</i>	White to cream coloured odourless crystal with a bitter taste & musty odour	Synthetic. Used as a human pharmaceutical for scabies & lice	See DDT above	Irritant; nervous system (acute & chronic)	Oral, acute, 0.01 mg/kg/day; intermediate, 0.00001 mg/kg/day	Equivocal

Table 3 continued.

Pesticide name & category	Chemical & physical characteristics	Sources & use	Potential routes of exposure	Acute & chronic effects by target organ	Minimum risk level (MRL) ¹	Cancer classification
Mercury <i>Heavy metal pesticide</i>	Elemental or metallic mercury is shiny, silver-white colour, odourless liquid. Inorganic salts are white powders or crystals	Naturally occurring metal; organic mercury formed in water & soil by bacteria. Used in thermometers, batteries, dental treatments, skin creams & to produce chlorine gas.	Elemental mercury is absorbed by inhalation of vapours. Mercury salts are absorbed by ingestion & application to skin. Organic mercury may be absorbed by any route	Irritant, kidney & nervous system; effects may be acute or chronic	Mercuric chloride; Oral, acute, 0.007 mg/kg/day; Intermediate, 0.002 mg/kg/day	Not classified (lack of human data)
Carbon Disulfide <i>Disinfectant & fumigant</i>	Colourless to light-yellow liquid with sweet ether-like odour. Commercial grade has rotten egg odour	Used as a solvent, production of cellophane, vacuum tubes, optical glass & intermediate for adhesives	Poisoning generally occurs after inhalation, but absorbed by any route	Irritant: nervous system (acute); cardiovascular (chronic); & liver (acute or chronic). Strongest of solvents.	Oral, acute, 0.01 mg/kg/day. Inhalation, chronic, 0.3 ppm	Not classified (lack of human data)
Carbon Tetrachloride <i>Halogenated solvent</i>	Clear, colourless heavy liquid with an ether-like odour	Banned from most commercial uses in the US. Used in the production of fluorocarbons. Was used as a degreasing solvent, dry cleaning agent and grain fumigant	May be absorbed by any route	Irritant: nervous system, liver & kidney (acute or chronic effects)	Inhalation: acute, 0.2 ppm; intermediate, 0.05 ppm. Oral: acute, 0.02 mg/kg/day; intermediate, 0.007 mg/kg/day	ACGIH-A2

Table 3 continued.

Pesticide & name category	Chemical & physical characteristics	Sources & use	Potential routes of exposure	Acute & chronic effects by target organ	Minimum risk level (MRL) ¹	Cancer classification
Naphthalene <i>Repellent</i>	White crystalline flakes or solids with a strong “moth ball” or coal tar odour	Occurs naturally in essential oils of <i>Radix</i> & <i>Herbaononidis</i> . Chemical intermediate for indigo & other dyes & other products. Most commonly used as a moth repellent & in air freshener & toilet bowl deodorisers	May be absorbed by any route	Irritant: liver (acute or chronic). Hemolytic anemia in patients with a specific enzyme deficiency (G6PD) (acute)	Oral , acute, 0.05 mg/kg/day; Intermediate, 0.02 mg/kg/day. Inhalation, chronic, 0.02 ppm	Not classified (lack of human data); may be associated with larynx-geal & intestinal carcinoma
Borax <i>Antiseptic & disinfectant</i>	White to light gray odourless solid	Used in pharmaceuticals, cleansers & cosmetics	Absorbed by ingestion, mucous membranes & abraded skin	Irritant with small acute exposures; skin (exfoliative rash) & kidney with large exposures.	Not classified (lack of human data)	Not classified (lack of human data)
Paradichlorobenzene <i>Repellent</i>	White to colourless crystals with a penetrating camphor-like odour	Replaced naphthalene as a safer ingredient in moth repellents and diaper pail deodorisers	Absorbed by ingestion & inhalation	Irritant: nervous system, blood & liver (mild), all chronic	Not classified (Lack of human data)	Animal carcinogen
Thymol <i>Antiseptic & disinfectant</i>	Aromatic oil with characteristic odour of the spice thyme	Essential oil from thyme. Used as a disinfectant, deodorant, in mouth washes & in dentistry.	Unknown; potential for all routes.	Irritant; nervous system (acute)	Not classified (lack of human data)	Not classified (lack of human data)

¹Duration of exposure for MRLs are acute (1-14 days), intermediate (15-364 days, & chronic (365 days & longer).

2.5 Safety Measures on the Use of Contaminated Museum Collections

Medical treatment for many exposures to pesticide chemicals particularly heavy metals is often not completely effective. Therefore, prevention of exposure is better than treatment (Boyer *et al* 2005). A preventive programme that protects individuals from exposure to pesticides should be instituted in museums. This programme encompasses training for the production of fact sheets, signs, and posters on safe handling procedures, possible health effects and emergency measures for an acute exposure event, and medical assistance information. It also includes the establishment of enclosures for quarantining contaminated objects, ventilation of storage places, observance of personal hygiene such as bathing, washing hands and face before eating and washing clothes used when handling contaminated artefacts separately. Protective equipment should be disposed of carefully, with discarded gloves being turned inside out as they are removed. The programme should include environmental and biological monitoring, and disease surveillance (Osorio 2001; Odegaard *et al.* 2005).

Objects known or highly suspected to have been contaminated with pesticides should be placed in storage containers such as polyethylene bags, or archival boxes and envelopes to isolate them from other objects. Further, they should be stored in storage cabinets that lock and seal (Odegaard *et al.* 2005). Safety guidelines for handling museum collections should be publicised and enforced in museums and be given to people entering museum collection areas. Epidemiological studies of museum workers, past and present should be conducted and regular medical monitoring should be done on museum staff during employment with special attention to the effects of pesticide poisoning. Museum staff should undergo blood and urine test for pesticides upon hiring and at each regular medical monitoring thereafter.

Further, protective equipment such as nitrile gloves, respirators, and lab coats should be worn when handling contaminated collections. Nitrile gloves are recommended because, unlike cotton gloves, they do not absorb pesticide contaminants. They also offer puncture resistance, comfort and dexterity and are a suitable choice for handling potentially contaminated artefacts. After use the gloves should be disposed of and must not be used again. To be effective, protective garments such as lab coats or overalls should cover the front of the body and the arms and they must be maintained, cleaned and inspected regularly for damage. A fit-tested respirator equipped with a high-efficiency particulate air (HEPA) filter should be put on. Workplaces should be well ventilated and work surfaces should be cleaned with a HEPA vacuum (Kaminitz 2001; Nason 2001c; Odegaard *et al.* 2005). Work on contaminated

collections should be conducted in a well-ventilated area. It is advisable to use a fume hood and to avoid extensive examinations in small rooms or closets that are not ventilated. Work surfaces that have been in contact with artefacts should be cleaned using a sponge or wet mop with soap and water (Davis *et al.* 2001; Odegaard *et al.* 2005). (Davies *et al.* 2001; Odegaard *et al.* 2005).

As a precaution for safeguarding people who handle collections, it should be assumed all collections have been treated with pesticides in the past. Children, the elderly, pregnant women, and people with a weakened immune system are considered to be more susceptible to chemicals such as arsenic, mercury and lead among other toxins and should avoid using contaminated collections (Kaminitz 2001; Odegaard *et al.* 2005). Contaminated artifacts should be placed in containers to restrict access and they should also be red-tagged (Nason 2001c). Artefacts known to be contaminated should not be used for hands-on activities and should be removed from use in museums. After handling artefacts, hands must be washed with soap and water (Kaminitz 2001; Nason2001c).

Storage cabinets housing contaminated collections should be labelled. Objects known or highly suspected to have been contaminated with pesticides should be labelled with a warning that indicates the name of the chemical used (Kaminitz 2001; Odegaard *et al.* 2005). With regards to mercury, all museum artefacts that are contaminated should be clearly labelled so that caution can be exercised when handling them. Liquid mercury is heavy and is usually contained in glass, such items require special attention. The Vapour pressure of mercury increases dramatically as temperature rises, leading to more vapour in the air. Therefore, artefacts containing mercury or mercuric compounds should be stored in a cool environment. Should airborne mercury be well below the level of concern, zinc dust should be sprinkled in the area and be brushed onto the surface (zinc will combine with mercury and render it harmless) (Canadian Conservation Institute 2002). Sealed plastic bags should be used to isolate contaminated objects for the prevention of the dispersal of residues and fumes. Contaminated artefacts should be quarantined to lessen the risk of contaminating other collections (Kaminitz 2001). Eating, drinking or smoking in storage areas or around collections should be prohibited (Davies *et al.* 200; Kaminitz 2001; Nason 2001c).

While these safety measures are very useful in protecting people who access contaminated artefacts and environments in museums, they are not in place at the Natural History Museum

of Zimbabwe. Condition assessments of collections at the museum (See Chapter 4) showed that there are no safety measures in place for accessing potentially contaminated artefacts and environments in the museum. The museum could be forgiven for this as they do not know that their collections and environments could be potentially contaminated. However, as indicated earlier, it is prudent for museum staff to assume that their collections and environments are contaminated with toxic pesticides to protect themselves, researchers and visitors. This study will be handy to the museum as it covers this lacuna by establishing safety protocols for access and use of potentially contaminated artefacts and environments in the museum.

2.6 Chapter Summary

This chapter discussed the theoretical frameworks underpinning the study, which include the “The Planetary Trust: Conservation and Intergenerational Equity” and the Integrated Pest Management concepts. The chapter has demonstrated that museum artefacts across the globe have been treated with various hazardous insecticides from the 18th century up to recent times. It also revealed that these chemicals are not only harmful to humans who access and use contaminated collections but are also a threat to the conservation of the artefacts as they react with them leading to their deterioration. Apart from these aspects, the chapter highlighted on safety protocols that may be instituted in museums to protect humans from contaminated collections as well as to prevent cross-contamination in artefacts and their deterioration from pesticides. The next chapter addresses the issue of repatriation of potentially contaminated artefacts from the global north to the global south and the safety protocols that need to be adopted to prevent cross-contamination of artefacts and to protect recipients of these artefacts from hazardous pesticide contaminants on them.

Chapter 3

Potential Pesticide Contamination in Repatriated Artefacts in African Museums: The Need for the Adoption of Safety Protocols for Access and Use of Hazardous Artefacts.

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3.0 Introduction

This chapter addresses a very important aspect of collections care, that is the testing of artefacts for pesticide contamination and the adoption of safety protocols for their handling and use, which is seemingly being overlooked in repatriation negotiations between countries and museums in the global north and the global south. Prudent collections care should be instituted in repatriation processes to preventing cross-contamination of artefacts in receiving museums and to protect people receiving these potentially contaminated artefacts.

The current decolonisation discourse in museums has set the tone for the repatriation of looted artefacts from museums in the global north to the global south. Repatriation of looted artefacts from countries in the global north to Africa is a topical issue and it has gained prominence following the commissioning of the 2018 Sarr-Savoy report on the restitution of African artefacts by French President Emmanuel Macron and the subsequent call he made in 2020 for the return of looted artefacts from France to Africa. Prior to this, at least since the end of the colonial period, African countries have been demanding the return of artefacts looted by countries in the global north during the colonisation of the continent. However, what is missing from the decolonisation and repatriation discourses for museums in the global south is the issue of dealing with artefacts from museums in the global north that are potentially contaminated with harmful pesticides. Some historic pesticide contaminants on artefacts such as arsenic and mercury can result in diseases such as cancer, and lung, kidney, and heart failures among others (Dawson 1992; Osorio 2001). The legacy of pesticides continues to pose problems for staff and various collection users, especially the recipients of repatriated objects (Hawks 2001). Organic artefacts are contaminated through the direct application of pesticides by soaking, painting, rubbing, or spraying, whereas inorganic artefacts such as metal or stone artefacts may be accidentally contaminated through spraying of pesticides in museum storage and exhibition

places. The issue of scientific testing of repatriated artefacts to determine pesticide contaminants and to establish safety protocols for their handling and use is largely missing in current decolonisation debates in Africa.

Some countries in the global north, such as Germany and France have responded to the repatriation demands by African countries by agreeing to return the looted artefacts to Africa. Germany has agreed to return many bronze artefacts held in its museum collections, with the deal reportedly including the training of Nigerian museum staff, archaeological excavations, and assisting with the construction of a new museum in Benin that has been designed by the Ghanaian-British architect David Adjaye (Bakare2021; Mcgreevy 2021). In 2020, France approved the restitution of 26 artefacts from the Kingdom of Dahomey, located within present-day Benin, which had been pillaged in 1892 (Shemang 2021). The University of Aberdeen in the United Kingdom has agreed to return to Nigeria a Benin bronze sculpture depicting the Oba, or king of Benin, that was looted from Benin city in 1897.

Benin City is the capital of Edo State in Southern Nigeria, and it is different from the Republic of Benin found in West Africa. The bronze sculpture was part of thousands of artefacts taken when British forces looted Benin city in south-eastern Nigeria in 1897 (Bakare 2021). Aberdeen University principal and vice-chancellor Professor George Boyne and Ministers of Culture and Foreign Affairs in Germany Monica Grutters and Heiko Maas cited moral obligations and justice behind the reason for the repatriation of looted artefacts to Nigeria.

In all the repatriation cases cited above, testing of potential pesticide contaminants on artefacts from museums in the global north and the establishment of safety protocols for their handling and use in museums and communities in the global south are missing in the literature. It is not known whether such issues are addressed in repatriation negotiations. With the current decolonisation discourse that is unfolding across the globe, and as more artefacts are set to be repatriated to Africa, it is likely that some objects being repatriated may be contaminated with toxic pesticides from historical use, as many museums and collectors in the global north with traditional artefacts widely used pesticides for pest control.

3.1 Debates on the Repatriation of African Artefacts: The Restitution of African Knowledge and Objects

Debates on the repatriation of African artefacts have mainly addressed the issues of reparation to African countries and bilateral negotiations between the countries involved. On 25 May 2021, the Stellenbosch University Museum held an online discussion entitled “Just Conversations: The Restitution of African Knowledge and Objects”, where two speakers presented on this issue, namely Dr Laura Van Broekhoven (the director of the Pitt Rivers Museum of the University of Oxford in England) and Dr Olusegun Morakinyo, (Research Associate, Centre for Transdisciplinary Studies, University of Fort Hare, South Africa). The former highlighted that Pitt Rivers Museum has an extensive number of artefacts from Africa. These collections were looted from Africa during the colonial period. She highlighted that the museum is involved in discussions with communities from countries such as Kenya and Tanzania (Maasai), Uganda (Bunyoro), and Benin. These discussions are focused on the repatriation of the artefacts held by the museum to communities that are the owners of the artefacts. The latter presented the need for justice and reparations to communities that lost their artefacts through looting by African colonisers. He also proposed the setting up of a museum of guiltiness, which can be in the form of a virtual museum that showcases looted African artefacts. None of these discussions addressed the issue of the possibility of contamination of repatriated artefacts and the need for testing to ensure the safety of the recipients and users of the artefacts and to prevent cross-contamination with other artefacts that are free from contamination.

The issue of Museum International (Volume 61. No.1-2) published proceedings of a conference entitled “Return of Cultural Objects: The Athens Conference”. The conference was held on 17 and 18 March 2008 in Athens, Greece, and focused on discussions regarding the issue of the return and restitution of cultural property. The conference covered case studies of the successful repatriation of artefacts across the globe. The deliberations of the conference addressed the issues of dialogue, inter-governmental and inter-museum cooperation on the repatriation of cultural property as well as ethical and legal considerations on the repatriation of illicitly trafficked artefacts. The issue of testing repatriated artefacts for possible hazardous pesticide contaminants and the safety of the recipients was not highlighted at this conference.

3.2 The Discovery of Pesticide Contaminants on Artefacts in Museums in the Global North.

Harmful pesticide contaminants have been discovered on artefacts in some museums in Europe, the United Kingdom, the United States, Canada and Australia. Analyses conducted at the Germany Historical Museum between 2005 and 2012 revealed that some of its artefacts were contaminated with pesticides such as eulan, naphthalene, moth-killing paper, hylotox, DDT, DDE, lindane, methoxychlor compounds, lead, chlorine, arsenic, mercury, and toxic substances used in the manufacture of the artefacts (Falkenberg 2015, Hahn and Krug 2015, Lang and Zimmer 2015).

At the National Museum of Wales Herbarium, specimens were found contaminated with arsenic, mercury, barium, and naphthalene. Further tests conducted on selected museum staff indicated slightly elevated arsenic and mercury levels in their blood and urine, above the normal standard set by the Super Regional Assay Laboratories under the Health and Safety Executive (UK) (Purewal 2001). At the National Museum of Denmark, DDT was discovered on artefacts that were due for repatriation to the Greenland National Museum and Archives in Greenland. (Schmidt 2001). In Australia harmful pesticides such as arsenic, mercury and lead have been found in some indigenous artefacts in the Museum Victoria State collection (Goodall *et al* 2013). These discoveries are proof that some artefacts that are being repatriated from the global north to Africa may potentially be contaminated with hazardous pesticide contaminants.

3.3 The Standard Procedure for Repatriation of Cultural Property: The Native American Graves Protection and Repatriation Act (NAGPRA) (1990)

Contamination of museum collections is a global issue. The United States has demonstrated good practice in this area through the enactment of legislation that addresses the issue of contamination of artefacts in museums. Human safety from the use of contaminated museum collections has been formally recognised and enforced through the passage of the Native American Graves Protection and Repatriation Act (NAGPRA) (1990) in the United States. Section 10.10 (e) of the 1996 NAGPRA Final Regulations specifically requires museums and federal agencies to inform the recipients of repatriations of any “presently known treatment of human remains, funerary objects, sacred objects of cultural patrimony with pesticides, preservatives or other substances that present a potential health hazard to the objects or the persons handling the objects (Loma’ Omvaya 2001; Nason 2001a, Nason 2001b; Osorio 2001;

Tsosie 2001 Sirois *et al* 2008). Handling and use of the objects may expose users to pesticides that may still contaminate the objects (Sirois *et al* 2008). The passage of the Native American Graves Protection and Repatriation Act has led, since 1990 to extensive collection review and object handling (Nason 2001c). Repatriation has not only raised awareness of pesticide contamination of objects in museums but has also created a more urgent need to find ways to identify and quantify the extent of contamination (Sirois *et al* 2008). The enactment of NAGPRA was a positive formal step in raising awareness about the safety of Native Americans from the use of contaminated museum collections that have been repatriated. It established a legal basis for the adoption and implementation of safety measures in the handling and use of contaminated collections for Native Americans.

3.4 Review of Conventions, Principles, and Legislations that Dictate Standards Impacting Repatriation to Africa

While the NAGPRA acknowledges the problem of contamination of repatriated collections from museums in the United States and the need for subsequent protection of museum staff and communities from handling and use of contaminated collections, this is not the case with other international conventions and heritage legislations in Africa. A review of UNESCO's international conventions, principles and frameworks of action on repatriation in Africa, and selected heritage laws from African countries, in general, have shown that the issue of safety of museum staff and users of repatriated collections that are potentially contaminated has not been addressed. See table 4.

Table 4 Frameworks of action and legislations that dictate standards impacting repatriation to Africa.

Operational guidelines of the UNESCO 1970 Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property - Article 7 (b) (ii) highlights that at the request of the country of origin, state parties should take appropriate steps to recover and return any stolen cultural property imported. - Article 5 (c) specifies that state parties should promote the development or establishment of institutions such as museums, archives, or laboratories required to ensure the preservation and presentation of cultural property. The 1977 United Nations General Assembly Secretary General's report on the Restitution of Works of Art to Countries Victims of Expropriation - Addressed bilateral issues on the return of artefacts to their country of origin. Intergovernmental Committee for Promoting the Return of Cultural Property to its Countries of Origin 1986 Guidelines - Section A.6 on guidelines for the use of the "standard form concerning the request for return or restitution indicates that with regards to conservation, museum staff from the holding country should give all relevant information about the past and present care of artefacts, including storage, display, light, microenvironments, climatic conditions of the storage area and other supports. - It also states that the staff should provide information about mutilations, restorations, and conservation treatments. - With regard to the requesting country, section C.4 on museum facilities specifies that clear indications should be given on the range of curatorial services available at the place of display, the quality of the museum's architecture, security conditions, conservation infrastructure, and the number of staff available. The 1995 UNIDROIT Convention on Stolen or Illegally Exported Cultural Objects - Article 3 (1) obliges the possessor of a cultural object which has been stolen to return it. The 2006 Charter for African Cultural Renaissance - Chapter V for the protection of cultural heritage, articles 26, 27, and 28 calls for the return to Africa of looted cultural property and the establishment of appropriate physical and environmental conditions for safeguarding the returned cultural property. The Southern African Development Community (SADC) Protocol on Culture, Information, and Sport - Article 13 on the preservation of cultural heritage specifies that state parties shall establish policy guidelines for the preservation and promotion of the cultural heritage in the region in all its multi-various facets formulated in close collaboration with relevant stakeholders and shall seek to harmonise such guidelines in the interest of mutually beneficial integration of the region. - Article 14 (1) & (2) on cultural industries highlight that state parties shall undertake to make cultural industries a major cornerstone of their national economies and that they shall take such measures as are necessary to nurture, protect and promote their infant cultural industries. South Africa's National Heritage Resources Act Number (SAHRA) 25 of 1999 - Provides for the return of cultural property taken from the country. Article 33 (4) specifies that the South African Heritage Resource Authority with the consent of the Minister of Foreign Affairs may liaise and cooperate with the authority responsible for the protection of cultural property in any reciprocating state and may enter into agreements with such authority concerning the return to the country of origin of an artefact or cultural property which is illegally imported into South Africa or the reciprocating state. Zimbabwe's National Museums and Monuments Act [Chapter 25:11]; National Gallery of Zimbabwe Act [Chapter 25:09]; and National Archives of Zimbabwe Act [Chapter 25:06] - The acts do not address the repatriation of artefacts to Zimbabwe

It is acknowledged that these international conventions, African set of principles and frameworks on repatriation, and heritage legislations in Africa mostly became operational at a time when pesticide use in museums was commonplace and its negative effects on human

health were not given enough consideration. This could be a factor in why the testing of artefacts and adoption of safety protocols for their handling and use was not addressed. The situation is even dire with Zimbabwe's heritage legislations which do not address the issue of repatriation of Zimbabwe's artefacts that are in foreign lands. International conventions, African set of principles and frameworks on repatriation, and heritage legislations in Africa must be reviewed and address the issue of hazardous pesticide contaminants on artefacts. They must provide for the scientific testing of repatriated artefacts to determine toxic pesticide contaminants and pave the way for the establishment of safety protocols for their access, handling, and use in museums and communities. Without the legal basis to enforce the testing of the repatriated artefacts from the global north to Africa, museums in Africa should acknowledge that pesticide contamination of artefacts is real and they should take the initiative to address this issue in bilateral negotiations for the repatriation of artefacts with museums from the global north. Documentation of pesticides used in the treatment of artefacts should be included as a requirement in agreements or memoranda of understanding between the two parties.

3.5 Repatriation of Artefacts from the Global North to the Global South: The Zimbabwean and Republic of Benin Case Studies

Zimbabwe has received some of its looted artefacts from Britain and Germany. For instance, a walking stick owned by Mukwati (Mukwati was a spirit medium believed to possess supernatural powers who led the 1896-1897 Shona uprisings against British colonial rule) was repatriated back to Zimbabwe in 1998. After Mukwati's death, his wooden stick was confiscated by Lord Baden Powell, who was an officer in the British army and founder of the Boy Scout Movement during the colonisation of Zimbabwe. The stick was repatriated from Boy Scout Movement Headquarters in London to Zimbabwe where it was deposited at the Zimbabwe Museum of Human Sciences (Matenga 2011). In an interview that was conducted with Professor Munjeri (formerly the Executive Director of National Museums and Monuments of Zimbabwe (NMMZ), the Permanent Delegate of Zimbabwe to UNESCO and Vice President and Rapporteur of the World Heritage Committee, and a negotiating committee member for the return of Mukwati stick) and Mr Chipunza (the chief curator of the National Museums and Monuments of Zimbabwe and the head of Zimbabwe's negotiating committee for the return of the Mukwati stick), they both confirmed that no testing was done to determine whether the wooden stick was contaminated with harmful pesticides. They highlighted that the issues of testing the stick and safety protocols for its handling, use, and storage were not

discussed during negotiations for its repatriation to Zimbabwe. As well, it was indicated that the repatriation process and condition assessment of the stick was done in the absence of a specialist conservator from Zimbabwe. However, the stick came with a condition report which indicated that it was in a good state of conservation and that no remedial conservation work had been carried out. No chances should be taken on the possibility of chemical contamination of repatriated artefacts and a condition assessment report alone cannot substitute real testing. Some repatriated collections may lack adequate documentation on pesticide application and others may have been contaminated inadvertently during the application of pesticides by repatriating museums. Such artefacts pose a danger of cross-contamination when they are stored or displayed together with uncontaminated ones, and they are also a health hazard to staff, researchers, and visitors who access them.

Another example is a Zimbabwean soapstone bird fragment that was being kept at the Museum für Volkerkunde in Berlin, Germany for approximately 100 years after it was looted from Great Zimbabwe. It is possible that this artefact may have been contaminated with pesticides. It is important to remember that in older storage areas, the application of a pesticide targeted at an organic object may have also affected nearby artefacts that were not intended targets such as stone and metal artefacts, thus collateral damage from pesticide applications can impact and leave residues on very unexpected artefacts (Nason 2001b). This artefact was kept in different countries owing to the Second World War, firstly it was moved from Germany to a castle in Schrabendorf in Silesia Poland in 1944. It was then taken by the Russian army as spoils of the war and was deposited in the Leningrad Museum of Ethnography and Anthropology. The bird was taken back to Germany in 1978 and deposited in the Leipzig ethnographic museum, and in 1992 it was then sent to the Berlin Museum (Dewey n.d; Renold *et al* 2013). It was returned to Zimbabwe and is now kept alongside other soapstone birds at the Great Zimbabwe Museum.

The handover ceremony of the repatriated part of the bird was done on 14 May 2003 at the statehouse and it was presided over by the then president of Zimbabwe, Robert Gabriel Mugabe, cabinet ministers, politicians from the ruling party, traditional leaders, historians, war veterans, members from the diplomatic community and the former German ambassador to Zimbabwe Dr Peter Schmidt (Munjeri 2009; Matenga 2011; Renold *et al* 2013). The image of the president receiving part of the bird shows him holding it with bare hands without wearing protective clothing; no safety protocols were observed in the handling of the artefact. See Figure 1. During interviews that we conducted with Professor Munjeri and Mr Chipunza, they

both confirmed that no testing was done to determine whether the Zimbabwean bird fragment was contaminated with chemicals and no conservator was involved in the assessment of the artefact or in formulating safety protocols for its handling, display, and storage. Discussions on the repatriation of the object focused only on negotiations about its ownership between the Trustees of the Prussian Cultural Heritage Foundation, who are the “legal owners” and the Zimbabwean government. Authorities of museums in Zimbabwe, Germany, and Belgium and their respective diplomats were involved in the negotiations (Munjeri 2009).



Figure 1 Former president of Zimbabwe, right, receiving the Zimbabwe Bird repatriated from Germany. Accu Net/APMulti-media Archive.

The Republic of Benin celebrated the repatriation of 26 artefacts in November 2021 from the Quai Branly-Jacques Chirac Museum in France. The artefacts are on display at the presidential palace in the Salle du Peuple, in Cotonou Benin, awaiting transfer to a new museum that is under construction. Gaelle Beaujean who is a curator at Quai Branly-Jacques Chirac Museum and Imorou Abdoulaye who is a Site Manager of the Royal Palaces of Abomey, and was also involved in the repatriation process indicated that the 26 artefacts returned consisted of organic, inorganic, and a mixture of both organic and inorganic elements in some artefacts. Eleonore Kissel who is the current Head of Preservation at Quai Branly-Jacques Chirac Museum confirmed that 25 artefacts were tested for arsenic and they were all negative, save for one artefact which until repatriation was conserved in off-site storage. She further explained that this artefact is part of a subgroup of 18 artefacts inventoried in 1895 which all tested negative for arsenic, thus there was no reason to be worried about the contamination of this particular artefact. However, it seems the testing for arsenic on the repatriated artefacts was done in the absence of museum staff from Benin and they were not aware of it. Imorou Abdoulaye indicated that he was unaware of chemical testing on the artefacts, but he confirmed that as a

precautionary measure they handled the artefacts wearing gloves and face masks. This suggests that there was inadequate briefing between the museum staff from these two countries about pesticide treatment and testing, and underscores the need to address the issue in repatriation negotiations between countries and their respective museum staff. While it is commendable that the Quai Branly museum tested the artefacts for arsenic contamination, other equally harmful inorganic pesticides such as mercuric chloride and lead, and organic pesticide contaminants should also be considered for testing to allow recipients of the repatriated artefacts to make informed decisions on safety protocols which must be taken in the handling, use, and storage of such artefacts.

With regards to organic pesticide contaminants, Eleonore Kissel stressed that “Until performing detailed condition reports for these objects, no signs were observed that could lead us to believe that organic pesticides were used on these artefacts, such as stains or the glitter characteristic of specific pesticides that are reported in the technical literature”. In the circumstance of contaminated artefacts, it may be difficult to accurately identify a pesticide contaminant based on the availability and accuracy of the records of the collector or museum. Collections may have been preserved in the field before reaching a museum and this information may not be recorded (Kearney 2001). Additionally, the object may show no visible sign of previous treatment.

The issue of repatriation of artefacts without testing for possible pesticide contamination, or inadequate briefing of recipients of the artefacts on testing and treatment history of artefacts against pest attack could also be happening in other countries in the global south that are receiving artefacts from the global north. The treatment history against pest attack of the artefacts that have been repatriated or are being repatriated to Africa may not have been well documented. For example, an analysis done by the Canadian Conservation Institute showed that five Ornithology specimens that came from Africa in the Democratic Republic of Congo in 1938 had high arsenic concentrations. These specimens were collected around the 1920s-1930s suggesting that specimens from this period should be treated with caution (Sirois 2001). Many artefacts are yet to be repatriated from the global north to Africa. There are 3157 (including the 26 artefacts returned to Benin) artefacts from Benin that are in the Quai Branly-Jacques Chirac Museum’s inventory while other African countries also have thousands of artefacts in this inventory, notably Ivory Coast 3951, Mali 6910, Madagascar 7781, Cameroon 7838, Chad 9296, and Zimbabwe 278 (Sarr and Savoy 2018). With repatriation gaining

momentum in Africa, more artefacts will be returned to African museums. It is therefore important for collections care staff in African museums to be aware of the issue of pesticide contamination of the artefacts and be involved in discussions for their testing.

Repatriation may create situations where the objects are used in very different ways than they would be in their museum setting. For instance, the objects may move from a controlled environment where the potential hazards are likely known by those handling them to one where the objects are used by a public unaware of the possible presence of pesticide residues (Sirois *et al* 2008). Further, some artefacts received from other institutions through exchanges or by purchase from dealers may be contaminated, and that one cannot assume that the source did not treat artefacts with pesticides (Nason 2001b).

3.6 The Capacity for Testing for Pesticide Contamination of Artefacts in Museums in the Global South

Most museums in the global south do not have the capacity to test for pesticide contamination on artefacts. Testing for inorganic pesticides requires analysis methods such as XRF spectroscopy, Fourier transform infrared spectroscopy (FTIR) and Raman spectroscopy which is very expensive and cannot be afforded by many museums. The same challenge is also experienced in testing organic pesticides which requires expensive processes such as gas and liquid chromatography. The equipment that is required to conduct chemical testing is beyond the reach of many museums in Africa. This is a challenge that may impact the health of museum staff, researchers, and visitors in museums in Africa as well as the conservation of artefacts in the museums. African museums should consider forming regional consortiums and pulling resources together to set up testing centres for artefacts. Alternatively, museums should consider establishing partnerships with universities for the testing of artefacts. This has been successfully done at the Natural History Museum of Zimbabwe (during Davison's Chiwara's PhD project) where the Department of Tangible Heritage Conservation at the University of Pretoria offered XRF spectrometry and chromatographic resources for the testing of inorganic and organic pesticides on specimens from the museum. The project involved working with museum staff in the testing of the specimens and equipping them with knowledge on testing artefacts for pesticide contaminants. The project is probably one of the few, if not the first of its kind to be conducted in Africa on testing of museum artefacts for pesticide contaminants. Further, African museums also should invest in training their staff on testing and identification of pesticide residues on artefacts.

3.7 Conclusion

Pesticide contamination of museum artefacts is an urgent problem that also beyond repatriation, directly affects the potential future uses to which we can safely put the objects in our collections, including research and education (Nason 2001c). The approach to addressing the issue of pesticide contamination in museums in Africa should be holistic, encompassing both the repatriation process and in-house collections conservation. The issue should be tackled both at the international and local levels. The period that artefacts were looted from Africa (colonial period) coincided with the widespread use of harmful pesticides in the global north. An estimated 95% of artefacts from sub-Saharan Africa are kept outside the African continent and they have been lost through violence over many centuries (Godonou 2007 cited in Gofswald 2009). Possibly some of these artefacts could have been treated with harmful pesticides as a way of preserving them and they could be repatriated back to Africa. This is an important issue that deserves urgent attention at international forums on repatriation and negotiations for the return of artefacts between museums in the global north and African museums. Addressing the issue at such forums helps in alerting people on precautionary measures which must be taken during repatriation to protect staff, researchers, and other users of the artefacts from the hazardous effects of chemical contaminants on the artefacts as well as prevent cross-contaminating artefacts in local museums. Professor Munjeri (the former Permanent Delegate of Zimbabwe to UNESCO and Vice President and Rapporteur of the World Heritage Committee) indicated that the issue can be taken up by ICOM's Ethics Committee, which is better positioned to recommend to UNESCO's Intergovernmental Committee for promoting the return of cultural property to its countries of origin so that it can be mandated to address it during repatriation negotiations. International conventions, charters, and treaties on repatriations should be reviewed to address the issue of pesticide contamination of artefacts.

At a local level, African countries must urgently review their respective heritage legislations and address the issues of repatriation, testing of artefacts for pesticide contaminants, and human safety from contaminated artefacts. The United States has demonstrated good practice by enacting an enabling legislation (NAGPRA 1990) which addresses the issue of pesticide contamination of artefacts. For instance, since 1995 the Arizona State Museum with guidance from the NAGPRA regulation has been involved in an in-depth review of possible pesticide residues on all traditional artefacts undergoing the repatriation process. This review was based on the NAGPRA repatriation check sheet which addressed the following aspects of pesticides: evidence of prior infestation; evidence of residual pesticides; evidence of museum repairs,

restorations, and alterations; written records suggestive of pesticide use; and based on past storage locations, which pesticides might typically have been used on or near an artefact (Odegaard and Sadongei 2001). These same issues must be addressed in heritage legislations in Africa to enforce good practices in collections care with regard to testing for contamination and repatriation.

Bilateral negotiations for the repatriation of artefacts between countries and museums should include collections care staff from the outset so that they influence deliberations on testing of artefacts for repatriation and the establishment of safety measures for their handling, use, and storage. Collections care staff must be fully briefed about the treatment history of the artefacts for pest control and establish whether the artefacts were tested for pesticide contamination and what type of tests were done. During repatriation negotiations, respective countries and their museums' collections care staff should sign memoranda of understanding (MOUs) that include testing of collections for pesticide contamination, and the documentation of pesticide treatment of artefacts. Addressing these issues will enable them to take necessary measures that prevent cross-contaminating of local artefacts and protect museum staff, researchers, and community members from possibly contaminated artefacts.

In cases where repatriations are done without testing of artefacts and with inadequate documentation of pesticide treatment applied on artefacts, the safest course of action is to assume that some artefacts in a collection are contaminated with pesticide residues, and there is a need to consider implementing new procedures for collection handling and collection management based on that assumption to be prudent (Nason 2001b). Safety protocols for the handling and use of potentially contaminated collections must be instituted in museums in Africa for the protection of staff and users from toxic chemicals on artefacts.

Chapter 4

Methodology

4.0 Introduction

This chapter discusses the methodology that was used in data collection. It highlights the data collection instruments that were used in collecting data that addressed the objectives of the study. Mixed methods research was used to address the quantitative and qualitative aspects of the study which. The chapter also presents the procedures that were taken for the analysis of specimens using XRF and Gas Chromatography-Mass Spectrometry.

4.1 The Mixed Methods Triangulation Convergence Design

The study used the Mixed Methods Triangulation Convergence Design (See Table 5). It is a single-phase design in which researchers implement the quantitative and qualitative methods during the same timeframe and with equal weight. It generally involves the concurrent, but separate collection and analysis of quantitative and qualitative data so that the researcher may best understand the research problem. The purpose of this design is to obtain valid and well-substantiated conclusions about a single phenomenon (Creswell 2009). The study used this design to corroborate quantitative results with qualitative findings on the level of pesticide contamination on artefacts at the Natural History Museum of Zimbabwe. The methods used included X-Ray Fluorescence Spectrometry, chromatography, condition analysis of the artefacts, observations, desktop survey and interviews with the museum staff.

Table 5 Mixed methods triangulation design procedure (Adopted from Creswell 2009)

Design Type	Variant	Timing	Weighting	Mixing	Notation
Triangulation	Convergence	Concurrent: Quantitative data (XRF and Chromatographic analysis of artefacts), and Qualitative data (Condition assessments of artefacts, observations, interviews and desktop survey) collected at the same time.	Equal	Merging the data during interpretation or analysis	Quantitative + Qualitative Research

This design model was used in the study to obtain different but complementary quantitative and qualitative data on pesticide contamination of organic collections at the Natural History Museum of Zimbabwe. It helped in establishing the pesticides that have been applied in the control of pests at the museum. Due to the overwhelming number of Ornithology and Mammal collections at the Natural History Museum of Zimbabwe as well as the costs involved in testing, not all collections were assessed and tested. A representative number of 300 specimens were selected for assessment and testing. Of these, 114 were analysed using XRF spectroscopy (See Appendix 10) and by Chromatography analyses. This sample number was chosen as it was within the limit of the costs and time needed to conduct the study. The selected specimens covered the entire history of the museum from the time it was established in 1902 up to the present time, and they were collected from different parts of the world including North America, South America, Europe, Asia and Africa. However, there are a few specimens from the turn of the millennium up to the present time that were assessed and tested as they were rare to find in the research sample.

4.1.1 Triangulation Design Procedure

4.1.2 Timing Decision

Timing is often discussed in relation to the time the data sets are collected. Concurrent timing occurs when the researcher uses both quantitative and qualitative methods during a single phase of the research study. Thus the quantitative and qualitative data are collected, analysed and interpreted at approximately the same time (Creswell 2009). The study used concurrent timing in the collection and analysis of quantitative and qualitative data on pesticide contaminants in collections and their effect on the conservation of the collections, and human health at the Natural History Museum of Zimbabwe.

4.1.3 Weighting Decision

Weighting refers to the relative importance of the quantitative and qualitative methods in answering the study's questions (Creswell 2009). The study gave equal weight to both quantitative (XRF spectrometry, gas chromatography) and qualitative methods (artefact analysis (condition assessment), XRF spectrometry, desktop survey, observations and semi-structured interviews) in addressing the issue of contamination of collections by pesticides at the museum.

4.1.4 The Mixing Decision

The data are merged when the researcher takes two data sets and explicitly integrates them. Researchers can merge the two data sets during interpretation by analysing them separately in a results section and then merging the two sets of results together during the interpretation or discussion phase (Creswell 2009). The data obtained through quantitative methods (XRF spectrometry and chromatography) was analysed separately from the data obtained through qualitative methods (artefact analysis, observations, desktop survey and semi-structured interviews). The two data sets were then merged during the interpretation and discussion of the research findings.

4.2 Research Population

A population is the full set of elements from which the sample is selected, or all the events, things, or individuals to be represented (Christensen. *et al* 2015). The research population were the staff of the Natural History Museum of Zimbabwe. They were drawn from the departments of Mammalogy, Ornithology, Entomology, Archaeology, Ichthyology and the Library. The

total number of research participants was eight. The research population also included at least 300 artefacts that were subjected to assessments.

4.2.1 Sampling of Research Population

Sampling is the process of selecting a few (a sample) from a bigger group (sampling population) to become the basis for estimating or predicting the prevalence of an unknown piece of information, situation or outcome regarding the bigger group (Kumar 2011). Therefore, the purposive sampling method was used in the study in selecting the research population which had knowledge about pest control practices at the Natural History Museum of Zimbabwe. In purposive sampling, the researcher identifies the characteristics of the population of interest and then locates individuals who match the needed characteristics (Christensen. *et al* 2015). Long-serving curatorial and technical staff were selected to participate in the study. They were selected based on their knowledge of pest control and treatment of the collections against pest attack at the museum.

4.3 Data Collection Strategies

Compiling the history of pesticide use in museums involves analysis of internal records such as catalogue cards, specimen treatment cards and loan records; receipts and purchase orders for pesticides used in the museum; contracts with pest control operators; published archaeological field notes; correspondence by staff members; monthly or daily reports by staff members; interviews with present long term staff members; physical evidence such as containers, application equipment, residues, odours around museum artefacts and in storage and exhibit areas; tags labels and marks on specimens; old, well-preserved artefacts made of materials known to be susceptible to pest attack; results from chemical analysis of artefacts and museum storage cabinets (Odegaard *et al.* 2005). The research used most of these ways in compiling the pesticides applied in the museum and on artefacts. Artefact analysis (condition assessments), observations, desktop survey, interviews, XRF and chromatographic analysis yielded valuable information on pesticide use at the museum.

4.3.1 Condition Assessments

At least 242 Ornithology and 58 Mammalogy artefacts were assessed using a condition assessment form (See Appendices 9 and 14 for the condition assessment form and the specimens that were assessed respectively. This disparity in the number of collections assessed in these two departments is attributed to the availability of staff who assisted in assessing the

collections. The assessments were done during the 2021 COVID-19 lockdown when the museum was partially operational, hence most of the curatorial staff were not reporting for work daily. Arrangements were made with some curatorial staff to assist with the assessments. Many Ornithology collections were assessed compared to Mammalogy because curatorial staff from the Ornithology department were on duty during the time of the assessments, whereas some curatorial staff from the Mammalogy department were on leave. A special arrangement was made to ensure that curatorial staff from Mammalogy assisted with the assessments.

The other factor attributed to the low number of Mammalogy collections assessed is that of security. The mammalogy department has some valuable animal skins, particularly of animals such as elephants, giraffes, lions, rhinoceros, leopards, and buffalos. There have been reports of theft of some of these valuable skins at the museum. Therefore, security has been tightened and permission had to be sought from the director of the museum to get access to the storerooms of these skins. It is a process which took some time for permission to be granted. Further, work done in the Mammalogy department was supposed to be under strict supervision from security personnel to prevent the theft of valuable skins. Therefore, when security personnel were overwhelmed with other security work in the museum, we could not do the assessments during their absence. These limitations contributed to the low number of collections assessed in the Mammalogy Department.

Condition assessment of Mammal and Ornithology collections involved the documentation of the state of conservation of the collections on condition assessment forms. The documentation addressed issues such as colour changes or fading on collections possibly caused by reaction with pesticide contaminants, as well as noting signs of deterioration on collections. These included signs of wear, weakening, dropping or falling of fur, feathers or hairs from the skins of birds and mammal collections. The data from condition assessments were recorded on condition assessment forms, excel forms and were also captured on camera. Systematic random sampling was used in the selection of artefacts for assessment. The sampling is accomplished by choosing elements from a randomly arranged sampling frame according to ordered criteria (Dane 1990). The samples were selected in a manner which ensured that at least 5 specimens were assessed at twenty-year intervals of their dates of acquisition from the time the museum became operational in 1902 up until the turn of the new millennium. The intervals were as follows: 1902-1922; 1923-1943; 1944-1964; 1965-1985; 1986-2006. This was meant to ensure that each period of the museum's existence was well covered in terms of the state of

conservation of the artefacts. Systematic random sampling was chosen because it eliminated bias in the selection of the artefacts for analysis, and it also ensured that the results obtained were generalised for all mammalogy and ornithology collections at the Natural History Museum of Zimbabwe.

4.3.1a. Safety Precautions

Pesticide contaminants are harmful to human health. To mitigate against these human health hazards, we assumed that hazardous pesticide contaminants were present in all the artefacts, and in the environment where we worked. Thus, we worked in a ventilated area with windows open in the storerooms. We wore personal protective equipment in the handling, assessment, and testing of the collections. These included lab coats and work suits, disposable nitrile gloves, goggles, and respirator masks. Lab coats and work suits helped in keeping dust and pesticide contaminants off our clothing. We ensured that they were always clean to avoid transferring contaminants to our clothing. We used nitrile gloves for handling the objects as they offered protection against a broad spectrum of chemicals, and unlike rubber or latex gloves, they do not leave residue on objects, and they do not cause allergic reactions (National Park Service 2010). After using the nitrile gloves, we discarded them and washed our hands with soap and running water. We avoided eating or drinking in work areas to prevent ingestion of pesticide contaminants.

4.3.2 Observations

Observations were used to complement the XRF and chromatographic analysis of the collections. XRF is best used in combination with other methods, even if the method is only visual observation (Bezur. *et al* 2020). An observation guide (See Appendix 8) was used in the study to identify the presence of pesticide residues that can be seen by the naked eye on organic collections, and pesticides within storage and display areas. The observation focused on the presence of whitish, grey or any powder or crystalline deposits on organic collections and in storage and display areas of the museum. Observations were also done on people who assisted with condition assessments and testing of the artefacts in the museum's storerooms on how they reacted to the chemical odours that were coming from the museum's storerooms. Further, the observations focused on the state of ventilation in the museum's storerooms and office space. Photos of observed chemical residues on collections, or in museum storage and display areas and the general museum environment were taken. For some pesticides one can visually examine objects for white crystal residues or smell a strong odour, for instance,

paradichlorobenzene and naphthalene produce a strong mothball odour (Nason 2001c). If a whitish powder or crystalline deposits are evident on natural history specimens or any other collections, the powder should be identified. If not arsenic, the residues/deposits could be borax or boric acid, DDT, or another such substance (Dawson 1992; National Park Service 2001; Hawks and Williams 1986).

4.3.3 Desktop Survey

Permission to access records was granted by the Natural History Museum of Zimbabwe. The study surveyed staff notes, curatorial records, skin tanning records and the museum's annual reports from the period 1905-2020. The pesticides that were used in the museum and on artefacts were recorded. A careful search through collections records is and should be an important first step as notations may be found in accession files, catalogue entries, annual reports or other curatorial records about what pesticides were used on which specimens and when (Nason 2001c).

4.3.4 Semi-Structured Interviews

An interview guide was used to probe research participants on the history of pesticide use in the museum. The interviews helped to bring out the pesticides used in the museum historically and how current pesticide applications may have a bearing on possible chemical contamination of the museum's collections. A total of eight research participants including senior staff that have knowledge of the history of pesticide use and those that are currently involved in the application of pesticides in the museum were interviewed. The interviews solicited pesticides that have been used or are currently in use at the Natural History Museum, looking at how, where, when and by whom they have been applied in the museum. The interviews also ascertained the safety of humans and collections from pesticide use at the museum by interrogating the protocols that have been instituted by the museum in the application of pesticides (See the interview schedule in Appendix 7).

4.3.5 Artefact Analysis

Artefact analysis involved testing the collections to determine the presence of pesticide contaminants. XRF and chromatographic analysis were used for the characterisation of pesticide contaminants in the collections. Analytical techniques that utilise specialised instruments allow for the determination of exact quantities and qualities of a chemical substance present in a sample (Odegaard and Sadonge 2001).

4.3.6 XRF Analysis

XRF spectrometry is both, a quantitative and qualitative method for analysing inorganic pesticide contaminants in museum collections. Quantitatively, it can show percentages of pesticide contaminants on particular sample spots analysed. Out of the targeted 300 artefacts, a total of 114 samples were analysed, with 69 from Mammalogy and 45 from Ornithology departments (See Figures 2 & 3 showing the analysis of the specimens using the XRF spectrometer). This low number of artefacts analysed is attributed to time constraints and administrative issues at the Natural History Museum of Zimbabwe. The XRF spectrometer was brought by the researcher's supervisor Maggi Loubser from the Department of Tangible Heritage Conservation, University of Pretoria, South Africa. We had a specific schedule that we were operating under as she was due to return with the XRF to South Africa after a week. Therefore, due to this, we had to work with a certain number of artefacts that were within the limit of the time that we had. The low number of ornithology specimens tested compared to mammalogy was because the Assistant Curator of Ornithology who was assisting us with the testing of the samples from the Ornithology Department had to take unexpected leave. Therefore, this limited the time that we spent on the analysis of ornithology specimens. The mammalogy samples included both taxidermy specimens as well as skins. The samples were selected in a manner which ensured that at least 2 specimens were assessed at twenty-year intervals from the time the museum became operational in 1902 up until the turn of the new millennium. The intervals were as follows: 1902-1922; 1923-1943; 1944-1964; 1965-1985; 1986-2006. This was meant to ensure that each period of the museum's existence was well covered in terms of analysis of the pesticides that were applied to the artefacts.

A Bruker Tracer 5i handheld X-Ray Fluorescence spectrometer was used in the study for determining the presence of heavy metal pesticide contaminants such as arsenic and mercury, and their contamination levels in collections. This handheld XRF spectrometer has a silicon drift detector (SDD) that has a higher resolution of approximately 140-150 eV, and better sensitivity making trace-level analyses possible (Shugar and Sirois 2012). The XRF spectrometer is a non-destructive technique and a far more efficient way of establishing the presence or absence of arsenic, lead and mercury residues. It is easy to use and analyses many elements in materials and it offers downloadable data of the analysis of collections in the museum (Odegaard 2014). The XRF spectrometer was brought to the Natural History Museum of Zimbabwe from the department of Tangible Heritage Conservation at the University of Pretoria for in situ analysis. Analyses were executed directly on the specimen to identify any

possible inorganic contaminants. The handheld X-ray Fluorescence Spectrometer cannot determine elements lighter than Na (atomic number 11) and could thus only determine heavy metal pesticides. The geological factory calibration covering the periodic table between Na and U was used, and quantitative data was collected. It has to be taken into consideration though, that the values represented have to be seen as relative concentrations because representative sampling of a specimen is not possible when using it in a non-destructive manner. Its use provided a quick screening tool for inorganic hazards and their relative quantities in the specimens, thus enabling us to survey multiple specimens in a relatively short amount of time.

The fundamental operation of the XRF spectrometer is that its X-ray tube voltage setting should generate X-rays of sufficient energy to excite the inner shell electrons of the elements being analysed. The voltage was set high enough at 40kV to excite the elements of interest, mainly lead, mercury, arsenic and possibly bromine, zinc and chloride. Unless an excitation voltage exceeding the binding energy of the element of interest is chosen, the elements will not be excited. When looking for many elements, a voltage based on the highest binding energy must be chosen. The parameters chosen should effectively excite the region of interest in the resulting spectrum. For analysis of heavy metal pesticides, the recommended voltage setting for the XRF instrument is 40 kV with the maximum current possible ensuring the dead time is limited to no more than 30% (typically scan times of approximately 60 seconds are considered acceptable) (Shugar and Sirois 2012). Further, we used the TiA1 filter to reduce unwanted background scattering of x-rays in the region of interest of elements that we analysed to enhance the detection of weak fluorescence signals. We also cleaned the XRF nose by wiping it before moving the instrument to another spot to prevent cross-contamination (Bezur. *et al* 2020).

Working practice guidelines that we followed to limit data variability in the analysis of artefacts included setting up a consistent working distance between the XRF instrument and the artefact, holding the instrument still and avoiding contamination of the instrument head. When analysing the skins, we had problems because of a lack of backscatter which caused the X-rays to switch off as a safety mechanism. This was overcome by using a tungsten background plate. This further helped to form a barrier between the skin and the table on which it was, allowing the XRF to only scan the specimens that we were analysing. For statistical precision, multiple spots on each specimen were analysed. Thus, all the specimens that we analysed for pesticide contaminants were subjected to multiple analyses on at least two spots per specimen, covering

different zones that may have different material types and different concentrations of pesticide residues. All specimens were analysed under identical conditions, using the same factory calibration to enable consistent analyses that could be compared across the board.

The spectrometer should be configured for optimal performance for the specific application. In this case, the geological calibration was chosen as it has the optimal setting for the heavy metal pesticides. The matrix (organic objects like taxidermy birds, mammals, and skins) is organic and thus a lot lighter than the average geological reference material the instrument was calibrated with. This would definitely impact the quantitative accuracy of results but has no impact on the absence or presence of the relevant toxic residue elements, or the concentrations relative to each other. Instrument check samples were analysed at the start of each session to ensure the instrument is stable and accurate.

4.3.6a Safety Precautions

X-rays produce ionising radiation capable of causing damage to organic compounds and living tissues, including cells and DNA (Bezur. *et al* 2020), therefore as a way of protecting users the X-ray spectrometer was configured in such a way that it automatically shuts off power in the X-ray tube unless the trigger is armed. Further as a way of protecting ourselves from the possible effects of radiation from the use of the XRF spectrometer, we also maintained a considerable distance from the radiation source (the tube of the XRF spectrometer) and set up our working space so that the spectrometer was always pointing away from other people. We also protected our eyes by ensuring that the XRF spectrometer was switched off before positioning it over areas of interest that we analysed on specimens. In addition to radiation safety, the analysis was done in a well-ventilated working environment to prevent inhalation of potentially hazardous chemical residues from collections, and appropriate personal protective gear was worn.

Research participants from the departments of Mammalogy and Ornithology at the museum assisted in the identification, handling and movement of the collections that were used in the study. The collections were potentially contaminated with pesticides used at the museum to conserve the collections; therefore, precautionary and safety measures were observed in the study to protect the participants and ourselves from hazardous pesticide residues on collections. Nitrile gloves, respirator masks and dust coats were worn to prevent direct contact with hazardous pesticide residues on the collections. This complied with ICOM's (2017) Code of

Ethics, Article 1.5 on health and safety which specifies that standards of health, safety and accessibility should be observed for museum staff and visitors.

4.3.6b Preliminary XRF Survey

An XRF survey involves detecting whether an element is present, and it also makes it possible to estimate its relative concentration in comparison to other elements and specimens. This is a very useful screening technique that helps to determine whether there is a potential problem within a collection. The starting point in doing the chemical analysis of the specimens at the Natural History Museum of Zimbabwe was to do a survey by randomly selecting and testing individual specimens among the thousands of mammalogy and ornithology specimens in collections at the museum. This XRF survey helped in determining potential problems of chemical contamination of the collections through the identification of inorganic pesticide chemical elements. A more thorough investigation of specific collections then followed.

4.3.6c Thickness and Chemical Make-Up Considerations of the Sample Matrix

Two material properties that affect the spectrum and the analytical mode chosen for data collection and interpretation are its thickness and the chemical makeup of the object. A pesticide treatment may have been applied to only one side of a specimen with no documentation or visual markers to indicate this. However, characteristic arsenic emission lines have much lower counts than the actual value and that discrepancy extends when examining thicker layers of skin. The thicker the layer of skin, the smaller the arsenic peak observed in the spectrum. It is recommended that XRF spectra be collected from both sides of an artefact if possible, to help address this issue (Shugar and Sirois 2012). To ensure that reliable findings were obtained in the study, specimens made from thick skin, and feathers were analysed from both sides.

Additionally, the total area and volume of the sample that is being irradiated have to be taken into account when considering what information is being collected by the XRF. To determine the penetration of X-rays into the material one must take the matrix composition, thickness (critical penetration depth) and density into account. If the object is essentially a thin film, the matrix does not contribute significant background to the XRF spectrum and so the composition of the object can essentially be ignored. For the bulk and intermediate thickness models, the matrix composition, the thickness (critical penetration depth) and the density must be taken into account. This leads to extreme difficulty in quantifying data (Markowicz 2008 cited in

Shugar and Sirois 2012). Therefore, to overcome potential problems coming from the above-mentioned factors, we analysed parts of the samples that had reasonable thickness for spectral assessments or used a zero background plate to prevent analysing underlying layers or the substrate on which we worked.

In addition to an artefact's thickness and chemical makeup, its surface geometry can have an adverse effect on the relative intensities of the resulting spectra. Effects such as surface roughness, particle shape, particle size and size distribution can all skew the proportional relationship between spectral intensity and elemental concentration (Jenkins *et al* 1995:271, cited in Shugar and Sirois 2012). This was often the case with rough surfaces, irregular shaped surfaces and variable geometrics of the specimens. This results in the object not being flush against the XRF window will affect the accuracy and precision of quantitative analysis, altering spectral intensities. All these factors show the difficulty in achieving representative and reproducible data from the specimen for quantitative analysis of pesticide residue. The study addressed this challenge by carefully selecting smooth, flat surfaces in the mammalogy and ornithology specimens and taking into consideration the fact that the numerical values are only relative values and not accurate % or ppm values.



Figure 2. Positioning a taxidermy specimen on the spectrometer.
 Natural History Museum of Zimbabwe. Photo: Maggi Loubser



Figure 3. Davison Chiwara and Maggi Loubser analysing skin samples in the Natural History Museum of Zimbabwe.
 Photo: Kith Gagisa Mkhwananzi .

4.4 Chromatography

Pesticides such as paradichlorobenzene, naphthalene, thymol, lindaneTM, dieldrin, VaponaTM and DDT were most frequently used for insect pest control in museums in the past. These particular pesticides are generally considered to be persistent although it is possible that they can be volatilised from an object given sufficient time, elevated temperatures, and high flow rates of air and sunlight. Their chemical properties make them amenable to various analytical methods, one of which is chromatography, both gas and liquid chromatography (Palmer 2001; Rushworth *et al.* 2014). In this study, GC-MS was used to confirm whether such pesticides were applied to specific mammalogy and ornithology collections at the Natural History Museum.

4.4.1 Sample Collection

The study used wipe-based sampling and collection of pieces of fur and skins that had fallen off specimens that were disintegrating, as well as chemical powders that were present in specimens and in cabinet drawers. See table 6. For wipe-based sampling chromatographic

paper was used to wipe on the specimens. All the samples that were collected were stored in amber glass vials so as to avoid disturbing them and prevent contaminating them and enable preparation directly in the vial. See Figure 4. The samples were taken for analysis at the University of Pretoria's Chemistry laboratory.

Table 6. Samples analysed by GC-MS.

	Name	Material
1	70295 Ornithology	Paper swab
2	68088 Marma bag	
3	4760 Monkeyfur	
4	Cabinet 15-97 drawer C	
5	Greypowder in skins room	Powder
6	Box in drawer	Powder-like



Figure 4. Folded paper swab in extraction vial. Photo: Ané Kritzingner.

4.4.2. Analysis: Gas Chromatography-Mass Spectrometry

The organic pesticides were extracted from the paper swabs and folded to fit in the bottom of a vial, (see Figure 4) with 2 mL hexane: acetone (1:1, v/v) using ultrasonication (5 min). For the powder and powder-like samples, 30 mg of the sample was extracted with 2 mL hexane: acetone (1:1, v/v) using ultrasonication (5 min) followed by centrifugation (4 min, 4000 rpm). 1.5 mL of the extract was transferred to an autosampler vial, the solvent was blown down with nitrogen to 0.5 mL and analysed by GC-MS. See Table 7, for gas chromatography parameters.

Table 7. GC-TOFMS Parameters.

Detector	LECO Pegasus 4D time-of-Flight Mass Spectrometer
GC	Agilent GC 7890A
Mass acquisition rate	10 spectra/s over a mass range of 40–450 Daltons
Source temperature	230 °C
Detector voltage	1750 Volts Electron impact ionisation (EI+) 70 eV
Inlet conditions	250 °C (splitless mode for 0.5 min) 1 µL injection volume
Carrier gas	Helium 5.0, 1.4 ml/min, constant flow mode
GC column	Rxi-MS 30 m x 0.5 mm ID x 0.25 µm film thickness
GC oven temperature programme	60 °C (1 min) @ 10 °C/min to 310 °C (2 min) Runtime: 28 min
Transfer line temperature	280 °C

For preliminary screening, single extractions were done and this was necessitated by costs of analysis, thus replicates and method validation were outside the scope of screening. Similarly, for screening purposes, analytical standards were not available due to prohibitive costs, thus compounds were tentatively identified at a $\geq 75\%$ mass spectral library match. When funds become available in future, follow up work on sample analysis will include confirmation of targeted compounds with analytical standards.

The destructive sampling technique which has greater chances for chemical detection was avoided because it is against the conservation ethics for heritage. Instead, a non-destructive sampling technique was used in the study. Although the non-destructive technique limited the chances for chemical detection, the study prioritised the conservation of specimens hence its use.

4.5 Chapter Summary

The chapter discussed the mixed-method triangulation convergence design which was used in the study. It is a research design which mixed quantitative methods that included XRF spectrometry and XRF spectrometry, and qualitative methods that include condition

assessments, observations, desktop survey, and semi-structured interviews in data collection. Both quantitative and qualitative methods had equal weighting in data collection. The chapter also highlighted the research population that was purposively sampled and selected from the Natural History Museum of Zimbabwe to participate in the study based on their knowledge of pest control practices at the museum. It also addressed why a limited number of samples had to be selected for quantitative analyses and why. Finally, the chapter addressed adherence to safety protocols in the handling and use of potentially contaminated artefacts at the museum, and the safe use of the XRF spectrometry.

Chapter 5

Data Presentation, Interpretation and Discussion

5.0 Introduction

This chapter presents the research finding based on the objectives of the study which are as follows: to investigate chemical residues on collections that could be indicative of pesticide residues of heavy metal and organic compounds on the collections at the Natural History Museum of Zimbabwe; assess the state of conservation of organic collections that have possibly reacted with pesticide contaminants at the Natural History Museum of Zimbabwe; to appraise pest control practices at the Natural History Museum to develop protocols that minimise the use of pesticides and to determine possible health risks to museum staff, researchers and visitors accessing contaminated collections and environments in the museum.

5.1 Chemical Residues on Specimens Indicative of Pesticide Residues of Heavy Metal and Organic Compounds at the Natural History Museum of Zimbabwe.

This objective sought to discover inorganic and organic pesticide contaminants on skins, mammalogy and ornithology specimens in the museum using XRF spectrometry and GC-MS. These analyses were preceded by physical condition assessments of over 300 individual specimens. The condition assessments were done using the naked eye by observing chemical powders on specimens and over 150 specimens mainly from the Ornithology department were contaminated (See Appendix 14 for specimens that were analysed). The condition assessments also involved observing the state of conservation of the specimens by noting obliterations in the colours of the specimens caused by pesticide contamination and noting signs of deterioration on specimens such as disintegrating and falling fur and feathers from the specimens (See sections 5.2 and 5.3). Pesticide residues that were discovered using XRF and gas chromatography-mass spectrometry are presented below in the form of tables and graphs with further explanations.

5.1.1 XRF Spectrometry Results

XRF spectrometry mostly analyses heavy metal inorganic pesticides (See Figures 5-9 about some inorganic pesticides found on specimens at the Natural History Museum of Zimbabwe). The analysis showed that the most prevalent chemicals that were applied to specimens in the museum are arsenic (As), mercury (Hg), lead (Pb), chrome (Cr) and sulphur (S). Out of the 114 specimens analysed for pesticide contaminants, only 16 showed no traces of chemicals on

them. This shows that the majority of the specimens analysed had pesticide residues in them. See table 12 for a summary of the number of specimens that were analysed and the chemicals that were detected. Table 8 shows the check sample data with certified data included were available, which was run daily before analyses commenced to check for instrument stability. Only common major element oxides as well as elements of interest were included in the table. The elements of interest were coloured.

Table 8. Daily check sample results.

GeoMining	OxideConcentrates																
Name	ID	Al ₂ O ₃	SiO ₂	S	K ₂ O	Ca	Cr	Mn	Fe	Cu	Zn	As	Cd	Sb	Hg	Pb	
CS-M2	Certified	11.02	68.31		4.64	0.58		0.08	1.60	0.02						0.08	
CS-M2	Instrument Check	12.87	71.86	0.16	4.48	0.60	0.00	0.09	1.42	0.02	0.06	0.00	< LOD	0.01	< LOD	0.07	
CS-M2	Instrument Check	12.73	70.55	0.17	4.44	0.58	0.00	0.10	1.40	0.02	0.06	0.00	< LOD	0.01	< LOD	0.08	
CS-M2	Instrument Check	12.30	69.49	0.19	4.30	0.59	0.00	0.09	1.40	0.02	0.06	0.00	< LOD	0.01	< LOD	0.08	
CS-M2	Instrument check	11.73	68.66	0.62	4.33	0.54	< LOD	0.09	1.42	0.02	0.06	< LOD	< LOD	0.01	< LOD	0.08	
	average	12.41	70.14	0.28	4.39	0.58	0.00	0.09	1.41	0.02	0.06	0.00	< LOD	0.01	< LOD	0.08	
	Acceptance Range min	9.32	64.89		4.41			0.06	1.40	0.01						0.07	
	Acceptance Range max	12.88	71.88		4.87			0.11	1.71	0.03						0.09	

As described in the methodology chapter each specimen was analysed in at least two spots, top and bottom, skin and fur etc. to try to capture any possible traces of toxic residues even if only applied to one surface. The data was divided into three groupings: Ornithology, Mammalogy and Skins to make the datasets easier to handle. The average of the multiple spots is used to make the data representation easier. Tables 9-11 present this average data for each specimen. (The complete datasets, with all elements analysed can be found in Appendices 10 - 13).

Table 9. Ornithology data: averages of different analysed spots.

ID	Species	Al2O3	SiO2	P	S	Cl	K2O	Ca	Cr	Mn	Fe	As	Hg	Pb
86350	Megalaima australis	< LOD	0.71	0.07	10.10	0.17	0.54	0.46	< LOD	0.00	0.11	1.22	0.01	0.01
70514	Capito niger	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.23	< LOD	0.00	0.01	< LOD	< LOD	< LOD
70515	Capito niger auratus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.18	< LOD	0.00	0.04	< LOD	< LOD	< LOD
51630	Trachyphonus margaritatus	< LOD	1.28	0.04	9.13	1.65	0.21	0.51	< LOD	0.00	0.11	3.07	0.03	< LOD
9818	Trachyphonus darnandii usambiro	< LOD	1.50	0.11	11.56	1.46	0.39	0.20	< LOD	0.00	0.19	1.34	0.01	0.00
34543	Aquila pomarina brehm	< LOD	0.79	0.03	9.46	0.59	0.17	0.39	< LOD	0.00	0.06	< LOD	< LOD	< LOD
34530	Accipiter nisus linn	< LOD	0.70	0.09	13.17	1.13	0.21	0.30	< LOD	0.00	0.11	0.43	0.05	0.01
34532	Accipiter nisus linn	< LOD	0.55	0.03	10.06	0.45	0.09	0.21	< LOD	< LOD	0.09	6.38	0.06	0.01
34531	Accipiter nisus linn	< LOD	0.44	0.06	11.07	0.66	0.14	0.18	< LOD	0.00	0.24	5.43	0.07	0.01
34534	Scelopizias brevipes (sen)	< LOD	1.47	0.04	7.34	0.39	0.57	0.48	< LOD	0.00	0.10	2.53	0.09	0.01
86148	Accipiter nisus	< LOD	0.13	0.04	8.30	0.14	0.06	0.56	< LOD	< LOD	0.03	4.81	0.04	< LOD
34528	Circus aeruginosus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.45	< LOD	0.02	< LOD	< LOD	< LOD	< LOD
34529	Circus aeruginosus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.26	< LOD	0.01	< LOD	< LOD	< LOD	< LOD
85520	Buteo lagopus	< LOD	0.47	0.06	9.69	1.22	0.26	0.14	< LOD	0.00	0.04	5.46	0.03	< LOD
72401	(Ardeola Grayii)	< LOD	0.42	0.11	10.81	0.41	0.47	0.15	< LOD	0.00	0.05	3.13	0.02	< LOD
72403	Butorides Virescens	< LOD	0.52	0.05	9.52	0.33	0.04	0.40	< LOD	< LOD	0.04	2.60	0.07	0.00
85537	RissaTridactyla	< LOD	0.37	0.05	12.58	2.32	0.10	0.08	< LOD	0.00	0.01	0.79	< LOD	< LOD
85531	Limosa Haemastica	< LOD	0.98	0.05	12.98	1.29	0.21	0.24	< LOD	0.01	0.08	4.88	0.05	0.00
72410	Capella delicate	< LOD	1.94	0.04	10.86	1.66	0.13	0.87	0.00	0.01	0.10	2.82	0.12	0.01
72413	Capella Stenura	< LOD	2.19	0.20	9.64	0.68	1.33	0.44	< LOD	0.01	0.19	8.82	0.08	0.01
73455	Heterotrogon Vittatum	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.17	< LOD	0.00	0.01	< LOD	< LOD	< LOD
70507	Trogon Citrealus	< LOD	0.88	0.09	6.96	0.35	0.13	0.15	< LOD	< LOD	0.04	4.12	0.03	< LOD
63628	Apus Pallidus	0.38	3.05	0.10	14.11	0.43	0.33	3.84	< LOD	0.00	0.26	0.14	< LOD	0.13
95952	Apus apus pekinensis	< LOD	3.40	0.06	10.97	0.24	0.40	1.58	< LOD	0.00	0.17	4.75	0.03	0.01
26480	Apus apus apus	< LOD	2.68	0.07	11.44	0.91	0.34	0.37	< LOD	0.01	0.82	2.28	0.03	0.00
46580	Apus apus pekinensis	< LOD	2.82	0.34	9.63	0.74	2.06	3.72	< LOD	0.02	0.42	0.06	< LOD	0.00
63948	Apus apus apus	< LOD	1.24	0.05	12.35	0.39	0.12	0.41	< LOD	0.00	0.17	5.05	0.03	< LOD
Indian Mir	No pesticides only borax	< LOD	1.69	0.05	12.01	0.23	0.11	0.61	< LOD	0.01	0.12	< LOD	< LOD	< LOD
81231	Chaetura sabini	< LOD	0.59	0.08	11.70	0.53	0.16	0.14	< LOD	0.00	0.12	< LOD	< LOD	< LOD
66616	Chaetura Pellagica	< LOD	0.72	0.10	11.79	0.41	0.34	0.18	< LOD	0.00	0.03	< LOD	< LOD	< LOD
77650	Cypseloides n.borealis	< LOD	0.90	0.05	12.77	0.36	0.18	0.13	< LOD	0.00	0.03	< LOD	< LOD	< LOD
66845	Chaetura pellagica	< LOD	1.03	0.08	12.83	0.46	0.11	0.13	< LOD	< LOD	0.03	< LOD	< LOD	< LOD
70505	Chaetura vauxi	< LOD	2.42	0.18	11.63	0.68	0.41	0.13	< LOD	< LOD	0.07	< LOD	< LOD	< LOD
86715	Thraskiornis aethiopicus	< LOD	0.52	0.24	5.13	1.23	0.52	0.08	< LOD	< LOD	0.04	< LOD	< LOD	< LOD
92471	Milvus migrans	< LOD	1.10	0.05	5.21	0.36	0.10	0.19	< LOD	0.00	0.11	< LOD	< LOD	< LOD
89233	Milvus migrans	< LOD	0.50	0.04	10.66	0.71	0.07	0.11	< LOD	< LOD	0.03	< LOD	< LOD	< LOD
3771	Platalea alba	< LOD	1.72	0.05	10.07	0.67	0.19	0.16	< LOD	0.00	0.17	< LOD	< LOD	< LOD
22127	Ciconia abdimii	1.46	3.85	0.07	6.50	0.68	1.05	0.68	< LOD	0.00	0.21	< LOD	< LOD	< LOD
89210	Ciconia abdimii	< LOD	2.33	0.09	9.81	0.80	0.26	0.11	< LOD	0.00	0.13	< LOD	< LOD	< LOD
93045	Ciconia abdimii	< LOD	3.77	0.16	6.97	0.20	0.49	0.26	< LOD	0.01	0.20	< LOD	< LOD	< LOD
13827	Necrosyrtes monachus(Hooded vulture)	< LOD	2.36	0.09	7.70	1.01	0.50	0.43	0.00	0.01	0.22	< LOD	< LOD	< LOD
89050	Torgos tracheliotos (Lappet face Vulture)	< LOD	2.01	0.02	9.78	0.65	0.13	0.30	< LOD	0.01	0.25	< LOD	< LOD	< LOD
B827	Pseudo gyps africanus	< LOD	5.10	0.10	6.98	1.90	0.41	0.45	< LOD	0.01	0.60	< LOD	< LOD	< LOD

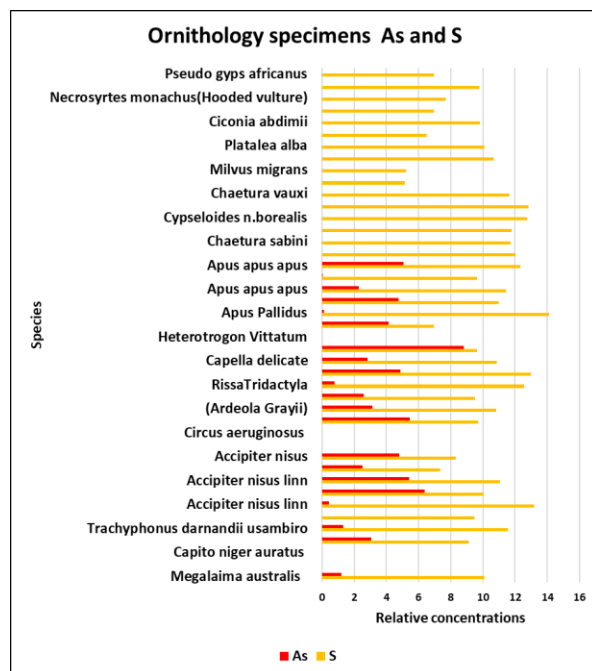


Figure 5. Ornithology specimens As and S.

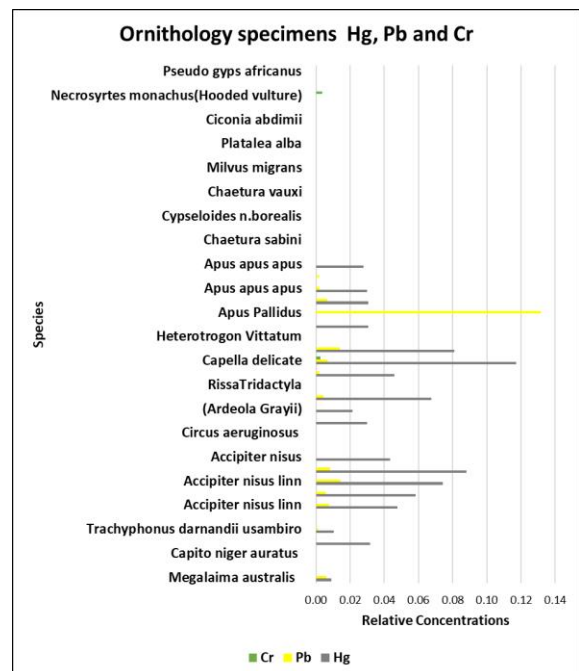


Figure 6. Ornithology specimens Hg, Pb and Cr.

As can be seen in Figure 5, there is sulphur present in all the specimens, and many of the inorganic pesticides are applied as sulphur salts, but the keratin in bird feathers also contain the sulphur-containing amino acid (cystine).

Arsenic was found in half the specimens tested and in relative concentrations up to 8% As. (Refer back to chapter 4 for the methodology where the limitations of accurate quantitative analyses were described). In Figure 6 mercury was observed in roughly half the specimens tested, probably applied as mercury salts. In 9 of the 43 ornithology specimens, lead was observed. Chrome was only observed in trace amounts in two samples but included in this graph as there was a lot more of it in the skins and mammalogy specimens.

Table 10. Skins data: Averages of different analysed spots.

ID	Species	Al2O3	SiO2	P	S	Cl	K2O	Ca	Cr	Mn	Fe	As	Hg	Pb
54193	Hystrix Africae Australis (Pocupine)	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.07	0.59	< LOD	0.07	< LOD	< LOD	< LOD
27413	Papio Ursinus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.04	0.60	0.01	0.05	< LOD	< LOD	< LOD
27968	Papio Ursinus	< LOD	0.68	0.08	6.39	1.01	0.01	0.08	1.32	< LOD	0.06	< LOD	< LOD	< LOD
56396	Manis temminck	0.33	3.49	0.08	9.04	1.67	0.06	0.15	0.08	< LOD	0.11	0.001	< LOD	< LOD
56293	Hyaena Brunnea	< LOD	0.93	0.10	8.42	2.61	0.04	0.08	1.47	0.02	0.24	0.038	< LOD	0.234
2578	Panthera Pardus	< LOD	0.57	0.09	14.54	1.07	0.10	0.17	3.32	0.06	0.52	0.046	< LOD	0.068
28766	Panthera Pardus	< LOD	1.19	0.14	13.50	3.31	0.06	0.17	1.27	0.02	0.17	0.042	< LOD	0.004
2648	Lycaon Pictus	< LOD	1.80	0.20	5.39	4.58	0.05	0.12	3.65	< LOD	0.40	< LOD	< LOD	0.225
33365	Crocuta Crocuta	< LOD	0.39	0.08	11.99	2.15	0.03	0.23	1.36	0.02	0.18	< LOD	< LOD	0.384
56740	Acinonyx Jubatus (cheetah)	< LOD	1.97	0.12	6.45	5.05	0.12	0.10	2.11	< LOD	0.21	0.005	< LOD	0.184
TG255	Vermilingua (Ant eater)	< LOD	1.13	0.20	5.04	1.98	0.24	0.14	1.03	0.01	0.25	0.002	< LOD	0.002
TNL10	Aepyceros Melampus (Impala)	< LOD	0.93	0.09	10.81	3.53	0.04	0.26	2.05	0.03	0.17	0.005	< LOD	0.009
11563	Kobus Vardon	< LOD	2.72	0.33	8.04	2.33	0.05	0.20	2.45	< LOD	0.25	0.005	< LOD	0.003
MSA67	Orycteropus Afer	< LOD	1.13	0.08	7.94	3.83	0.02	0.11	0.75	0.01	0.10	< LOD	< LOD	0.002
TNL4949	Aepyceros Melampus	< LOD	1.14	0.16	9.60	2.71	0.02	0.07	0.93	0.01	0.11	0.025	< LOD	0.011
0189	Redunca Arundinum	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	r4	< LOD	< LOD	< LOD	< LOD	< LOD
nm3365	Redunca (Reed Buck)	< LOD	1.26	0.04	7.65	5.34	0.05	0.15	0.70	0.01	0.17	0.012	< LOD	0.002
59200	Kobus leche	< LOD	0.72	0.09	7.10	2.38	0.02	0.08	2.38	0.04	0.09	0.007	< LOD	0.004
20539	Potamochoerus Porcus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.07	0.82	< LOD	0.20	0.006	< LOD	< LOD
25865	Phacochoerus africanus (warthog)	< LOD	2.03	0.07	1.99	1.76	0.04	0.07	0.37	0.01	0.16	0.001	0.00	0.002
25909	Potamochoerus Porcus	1.49	3.56	0.21	5.08	4.02	0.10	0.09	1.52	0.02	0.34	0.004	< LOD	0.003
25923	Phacochoerus africanus (Warthog)	< LOD	2.03	0.17	3.70	11.19	0.01	0.16	0.52	< LOD	0.15	0.004	< LOD	0.032
59314	Acinonyx Jubatus (Cheetah)	< LOD	0.81	0.12	10.03	9.55	0.03	0.08	1.12	0.01	0.11	0.042	< LOD	0.003
56283	Acinonyx Jubatus (Cheetah)	< LOD	0.98	0.11	12.22	4.41	0.02	0.07	0.50	0.00	0.11	0.038	< LOD	0.063
5014	Equus Buchelli (Zebra)	< LOD	1.12	0.08	6.50	3.91	0.02	0.06	0.39	0.00	0.14	0.007	< LOD	0.005
54716	Syncerus Caffer (Buffalo)	< LOD	0.48	0.06	8.34	1.85	< LOD	0.09	0.20	< LOD	0.12	0.054	< LOD	0.002
2071	Tragelaphus strepsiceros (Kudu)	< LOD	0.99	0.17	6.18	3.24	0.04	0.11	1.39	< LOD	0.11	0.002	< LOD	< LOD
21854	Sylvicapra Grimmia (Duiker)	< LOD	0.91	0.03	2.92	1.16	0.01	0.08	0.82	0.01	0.04	< LOD	< LOD	0.002
4044	Oreotragus Oreotragus (Klipspringer)	< LOD	0.58	0.07	7.60	2.44	< LOD	0.11	0.37	< LOD	0.03	0.011	< LOD	0.010
21960	Ourebia Ourebi	0.44	0.99	0.06	8.49	0.54	< LOD	0.23	2.22	< LOD	0.10	0.003	< LOD	0.007

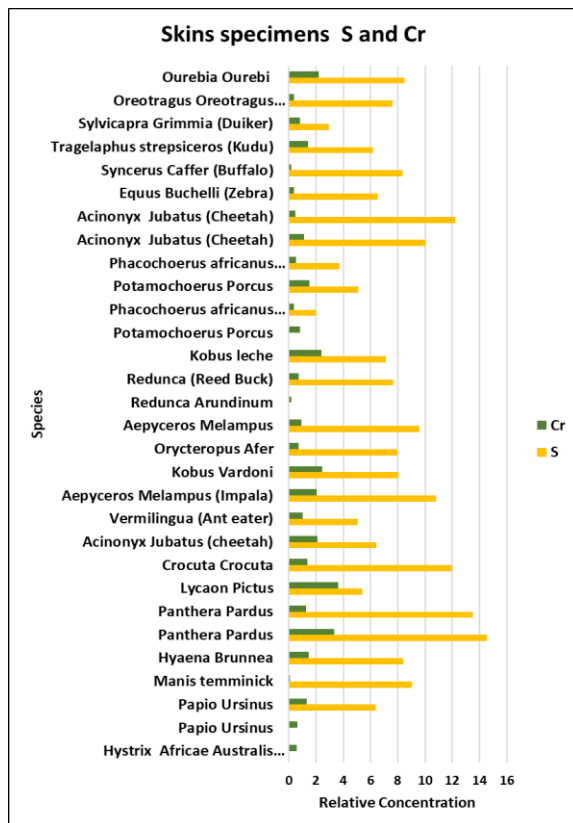


Figure 7. Skin specimens S and Cr.

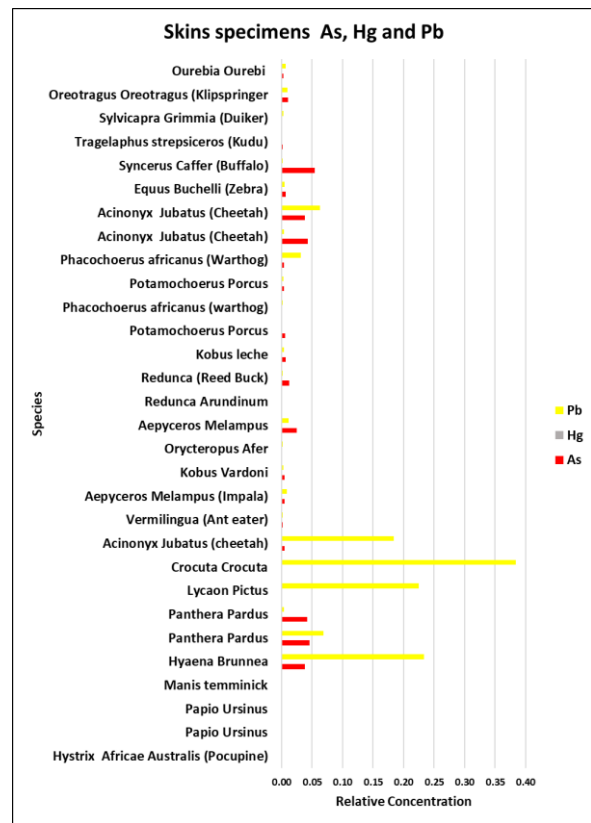


Figure 8. Skin specimens As, Hg and Pb.

Again, a relatively high percentage of sulphur is present in all specimens, and although many pesticides are applied as sulphur salts, this could also be due to the keratin in the hair of the animals. Chromium was present in all specimens, and this is indicative of a chrome tanning process. No mercury salts were observed in any of the skin specimens, different to the ornithology specimens where the presence of mercury was common. Traces of arsenic and lead are present in most of the specimens.

Table 11. Mammalogy data: averages of different analysed spots.

ID	Species	Al2O3	SiO2	P	S	Cl	K2O	Ca	Cr	Mn	Fe	As	Hg	Pb
68088	Otocyon megalotis	< LOD	0.59	0.09	2.71	0.28	< LOD	0.06	0.71	< LOD	0.03	< LOD	< LOD	< LOD
4362	Otocyon megalotis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.09	1.93	< LOD	0.13	< LOD	< LOD	< LOD
4770	Mus musculus	< LOD	1.01	0.05	11.87	1.21	0.93	0.49	< LOD	0.01	0.36	1.56	0.010	0.003
50743	Mus musculus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.17	< LOD	0.00	0.45	< LOD	< LOD	< LOD
52866	Mus musculus	< LOD	0.50	0.07	11.18	0.75	1.48	0.32	< LOD	0.00	0.08	2.52	0.02	< LOD
54079	Mus musculus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.24	0.00	0.00	0.03	< LOD	< LOD	< LOD
58132	Mus musculus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.20	< LOD	0.00	0.48	< LOD	< LOD	< LOD
50838	Mus musculus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.10	< LOD	< LOD	0.19	< LOD	< LOD	< LOD
77938	Mus musculus	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.18	0.00	0.00	0.30	< LOD	< LOD	< LOD
5892	Paraxerus cepapi	< LOD	0.60	0.12	5.34	0.32	1.18	0.59	< LOD	0.01	0.12	3.28	0.034	< LOD
17675	Paraxerus cepapi	< LOD	0.48	0.08	4.88	0.25	3.22	0.57	< LOD	0.00	0.11	11.58	0.030	< LOD
3472	Paraxerus cepapi	< LOD	4.65	0.16	8.90	1.04	0.82	0.55	0.01	0.01	0.51	1.45	0.013	0.008
4788	Paraxerus cepapi	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.12	< LOD	0.00	0.07	< LOD	< LOD	< LOD
69155	Paraxerus cepapi	< LOD	0.17	0.17	11.35	0.38	0.45	0.16	< LOD	0.00	0.06	< LOD	< LOD	0.01
26615	Felis lybica	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.07	0.08	< LOD	0.03	< LOD	< LOD	< LOD
55119	Felis lybica	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.05	1.29	< LOD	0.09	< LOD	< LOD	< LOD
55115	Felis lybica	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	0.97	< LOD	0.04	< LOD	< LOD	< LOD
55086	Felis lybica	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.14	0.35	< LOD	0.04	< LOD	< LOD	< LOD
55107	Felis lybica	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.14	0.81	0.00	0.14	< LOD	< LOD	< LOD
55051	Felis lybica	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.14	1.26	< LOD	0.06	< LOD	< LOD	< LOD
4760	Cercopithecus aethiops	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.23	0.00	0.00	0.16	< LOD	< LOD	< LOD
4411	Cercopithecus aethiops	< LOD	1.07	0.10	11.69	0.79	0.14	0.23	0.00	0.00	0.19	1.54	0.010	0.000
4405	Cercopithecus aethiops	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.14	< LOD	0.00	0.06	< LOD	< LOD	< LOD
56488	Aonyx capensis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.04	0.06	0.01	< LOD	< LOD	< LOD	< LOD
68605	Aonyx capensis	< LOD	1.17	0.11	3.44	2.84	0.03	0.11	0.88	< LOD	0.10	0.051	< LOD	0.002
56376	Aonyx capensis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	0.86	0.01	0.05	< LOD	< LOD	< LOD
68613	Aonyx capensis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.04	0.87	< LOD	0.04	< LOD	< LOD	< LOD
68685	Procavia capensis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.22	0.00	0.01	0.14	< LOD	< LOD	< LOD
68723	Procavia capensis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.12	< LOD	0.01	< LOD	< LOD	< LOD	< LOD
68728	Procavia capensis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.17	0.01	0.01	< LOD	< LOD	< LOD	< LOD
68760	Procavia capensis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.23	< LOD	0.01	0.12	< LOD	< LOD	< LOD
60585	Pedetes capensis	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.05	0.04	0.00	< LOD	< LOD	< LOD	< LOD
5218	Ichneumia albicauda	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	2.24	< LOD	0.05	< LOD	< LOD	< LOD
1318	Ichneumia albicauda	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	0.91	< LOD	0.05	< LOD	< LOD	< LOD
4293	Genetta genetta	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.20	< LOD	0.00	0.08	< LOD	< LOD	< LOD
2081	Genetta genetta	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.17	< LOD	0.00	0.15	< LOD	< LOD	< LOD
7481	Genetta genetta	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.22	< LOD	0.01	0.21	0.08	< LOD	< LOD
945	Genetta genetta	< LOD	0.54	0.09	14.00	0.91	0.32	0.13	< LOD	0.01	0.15	0.60	0--6	0.00
27921	Genetta genetta	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.2198	0.002	0.0041	0.22	< LOD	< LOD	< LOD

As can be seen in figure 9, In the Mammalogy specimens, the least inorganic pesticides were encountered. As a matter of fact, count rates were often so low that the XRF spectrometer would not collect all analyses conditions. This was the collection though, where we experienced physical discomfort due to the excessive amounts of naphthalene in the air and all drawers, so swipe samples were taken for chromatography analyses. Only about three samples showed traces of lead, mercury was mostly below the detection limits of the instrument, nine specimens had traces of arsenic, 18 of chromium and about half the samples contained sulphur.

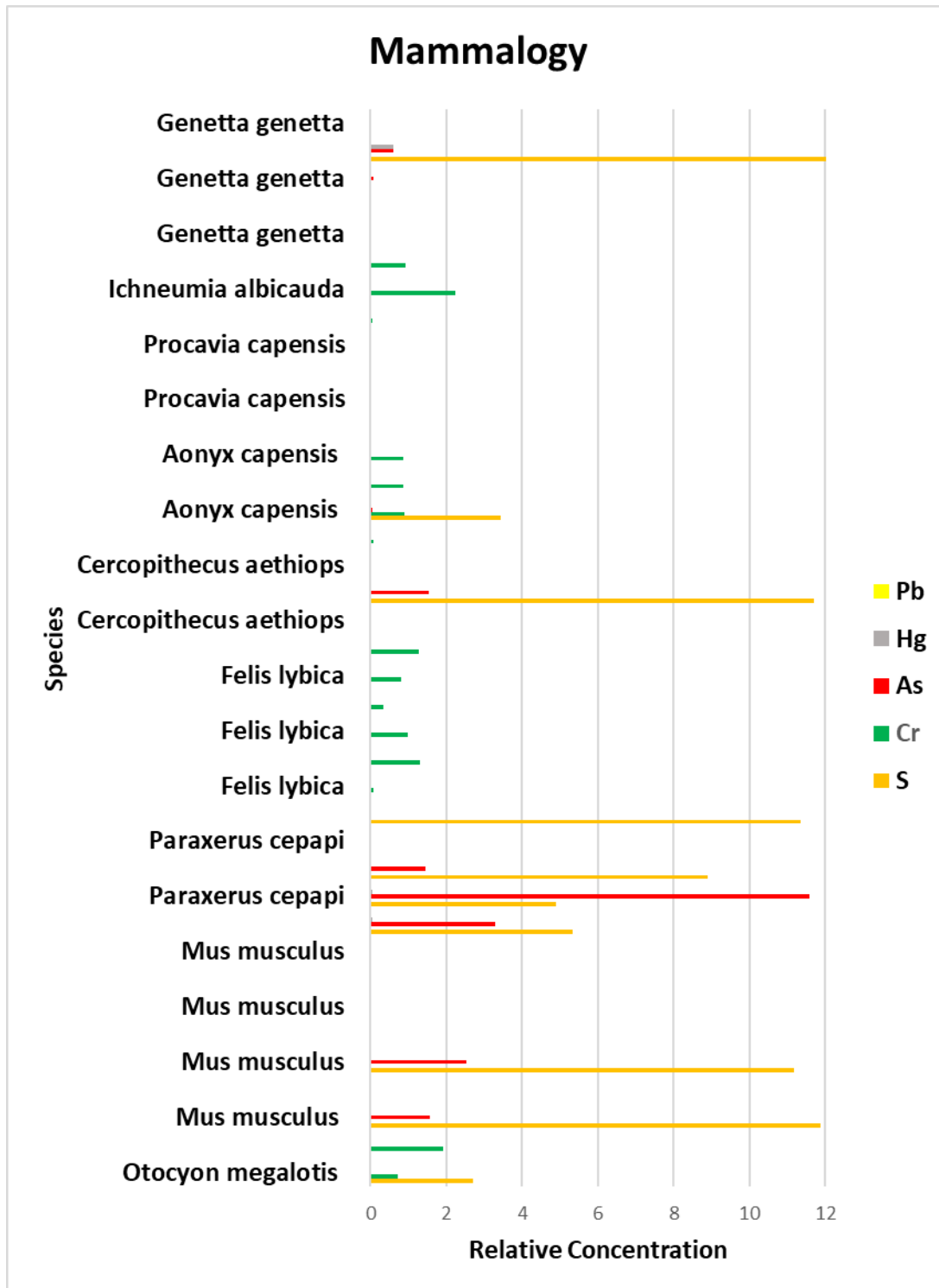


Figure 9. Mammalogy specimens Pb, Hg, As, Cr and S.

Table 12. Summary of XRF analysis of pesticide contaminants in collections at the Natural History Museum of Zimbabwe.

	Mammalogy Collections	Ornithology Collections	Total
Collections tested	69	45	114
Arsenic detected	32	21	53
Mercury detected	7	18	25
Lead detected	30	14	34
Sulphur detected	37	37	74
Chrome detected	54	3	57
Chlorine detected	36	41	77
No chemicals detected	8	8	16

In table 13 the XRF spectrometry results also showed that the majority of the specimens that tested positive for chemical contamination were contaminated by at least two or more types of chemicals, indicating multiple applications of different chemicals on the specimens. The specimens were collected from far and wide across the globe and they were collected between the 19th century and the 20th century, which is a very long period of exposure to chemical contaminants. However, due to a lack of treatment records for individual specimens in the museum, it could not be established whether some chemicals were applied on specimens in the field during collecting, or they were applied by the collecting institutions before they eventually found their way to the Natural History Museum of Zimbabwe, or whether some were applied at the Natural History Museum of Zimbabwe.

Table 13. The place of origin, period and chemical contaminants detected on specimens using XRF spectrometry.

1. Object I.D & Origin				Chemicals	Period	Collecting Institutions
34534, Beirut	34530, Scotland	34532 (N.d), Britain	34531, (N.d) Britain	Arsenic, Mercury, Lead, Sulphur, Chlorine	1857-1899	Norwich Castle Museum
34543, Permerania				Sulphur, Chlorine	1857-1899	Norwich Castle Museum
72413, Britain	72410, Britain	72403, California		Arsenic, Mercury, Lead, Sulphur, Chlorine	1857-1899	Museum of Zoology, University of Cambridge
85531, Fort Cosmos, USA				Arsenic, Mercury, Lead, Sulphur, Chlorine	1857-1899	
85537, Denmark				Arsenic, Sulphur, Chlorine	1857-1899	Museum of Zoology, Copenhagen, Denmark
72401, India				Arsenic, Mercury, Sulphur, Chlorine	1857-1899	
85520, Denmark				Arsenic, Mercury, Sulphur, Chlorine	1857-1899	
86148, Suffolk, Britain				Arsenic, Mercury, Sulphur, Chlorine	1857-1899	
95952, China				Arsenic, Mercury, Lead, Sulphur, Chlorine	1900-1910	American Museum of Natural History
63628, Tunisia				Arsenic, Lead, Sulphur, Chlorine	1900-1910	Natural History Museum, Wien, Austria
86350, India				Arsenic, Mercury, Lead, Sulphur, Chlorine	1900-1910	
46580, Afghanistan				Arsenic, Lead, Sulphur, Chlorine	1931-1940	American Museum of Natural History
63948, Austria				Arsenic, Mercury, Sulphur, Chlorine	1931-1940	Natural History Museum, Wien
1318, Zambia	27921, Zimbabwe			Chrome	1941-1950	
3771, Zimbabwe	77650, USA			Sulphur, Chlorine	1941-1950	
66616, USA				Sulphur, Chlorine	1941-1950	Texas Cooperative Research
945, Zimbabwe				Arsenic, Mercury, Lead, Sulphur, Chlorine	1941-1950	
2648, Zambia				Lead, Chrome, Sulphur, Chlorine	1941-1950	
2071, Zimbabwe	TG255 Zim (N.D)			Arsenic, Chrome, Sulphur, Chlorine	1941-1950	
2578, Zambia				Arsenic, Lead, Chrome, Sulphur, Chlorine	1941-1950	
3472 Zimbabwe				Arsenic, Mercury, Sulphur, Chrome, Chlorine	1941-1950	
52866 Zimbabwe				Arsenic, Mercury, Sulphur, Chlorine	1941-1950	
51630, Somalia	5892, Tanzania	17675, Malawi		Arsenic, Mercury, Sulphur, Chlorine	1951-1960	
9818, Tanzania	4771, Zimbabwe	4411, Namibia		Arsenic, Mercury, Lead, Sulphur, Chlorine	1951-1960	
26480, Sweden				Arsenic, Mercury, Lead, Sulphur, Chlorine	1951-1960	Malmo Museum of Natural History
4044, Zambia				Arsenic, Lead, Chrome, Sulphur, Chlorine	1951-1960	
5014 Zambia				Arsenic, Chrome, Sulphur, Chlorine	1951-1960	

7481, Zimbabwe				Arsenic	1951-1960	
66845 USA	22127 Zimbabwe			Sulphur, chlorine	1951-1960	
4788, Zimbabwe	4760, Namibia			Chrome	1951-1960	
26615, Botswana	55119, Botswana	55115, Botswana	55107, Zimbabwe	Chrome	1961-1970	
55051, Zimbabwe	68685, Zimbabwe	68728, Zimbabwe	27413, Zimbabwe	Chrome	1961-1970	
27968, Botswana	33365, Zimbabwe	11563, Botswana	21854, Zambia	Lead, Chrome, Sulphur, Chlorine	1961-1970	
56293, Botswana	28766, Botswana	TNL10, Botswana	NM3365, Zimbabwe	Arsenic, Lead, Chrome, Sulphur, Chlorine	1961-1970	
68088, Botswana				Chrome, Sulphur, Chlorine	1961-1970	
20539, Zimbabwe				Arsenic, Chrome	1961-1970	
25865, Zimbabwe				Arsenic, Lead, Chrome, chlorine	1961-1970	
25909 Zimbabwe	25923 Zimbabwe			Arsenic, Chrome, Sulphur, Chlorine	1961-1970	
70507, Mexico				Arsenic, Mercury, Sulphur, Chlorine	1961-1970	Los Angeles State Museum
MSA67 Botswana				Sulphur, Chrome, Chlorine	1961-1970	
81231, Kenya				Sulphur, Chlorine	1961-1970	US National Museum of the Smithsonian Institution
70505, Costa Rica				Sulphur, Chlorine	1961-1970	Museum of Zoology, Los Angeles State University
TNL4949 Botswana				Arsenic, Chrome, Chlorine, Sulphur	1961-1970	
54079, Zimbabwe	55086, Zimbabwe	56376, Zimbabwe	68613, Zimbabwe	Chrome	1971-1980	
86715, Zimbabwe	89233, Botswana			Sulphur, Chlorine	1971-1980	
68605, Zimbabwe	56283, Zimbabwe	54716, Zimbabwe		Arsenic, Lead, Chrome, Sulphur, Chlorine	1971-1980	
56396, Zimbabwe				Arsenic, Chrome, Sulphur, Chlorine	1971-1980	
69155, Zimbabwe				Arsenic, Lead, Sulphur, Chlorine	1971-1980	
77938, Zimbabwe	60585, Zimbabwe			Chrome	1981-1990	
92471, Zimbabwe	89210, Zimbabwe	8827 (N.D, NL)	89050 (ND, NL)	Sulphur, Chlorine	1981-1990	
59200, Botswana	59314, Zimbabwe			Arsenic, Lead, Chrome, Sulphur, Chlorine	1981-1990	
93045, Zimbabwe				Sulphur, Chlorine	1991-2000	
13827 No locality				Sulphur, Chrome, Chlorine	No Date	

5.1.2 Gas Chromatography Mass Spectrometry Analysis Results

Gas chromatography-mass Spectrometry (GC-MS) analyses organic pesticide residues that cannot be detected by XRF spectrometry. Table 14 shows three organic pesticides that were detected on the specimens and in storage cabinets through GC-MS. These include 1,4-dichlorobenzene, naphthalene and DDT.

Table 14. Tentative identification of targeted compounds $\geq 75\%$ mass spectral library match (NIST).

Sample	1,4-dichlorobenzene	Naphthalene	Dichlorvos	DDT	Thymol	Lindane	Dieldrin	Diazinon
Control	ND	ND	ND	ND	ND	ND	ND	ND
70294, Ornithology	ND	✓	ND	ND	ND	ND	ND	ND
68088, Marma bag	✓ *	✓	ND	✓	ND	ND	ND	ND
Grey powder in skins room	ND	ND	ND	ND (DDE?)	ND	ND	ND	ND
4760, Monkey fur	ND	✓	ND	ND	ND	ND	ND	ND
Cabinet 15-97 drawer c, white powder	✓ *	✓	ND	✓ (DDE?)	ND	ND	ND	ND
Box in drawer	✓ *	✓	ND	✓	ND	ND	ND	ND
				<i>o,p'</i> - DDT				
				<i>p,p'</i> - DDT				
				<i>p,p</i> -DDE				

✓ Detected, ND Not Detected, *Isomer to be determined with linear retention indices

The research findings presented above were corroborated by the data obtained through the desktop survey and observations presented below.

5.1.3 Desktop Survey

The Natural History Museum's annual reports and personal notes written by its former curators yielded valuable information on the history of pesticide use in the museum. The 1907 curator's report by F, P Mannell indicated that arsenical soap and alum were used in the drying of skins at the museum (Rhodesia Museum, Bulawayo (Natural History Museum), Sixth Annual Report 1907). The 1908 curator's report by the Acting Director of the museum, E.C Chubb also highlighted the use of arsenic in the drying of skins at the museum (Rhodesia Museum, Bulawayo (Natural History Museum), Seventh Annual Report 1908). The 1909 curators report by E.C Chubb indicated that the museum poisoned some specimens with corrosive sublimate to preserve them from pest attack. The report further stated that during the preparation of skins, they applied arsenical soap on the inside of the skins in the form of a lather using a brush (Rhodesia Museum, Bulawayo (Natural History Museum), Eighth Annual Report 1909). The 1910 curator's report by A.E.V Zealley indicated that the museum carefully poisoned and preserved the specimens but did not specify the chemical used (Rhodesia Museum, Bulawayo (Natural History Museum), Ninth Annual Report 1909).

The 1913 annual report highlighted that arsenical soap was applied on the inside of skins to preserve them (Rhodesia Museum, Bulawayo (Natural History Museum), Twelfth Annual Report 1913). The 1922 curator's report indicated that turpentine was used in the treatment of specimens as a way of preserving them (Rhodesia Museum, Bulawayo (Natural History Museum), Twenty-First Annual Report 1922). The 1940 Zoology report mentioned the poisoning of specimens but did not specify the chemicals used (National Museum of Southern

Rhodesia, Bulawayo (Natural History Museum), Thirty-Ninth Annual Report 1940). The 1948 Zoology report mentioned the poisoning of specimens but did not specify the chemicals used (National Museum of Southern Rhodesia, Bulawayo (Natural History Museum), Forty-Seventh Annual Report 1948). The 1955 Zoology report indicated that a large cement tank was built adjacent to the storeroom for chemical treatment of the skins and that the whole treatment was now being done in the tank (National Museum of Southern Rhodesia, Bulawayo (Natural History Museum), Fifty-Fourth Annual Report 1955). The 1968 technical department report on the tanning of skins, and subsequent reports for 1969, 1970, 1971, 1983, 1984-1985, 1985-1986, 1987 and 1989 indicated that chrome was used for tanning mammal study skins at the museum (National Museum of Southern Rhodesia, Bulawayo (Natural History Museum), Annual Reports). The 1985-1986 National Museum and Monuments of Zimbabwe Annual Report indicated that 6 monthly fumigations of the whole museum with insecticide in gas form were done and that VaponaTM blocks were used by the museum to protect specimens against pest attack. The report further stated that more VaponaTM stocks worth \$1,500 Zimbabwean dollars were imported by the museum.

Jones who was the former curator of the Natural History Museum in 1980, wrote that during a personal communication with another former curator of the museum Dr E.C.G Pinhey indicated that the museum heavily relied on naphthalene for pest control and that at the time the museum was unable to purchase naphthalene in large quantities as it was in short supply. Further, Jones indicated that the museum used paradichlorobenzene, EdolanTM and GamatoxTM for pest control (Jones personal notes, 1980).

A 2009 quotation from W & M Chemical Suppliers Enterprises (Pvt) Ltd, which was a response to the enquiry by the Natural History Museum of Zimbabwe, indicated that they had 25 kgs of naphthalene for US\$0,6 cents per kg and that the company was looking forward to supplying the museum's requirements. The 2009 museum's report on the current status of collections in the departments of Mammalogy, Ornithology, Herpetology, Invertebrates and Palaeontology/Geology noted with concern the deterioration of some organic specimens from pest attack in the museum and recommended the use of naphthalene, paradichlorobenzene, aluminium phosphate, methyl bromide, dichlorvos, permethrin, formalin, and isopropyl alcohol to preserve the specimens. The report indicated that skins and skull specimens in the department of Mammalogy were in fairly good condition owing to the raw naphthalene that was applied to the collection. It was also reported that a local company was hired and applied

methyl bromide and permethrin for fumigation and fogging respectively, with the sole purpose of preserving the mammal specimens. The report further recommended the fumigation of museum premises four times a year at three-year intervals.

Chrome, alum, formic acid, SyntanTM and calcium formate were also used for the tanning of animal skins in the museum. Notes prepared by J. Hutton, and T. Sango-Moyo, former curators of the museum showed the process of tanning skins in the museum. This involved relaxing the salted skins by soaking them in an aqueous mixture of alum, formic acid and salt. This was followed by the actual tanning process through the soaking of the hides in a salt solution with the addition of formic acid and chrome salts. Syntan and sodium bicarbonate were subsequently added to the skins. The hides were then oiled by placing them in a bath of FurliquorTM and later tumbled in a drum with sawdust until they were dry and soft. For re-tanning alum-tanned skins, synthetic retan solution, SyntanTM, salt and calcium formate were used. (Hutton and Sango-Moyo notes on the chrome tanning process used at the National Museum of Zimbabwe (Natural History Museum) 1983). These findings reflect the information captured in the South African Museums Association Bulletin of 1968 (SAMAB) on the use of chrome in the tanning of skins. SAMAB published lectures by Coffin Grey on the use of commercial chrome and synthetic tanning on natural history specimens to conserve them against pest attack in 1968. Zimbabwean museums were part of the South African Museums Association (SAMA) in the early days of the organisation's establishment.

A curator's notes on the treatment of specimens indicated that prepared study skins were treated with powdered borax. The notes also indicated that creosote was used as a preservative for specimens and that it was sprinkled onto the brain cavity of birds, and on the ends of the leg, foot and wing bones. The notes further indicated that sodium fluorosilicate was used as a preservative on the museum's specimens by painting a saturated solution of it onto the underside of the skins before stuffing (during taxidermy) or applying it onto the fur of the skin after stuffing. The notes also highlighted that skeletons and skulls of animals once they were cleaned of flesh, were submerged in a super-saturated solution of sodium fluorosilicate as a way of preserving them. See table 15 that shows the pesticides that were discovered through a desktop survey. However, there are other chemical powders that the researcher came across whose names he could not establish. See Figure 25.

Table 15. Pesticides discovered through desktop survey at the Natural History Museum.

Chemicals	Year	Source
Arsenical soap, alum	1907	Annual report
Arsenic	1908	Annual report
Corrosive sublimate, Arsenic	1909	Annual report
Unspecified poison	1910	Annual report
Arsenical soap	1913	Annual report
Turpentine	1922	Annual report
Unspecified poison	1940	Annual report
Unspecified poison	1948	Annual report
Tanning of skins using chrome, alum, formic acid, syntan, calcium formate, sodium bicarbonate, furliquo, synthetic retan solution	1969-1989	Annual reports; Curators' notes on tanning
Naphthalene, paradicholobenzene, edolan, gamatox	1980	Former curator's personal notes
Insectgas, Vapona	1985-1986	Annual report
Naphthalene	2009	Quotation from W & M Chemical suppliers Enterprises (Pvt) Ltd
Naphthalene, paradichlorobenzene, aluminium phosphate, methyl bromide, dichlorvos, permethrin, formalin, isopropyl alcohol	2009	The Departments' report on the conservation of collections
Borax, creosote, sodium fluosilicate	No date	Curator's notes

The data presented above shows the contamination of specimens at the Natural History Museum of Zimbabwe by inorganic and organic pesticides. There are at least 30 different pesticides that have been applied multiple times directly on collections and in storage and display environments in the museum. This figure is not exhaustive as it is only a reflection of specimens that were analysed and information that was obtained from documents that were accessible during the conduction of the research. These findings are an indication of the persistent application of pesticides on collections at the Natural History Museum of Zimbabwe for a period spanning over a century of years from around 1906 up to recent times. What is alarming about these findings is that out of the total number of 117 (114+3) specimens analysed through XRF and gas chromatography-mass spectrometry respectively, only 16 showed no evidence of contamination by pesticide residues. These findings indicate that the museum's default method of pest control has always been and still is pesticide application. However, it

must be noted that some collections may have been treated with these pesticides by collectors or other museums across the globe before they were eventually acquired by the Natural History Museum of Zimbabwe as their dates of collection predate the establishment of the museum, which was established in 1902 (See Table 13). The collections could have been further subsequently treated when they were then acquired by the museum. The data prove beyond reasonable doubt that staff, researchers and visitors at the museum are working with poisoned collections.

5.2 Effects of Pesticides in the Conservation of Organic Collections

Observations made which were corroborated by findings from the desktop survey show that since the first half of the 20th century, the Natural History Museum of Zimbabwe has been experiencing challenges of deterioration of some of its specimens which persist in present times. The 1922 curator's report indicated that some specimens such as the ant-bear and the civet were going bald as a result of turpentine which was used in the treatment of specimens to preserve them (Rhodesia Museum, Bulawayo (Natural History Museum), Twenty-First Annual Report 1922). Further, during a personal communication between two former curators of the museum Jones, E.M and Dr E.C.G Pinhey, there was an admittance of the use of naphthalene in the museum for the conservation of specimens against pest attack between the curators and the latter indicated that naphthalene was found to alter colours of specimens (Jones E.M personal notes (1980).

This conservation challenge of specimens deteriorating most likely from reacting with pesticides persists today as shown in Figures 11 & 12, where the *Tatera Leucogaster* specimens (bushveld gerbil) are losing fur. While there is no direct evidence of turpentine as a cause for the baldness of the specimens as was the case with ant-bear and the civet specimens as reported in the 1922 curator's report, powder chemical residues mixed with fallen fur from the specimens that were tested through gas chromatography-mass spectrometry indicated that the chemicals that were present were 1,4 dichlorobenzene, naphthalene and DDT. Other specimens have disintegrated beyond restoration such that they are now being stored in plastic bags to keep the disintegrated parts in one place (See Figures 12-15). XRF spectrometry analysis that we did on these deteriorating specimens indicated that they are contaminated with arsenic, mercury, lead, chrome, sulphur and chlorine.

While it cannot be absolutely claimed that the deterioration of these specimens is attributed to pesticide contamination, the discovery of these chemicals associated with the falling fur and disintegration of the specimens likely points to pesticide contamination as the probable cause of the deterioration of the specimens. There could be some reaction that is taking place between these varied chemicals and the specimens resulting in their baldness and disintegration respectively. While there are other factors that may contribute to the deterioration of the specimens such as fluctuating temperature and relative humidity, poor storage and exposure to light and ultraviolet radiation, these threats may be minimal because the specimens are kept in purpose-built storage facilities that offer multiple layers of protective enclosures starting from the walls of the building, storage cabinets and the padding (See Figure 10). They are well insulated and sealed against the exterior environment. They are designed to maintain a narrow temperature and relative humidity range. They exclude daylight & ultraviolet radiation and chances of light reaching the specimens are very slim as they are always switched off in storage rooms except in cases where staff and other users are working with the specimens. Therefore, this makes pesticides the likely cause of the deterioration of the identified specimens in the museum. If not pesticides alone, it could be a combination of the pesticides and minimal exposure to other agents of deterioration such as light and fluctuating temperatures and relative humidity.

Besides the deterioration of the material of the specimens, chemical contaminants affect the authenticity of the material of the specimens. Research has shown that pesticides affect the DNA of specimens. All chemical agents applied to animal skins change the characteristics of their material and structures (Bock and Quaissser 2019). While pesticides may make the specimens look well preserved, their DNA may have been altered by the chemicals, which negatively impacts the research potential of these natural history specimens. This negatively impacts research on organic natural history specimens. Further, one curator indicated that some ornithology specimens were experiencing discolouration on their plumage as a result of reactions with pesticides. Observations made by the researcher showed that some ornithology specimens were heavily contaminated with white powder chemical residues which tainted the colours of some ornithology specimens thereby affecting their originality and integrity [See Figures 16 (skin), 20-24 (ornithology)].

Building envelope (Outer Walls)

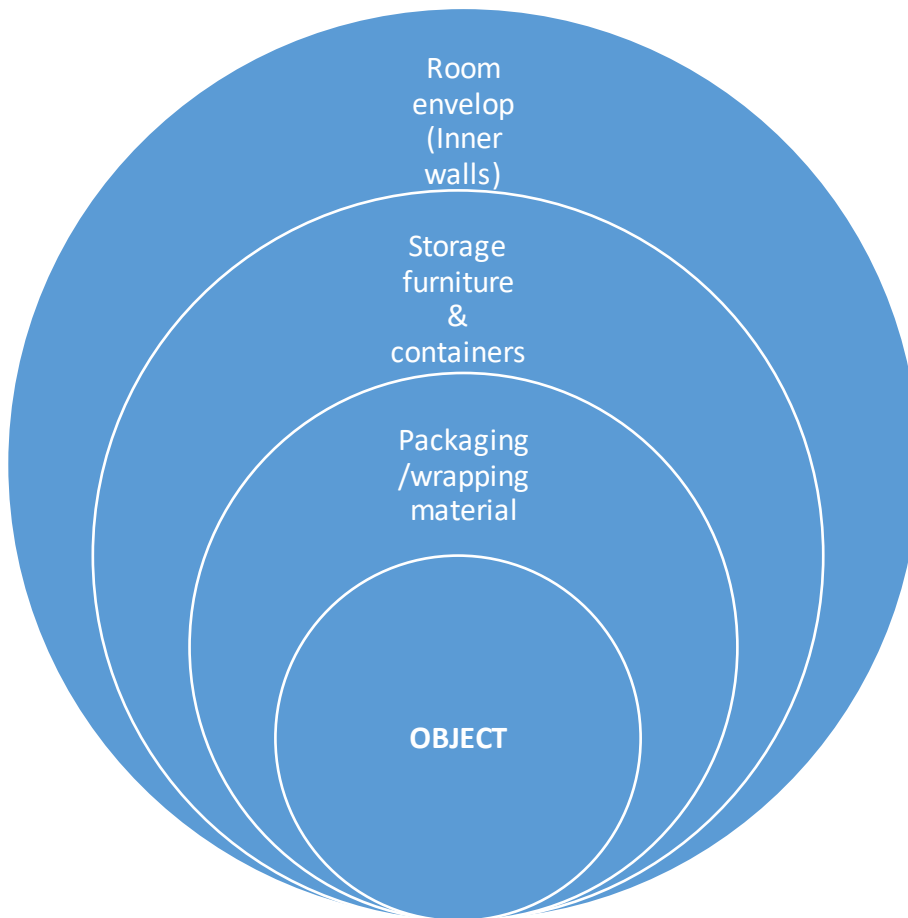


Figure 10. Multi-layered protection of an object: Adopted from National Park Service (2016).



Figure 11. *Tatera Leucogaster* specimens deteriorating at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.



Figure 12. Disintegrating *Kobus Vardoni* specimen (Accession Number 11563) contaminated with lead, chrome, sulphur and chlorine. Photo: Davison Chiwara.



Figure 13. Disintegrating Warthog specimen (Accession Number 25865) contaminated with arsenic, lead, chrome, and chlorine. Photo: Davison Chiwara.



Figure 14. Disintegrating Potamochoerus Porcus specimen (Accession Number 25909) contaminated with arsenic, lead, chrome, and chlorine. Photo: Davison Chiwara.



Figure 15. Disintegrating *Acinonyx Jubatus* specimen (Accession Number 59314) contaminated with arsenic, lead, chrome, sulphur and chlorine. Photo: Davison Chiwara.

5.3 Pest Control Practices at the Natural History Museum of Zimbabwe.

To understand the context of pest control at the museum, eight members of staff which included curators of Mammalogy, Ornithology, Archaeology, Ichthyology, Entomology, Herpetology and Galleries as well as the librarian were interviewed. Three of the interviewed staff from Herpetology, Mammalogy and Galleries are senior curators of the museum, having worked for the museum for 40, 33 and 26 years respectively. The interviews were meant to answer the following questions: what are the pesticides that have been used in the museum both historically and currently?; does the museum systematically document pesticides used?; who is responsible for pesticide application?; what is the frequency of pesticide use in the museum?; which precautionary measures are taken by the museum staff to prevent pesticide contamination of artefacts during the application of pesticides?; what are the perceptions of the museum's staff regarding pesticide use on the conservation of collections?; what other non-pesticide methods of pest control are used by the museum?

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Regarding pesticides used for conserving pesticides against pest attack in the museum, the curators identified the following pesticides; VaponaTM strips, naphthalene, DiazTM, PyrethrumTM, acetone, alum (for tanning of skins), acetate, aluminium phosphate, benzene, carbon tetrachloride, chloroform, formic acid, ethanol (in fluid-preserved specimens), formaldehyde (preservative for wet collections), borax, and alcohol and formalin (for wet

collections). Some curators also indicated that unknown tablets and chemical liquids were used for fumigation and fogging respectively. The curators only identified the organic pesticides and from their responses, they were not aware that some of the museum's specimens are contaminated with harmful inorganic pesticides such as arsenic, mercury and lead. These findings show that many pesticides have been used in the museum. Some of the pesticides that were mentioned by the interviewees were not identified through XFR and gas chromatography-mass spectrometry and were also missing from the documents that were analysed through the desktop survey. There is a lack of a coordinated approach in the museum to systematically document all the pesticides that are used for reference purposes. This was confirmed by the curators who indicated that there was no documentation system in place for the recording of the pesticides used in the museum. The researcher can attest to this as he experienced difficulties in unearthing the chemicals used from piles of documents from various departments and the museum's annual reports from the library.

In terms of responsibility for the application of pesticides in the museum, the curators indicated that the museum outsources pest control to private companies. One curator identified Pestkill and Paul's Pest Control as some of the companies that have administered pest control in the museum. The curators indicated that they work collaboratively with the companies that apply pesticides in the museum. With regards to the frequency of application of pesticides in the museum, all the curators indicated that fumigation of the museum premises is conducted at least twice per year. The curator of galleries further indicated that in cases where there is heavy pest infestation in individual departments, fumigation is done three or four times per year. These findings indicate that the museum is invested in the use of chemicals for pest control. Pesticides are the preferred method for pest control in the museum.

On the issue of precautionary measures taken by the museum to prevent pesticide contamination of artefacts during fumigation, most curators indicated that in some instances they monitor the companies during the application of pesticides in the museum. However, another curator indicated that in some instances it is difficult to monitor the application of pesticides in the museum as the museum is closed off during the time of application of the pesticides as a way of protecting museum staff and visitors from toxic pesticides applied mostly through fumigation. Therefore, the application of pesticides is done in the absence of curators and collections care staff who enforce measures that prevent the contamination of collections by pesticides. Observations made by the researcher during condition assessments and chemical

analysis of the specimens showed that the application of pesticides in the museum is done indiscriminately with visible powder chemicals applied directly on specimens and in cabinets where the collections are stored. See figures 16-24 showing contaminated specimens and cabinets. This indiscriminate application of pesticides indicates that there is a lack of strict supervision by the museum during the application of pesticides by the pest control companies, and personnel from pest control companies do not know the effects of the direct application of pesticides on the conservation of the specimens. The contamination of the specimens is a threat to their conservation and negatively impacts their research potential.



Figure 16. Powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.



Figure 17. Powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.



Figure 18. Powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.



Figure 19. Powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe (Deteriorating skins with signs of fur falling off). Photo: Davison Chiwara.



Figure 20. Storage cabinets contaminated with powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.



Figure 21. Storage cabinets contaminated with powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.



Figure 22. Storage cabinets contaminated with powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.



Figure 23. Storage cabinets contaminated with powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.



Figure 24. Storage cabinets contaminated with powder chemicals applied directly on specimens at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.

With regards to the museum's staff perceptions of the effects of pesticides on the conservation of the specimens in the museum, the curators of Mammalogy, Ichthyology and Galleries indicated that some specimens showed some adverse signs of possible reaction to chemical pesticides. However, the curators could not fully attribute the deterioration of the specimens to chemicals only but hinted that there could be other factors attributed to the deterioration of the specimens. The curator of galleries highlighted that Mammalogy and Ornithology departments are mostly affected, with some specimens in the Department of Ornithology showing signs of discolouration. The curator indicated that an oil-based pesticide is said to have affected some specimens and may have led to their deterioration. The curator of Mammalogy explained that some fur was falling off the skins, whereas the curator of Ichthyology highlighted that some skeletons were experiencing colour changes from whitish to blackish, possibly due to chemicals used for fumigation. However, the curator of ornithology indicated that pesticides do offer protection to specimens against pest attack and do not affect the conservation of the

specimens. Curators of Entomology, Archaeology and Herpetology indicated that they had no knowledge of the deterioration of specimens from reactions with pesticides.

The above findings indicate mixed opinions by museum staff on the effects of pesticides in the conservation of specimens. The acceptance by some of the curators that pesticides negatively affect the conservation of collections in the museum is a positive sign that the museum should build on to alert other staff members about the negative effects of pesticides in the conservation of collections. It is only when staff know about the negative effects of pesticides that collective decisions are taken to act against the indiscriminate application of pesticides on collections by pest control companies.

On the issue of non-pesticides methods used in the control of pests in the museum, all the curators indicated that they practice housekeeping, freeze specimens infested by pests, and quarantine specimens affected by pests and newly acquired specimens. One curator indicated that although they use freezing in killing pests on specimens, this method is ineffective due to the number of specimens that need to be frozen in the museum as the freezers in the museum are not enough. Another curator indicated that the museum temporarily used sticky traps to capture pests. However, the use of traps has since been stopped as it was a temporary project done by the department of Entomology. The findings indicate that non-pesticide methods of pest control are considered options that can be employed as stop-gap measures of pest control during an outbreak of pest infestation. Priority is mostly given to pesticide use in the museum. There is a need for a shift in the mindset of museum staff in terms of pest control and focus resources towards non-pesticide methods of pest control that are both user and environmentally friendly and conserve the collections of the museum.



Figure 25. Chemical powder found at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.

5.4 Possible Health Risks to Museum Staff, Researchers and Visitors Accessing Contaminated Collections and Environments in the Museum.

To understand the museum's staff views regarding the issue of the possible effects of pesticides on their health and that of researchers and visitors, seven curators and the librarian were interviewed. They all indicated that they experience a strong smell of chemicals, particularly naphthalene within the museum's premises, especially in storage rooms. One curator highlighted that just getting into the storeroom leaves her clothes smelling naphthalene and she goes with that smell into her office. The researcher can also attest to this experience of smelling naphthalene. When we were doing condition assessments of the collections and XRF analysis of the specimens with my PhD supervisor Maggi Loubser and other museum staff in the Mammalogy and Ornithology storerooms, our dust coats and equipment that we used during the exercises were left with a choking smell of naphthalene. Another curator explained that the environments in the museum's storerooms are saturated with the smell of chemicals and the smell had become normal to them. The librarian indicated that she experiences breathing problems after the application of naphthalene in the museum as her office is completely

saturated with the chemical. Further, a certain curator highlighted that in 2004 a health emergency was experienced from handling contaminated specimens without protective equipment, during the shifting of the specimens from the basement storeroom to the upper storeroom of the Mammalogy Department. Sixteen members of staff who were involved in the exercise got sick, showing symptoms of chemical poisoning such as red eyes, flu-like symptoms, coughing, dizziness, and irritation of the respiratory tract. The curator indicated that the affected staff members took some days off work to recover from the reaction to the pesticides.

Another curator indicated that she experienced a strong smell of chemicals in storage areas for many years as her office is just adjacent to the storage area. She explained that she experiences perpetual headaches, blurred vision, and tiredness and at some point, she felt dizzy and suffered headaches after being exposed to chemicals while cleaning chemical bottles in the museum. The researcher can attest to this as he also experienced the choking smell of chemicals coming from the storeroom that was adjacent to her office. It is at this moment that the researcher alerted the curator about the effects of inhaling these chemicals on her health. The researcher had to politely ask her to permanently vacate her office and find another office to work from, and she duly complied. Further, another curator hinted that she gets choked by the smell of chemicals when fans are not working in the museum or during power cuts. While one cannot fully conclude that these effects could be because of exposure to contaminated environments in the museum without medical tests, the smell of chemicals experienced in the museum's storerooms is compelling.

With regards to the issue of safety measures that are in place to protect museum staff, researchers and visitors from possibly contaminated collections and museum environments, the curators indicated that sometimes they are offered protective equipment and sometimes they are not. They indicated that the equipment that they use includes dust coats, gloves and respirator masks. Another curator indicated that there is no budget for safety equipment and first aid kit in the museum and that the purchasing of the equipment is regarded as an afterthought because of the difficult economic environment in which the museum is operating.

These findings indicate that the museum staff, researchers, and visitors are at risk from working with contaminated collections and in contaminated environments in the museum. Their health could be possibly affected by the chemicals if they are exposed to them for a long time. Their

situation is worsened by the fact that there is a lack of adequate protective equipment for staff when working with these contaminated specimens and within contaminated environments. Further, the lack of adequate knowledge by museum staff about the dangers of contaminated specimens and environments exposes them more as they will be working without protection. There is also a lack of warning signage in the museum about contaminated specimens and environments. This is a health risk to museum staff as they work without safety measures to protect themselves.

5.5 Discussion

This section highlights how the overall research was conducted focusing on the research methods and research findings that are discussed considering the theoretical framework of the study. The overall aim of the study was to evaluate the extent of pesticide contamination on specimens at the Natural History Museum of Zimbabwe. To get an in-depth understanding of the overall context of contamination of specimens and pesticide use in the museum, the study used the mixed methods triangulation convergence design. It is a single-phase design which allowed the researcher to implement the quantitative and qualitative methods of data collection and analysis concurrently and with equal weight. The methods that were used included X-ray Fluorescence Spectrometry, Gas Chromatography-Mass Spectrometry, condition analysis of the artefacts, observations, desktop surveys and interviews with the museum staff. These methods enabled the researcher to obtain valid and well-substantiated findings about the contamination of specimens and the application of pesticides in the museum.

The objectives of the study were: (i) to investigate chemical residues on collections that could be indicative of pesticide residues of heavy metal and organic compounds in the collections at the Natural History Museum of Zimbabwe; (ii) to analyse the state of conservation of organic collections that have been contaminated with pesticides at the Natural History Museum of Zimbabwe; (iii) to appraise pest control practices at the Natural History Museum to develop protocols that minimise the use of harmful pesticides and ensure the safety of museum staff and visitors from the use of contaminated collections at the Natural History Museum of Zimbabwe; (iv) and to assess possible health risks to museum staff, researchers and visitors from accessing contaminated collections and environments in the museum.

With regards to the first objective, the precursor to XRF spectrometry and gas chromatography-mass spectrometry analysis was condition assessments of the selected specimens which were

at least 300 in total. These condition assessments enabled the researcher to understand the state of contamination of the collections by observing signs of contamination such as white or grey powder on them. A lot of collections in both Mammalogy and Ornithology storerooms were contaminated with powder chemicals including the storage cabinets where they were stored. However, with these assessments only, the researcher was not able to ascertain the type of chemicals that contaminated the collections. Therefore, XRF spectrometry and GC-MS proved to be vital as they managed to pick inorganic and organic pesticides that contaminated the specimens in the museum. Out of the 117 specimens analysed for pesticide contaminants, only 16 showed no traces of chemicals on them. See table 12. The majority of the specimens analysed showed that they are contaminated with pesticides. Most of the specimens showed multiple applications of different pesticides on them, including inorganic and organic pesticides. The chemicals that were picked through XRF spectrometry analysis include arsenic, mercury, lead, chrome, sulphur and chlorine. The fact that XRF results showed that in most cases, specimens were treated with more than one type of pesticide, with multiple applications of different chemicals indicates the severity of the state of contamination of the collections in the museum. Whereas the chemicals that were discovered through gas chromatography-mass spectrometry included naphthalene, DDT and 1,4- dichlorobenzene.

These findings were also corroborated by a desktop survey and interviews with museum staff which unearthed more pesticides used in the museum. The fact that organic pesticides were discovered on specimens indicates that pesticide use in the museum is continuing and it is widespread in the museum. Organic pesticides are non-persistent, and they disappear from collections with time. However, their detection through GC-MS, coupled with observations made of white and grey powder residues on specimens and in storage cabinets in the museum shows that pesticides are continuously being used in the museum.

However, it must be noted that these analyses could not determine the absolute concentrations of contaminants on specimens. This can only be achieved through destructive analysis of the specimens, but it is against conservation ethics, thus the study used non-destructive methods of analysis. The non-destructive methods were sufficient as they managed to fulfil the objective of the study which was to know whether collections at the Natural History Museum were contaminated by pesticides. This was a pilot study which if funds permit, should be followed by extensive analysis of more specimens and decontamination of the affected specimens and environments in the museum.

In general, the findings of the study confirm what has been discovered by other museums and institutions in the global north including the United States, Europe, Canada and Australia [See Chapter 3 (3.2) & Chapter 1 (1.3)]. This shows that the application of pesticides on specimens particularly harmful inorganic pesticides such as arsenic, mercury and lead was done across the globe and collections from museums in Africa are no exception. The discovery of these pesticide contaminants on specimens at the Natural History Museum of Zimbabwe is an eye-opener for museums in Africa and paints a picture of the potential contamination of collections across museums in Africa. This pilot study needs to be expanded to other museums across Africa to ascertain whether their collections are contaminated and establish safety protocols for their handling and use by staff, researchers, and visitors.

On the second objective, the study established that there were specimens that were contaminated with pesticides in the Natural History Museum of Zimbabwe but were in a good state of conservation, particularly ornithology specimens. However, other specimens were contaminated with pesticides but were in a poor state of conservation showing signs of advanced deterioration such as balding and disintegration of parts of the specimens, particularly mammalogy specimens. These findings were buttressed by the discovery of personal notes written by former curators of the museum and annual reports published by the museum in the first half of the 20th century where the museum staff admitted that specimens were deteriorating in the museum because of reactions with pesticides. While these findings may need further analysis to confirm the effects of pesticides in the conservation of museum collections, the researcher affirms that pesticides can react with organic museum collections resulting in their deterioration, for instance, the *Tatera Leucogaster* specimens which were balding, and their fur were found contaminated with 1,4 dichlorobenzene, naphthalene and DDT. Other factors that cause the deterioration of specimens such as ultraviolet radiation, light, uncontrolled temperature and relative humidity, and poor storage were very minimal as collections were well taken care of. If these factors had any effect on the deterioration of the specimens, this was catalysed by the above-mentioned chemicals that contaminated the fur of the balding specimens.

Elsewhere Bock and Quaiser (2019) reported the same problem at the Museum für Naturkunde Berlin (MfN) whereby skins and hides in the mammal collection showed signs of deterioration over the last century. They have become brittle such that they easily tear, and

some specimens have fallen into pieces leading to the irrevocable loss of vital information. Their study revealed that decreasing pH appears correlated with loss of tear strength, suggesting that acid-caused decay contributes to the deterioration of the skin. However, the source of the acid was poorly understood with likely sources being inadequate neutralisation of applied acids during the tanning process; warm and humid storage conditions that can trigger acidic hydrolysis and the degradation of substances such as potash alum into sulphuric acid; oxidation of residual fat in skins that then break down into fatty acids causing fat burn; and external pollutants such as sulphur dioxide or nitrogen oxides that can trigger the deterioration processes. Differing histories of individual skins, different preservation methods and conservation treatments, changes in storage conditions, and the lack of proper documentation of this history make it difficult to reliably conclude on the factors responsible for the deterioration and their relative impacts. Thus, there is a need to test samples under controlled conditions including artificial ageing, to understand correlations and causal relationships among varied factors potentially causing the deterioration of the skins and hides. (Bock and Quaiser 2019).

However, Bock and Quaiser bemoaned the fact that this problem is poorly described in the literature and that there are only a few systematic studies about the degradation of mammal skins. The probable causes of the deterioration of the specimens as highlighted by Troxler and Meier (2003); Robinet *et al* (2014); and Schnepapat (2003) cited in Bock and Quaiser (2019), are high acidity from the original preparation of the skins. The acidity comes from potash alum, which after years of storage under conditions of high relative humidity and temperature, alum reacts with relative humidity creating sulphuric acid in a process called acidic hydrolysis. This process decreases the tensile strength of the skins (Larsen 1994, Florian 2006 cited in Bock and Quaiser 2019). Further, the other probable causes of the deterioration of skins are the oxidation of fats to fatty acids in inefficiently degreased skins and the degradation of proteins to amino acids which result in acidity that causes the deterioration of the skins (Ashley and Horie 1984, Hollstein 1987, Larsen 1994, Macket 2003, Florian 2006 cited in Bock and Quaiser 2019). The other possible causes of deterioration of the skins are exposure to air pollutants such as sulphur dioxide (Chahine and Rottier 1992, Breimblecombe 1996 cited in Bock and Quaiser 2019), and the decay of biocides applied on skins to protect them against pests are reported as other sources of acidity in the skins (Cross *et a.* 2007 cited in Bock and Quaiser 2019). The complexity of these interacting components makes it difficult to identify

causal relationships and understand the chemical processes that lead to degradation in skins (Mackert 2003 cited in Bock and Quaiser 2019).

In museum practice and conservation science, safeguarding the colour of feathers is achieved through the control of visible light and ultraviolet radiation in storage and display (Pearlstein 2021). At the Natural History Museum of Zimbabwe ornithology collections in storage are protected from both visible light and ultraviolet radiation through storage cabinets and the building envelop that offer them a protective shield (See figures 10 & 26), and the lights are always switched off when storerooms are not in use. While ornithology specimens in the museum's storerooms are protected from visible light and ultraviolet radiation, they are extremely exposed to pesticide contaminants that are applied directly to them. Conservators have questioned the residual effect of museum pesticides on colour changes in collections (Pearlstein 2021). There were signs of discolouration that were observed on some ornithology specimens that were possibly caused by pesticide contaminants and were confirmed by one curator through interviews and personal notes that were written by a former curator of the Natural History Museum (Jones 1980, personal communication with Dr E.C.G. Pinhey). There is a need for further scientific analysis of the specimens using the Munsell Book of Colour (a colour reference source) and examination techniques for tracking colour changes such as transmitted light and ultraviolet-induced visible fluorescence (Pearlstein 2021) to confirm whether the discolouration of the specimens is indeed caused by pesticide contamination.



Figure 26. Storage cabinets that shield specimens against visible light and ultraviolet radiation at the Natural History Museum of Zimbabwe. Photo: Davison Chiwara.

On the third objective, the study established that pest control at the Natural History Museum of Zimbabwe is outsourced to private companies which apply the pesticides indiscriminately on collections and in storage cabinets. These findings are very concerning as they seem to have been normalised in the museum whereby the direct application of pesticides on collections is regarded as an effective way of protecting them against pest attack. The indiscriminate application of pesticides directly on specimens in the museum shows that there is little understanding by pest control companies of the effects of pesticides in the conservation of collections. This is a practice that has continued in the museum from the time of its inception up to the present times. Pesticide use in the museum has been entrenched in the control of pests to an extent that non-pesticide control measures such as freezing, and the use of pest traps are regarded as stop-gap measures.

With regards to the fourth objective, research findings showed that specimens and storage environments at the Natural History Museum of Zimbabwe are poisoned with harmful inorganic and organic pesticides resulting from multiple applications for a period spanning over a century. These contaminated specimens and storage environments are a health risk to museum staff, researchers, and visitors. The warning signs are there with confirmation from staff members that they suffer headaches and reactions to chemicals after their application in the museum. The researcher can attest to this, during the analysis of the specimens there was a very strong smell of chemicals particularly naphthalene in the museum's storerooms. It was

even worse in the storeroom and office of the Department of Entomology when the researcher was conducting interviews with the curator of Entomology. The researcher experienced a choking smell of chemicals coming from the storeroom that was adjacent to the office of the department of Entomology. This is a red flag regarding the possible health effects caused by contaminated specimens and environments in the museum. The signs and symptoms reflect those discussed under literature review on the effects of pesticides on human health [See Chapter 2 on the effects of naphthalene and other pesticides on human health (2.4 Health Hazards of Pesticides Contaminants in Museum Collections)]. While these findings may not be conclusive, further studies need to be conducted in the museum environments and clinical tests should be done on museum staff to establish the level of exposure to harmful pesticides in collections and the museum environment.

5.6 The Planetary Trust: Conservation and Intergenerational Equity vs Hazardous Pesticide Use at the Natural History Museum of Zimbabwe.

The research findings reflect the concerns raised by Weiss (1984) in her theory of “The planetary Trust: Conservation and Intergenerational Equity”, about the damage being caused by humans on the earth including natural and cultural heritage through the indiscriminate use of toxic chemicals. There is considerable damage to specimens at the Natural History Museum of Zimbabwe that has been probably caused by toxic pesticides that contaminated them. Weiss (1984) argues that such damage being caused by human actions on natural and cultural heritage globally should make us concerned with the survival of this heritage that we pass on to future generations. As shown by the research findings at the Natural History Museum, a poisoned heritage was passed from the past museum staff who worked in the museum and from across the globe to the current generation of museum staff, and it is also being passed to future generations which negatively affects their use and enjoyment of this heritage. What worsens the situation is that the current generation is perpetuating the use of toxic pesticides on the collections and in the museum environment by outsourcing pest control to pesticide companies that apply the pesticides without due regard for the safety of museum staff and the negative effects of the pesticides on the conservation of the museum’s collections.

Weiss (1984) argues that the current generation must be concerned with both human and natural degradation of art objects and other cultural properties and that new causes of degradation must be prevented to conserve the heritage for posterity. Further, Weiss contends that our fiduciary obligation as trustees of the planetary trust can be inferred from the nearly

universal recognition and acceptance among peoples of an obligation to protect the natural and cultural heritage for future generations. Under the principle of conservation of quality, Weiss (1984) also challenges people to pass on the heritage to future generations in no worse condition than they found it. In cases, where one generation fails to meet this obligation and passes the heritage in worse condition than it received it, the inheriting generation has an obligation to ensure that the planet does not deteriorate further. For instance, the principle states that if a past generation has disposed of hazardous substances in such a way that their ill effects are felt by the present generation, the present generation is responsible to take whatever measures are necessary to ensure that the substances do not harm future generations (Weiss 1984). Therefore, the current generation of museum staff at the Natural History Museum of Zimbabwe has a responsibility to invest in decontaminating its collections and institute non-pesticide methods of pest control for the safety of museum staff, researchers and visitors and to prevent chemical reactions that lead to deterioration of its collections. The museum also has a responsibility to stop outsourcing pest control to pest control companies which has resulted in the contamination of the collections through the indiscriminate application of pesticides on collections in the museum.

5.7 Application of the Integrated Pest Management Concept at the Natural History Museum of Zimbabwe.

Research findings indicated that the Natural History Museum of Zimbabwe implements some aspects of the Integrated pest management concept not as a planned schedule of pest control activities, but mostly as a reaction to an infestation of pests in its collections. Integrated pest management (IPM) was introduced to museum use in the early 1980s when conservators felt unconvinced by the widespread use of pesticides on artefacts without clear knowledge about what insects were present. Conservators that adopted the IPM approach to museum pest control became aware of pesticide products, the chemical reactions they could have on various artefact materials and the potential human health hazards they may present. IPM underscores the prevention of pest damage by combining monitoring and eradication methods with the least possible hazard to people, property and the environment (Odegaard and Sadongei 2001).

The museum staff need to invest in Integrated Pest Management to ensure the safety of staff and other users of the artefacts and of future generations, and to prevent the deterioration of collections caused by reactions with chemical pesticide contaminants. The museum needs to buy more freezers and establish a routine schedule for freezing its specimens to prevent

possible infestation rather than resorting to freezing as a stop-gap measure during an outbreak of pest infestation on its collections. This can be complemented by a pest trapping programme that can be implemented in the museum's storerooms and display areas to monitor pest activity. Sticky traps and rodent traps can be used. Such a programme equips the museum staff with knowledge about the types of pests that affect their collections and how often they frequent the museum's storage and display places which help it in controlling the pests. These two measures are relatively cheap and affordable. However, there are other non-pesticide methods of pest control that are very expensive as they entail investing in changes to the museum's storage and display facilities and building structure. Facilities such as gasket-sealed containers and insect-proof displays that accommodate all the museum's collections are very expensive. Changes to the building's structure require installing some seals on windows, entry and exit points to the museum and closing all cracks and crevices on the museum building that allow pests into the museum. Such changes to the museum's building structure can require a lot of money which the museum is lacking.

5.8 Our Collections Matter Project of the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) & United Nations Decade of Action to deliver Sustainable Development Goals by 2030.

The research findings reflect the critical issues highlighted in the *Our Collections Matter Project* of the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and the United Nations Decade of Action to deliver sustainable development goals by 2030. The former's worldwide mission and commitment is to promote the conservation and sustainable use of collections for the benefit of present and future generations. Collections and their conservation have a critical role to play in sustainable development. They are an effective way of safeguarding and transmitting cultural and natural heritage and they also provide the basis for enabling a wide range of activities and programmes in museums. These activities and programmes include learning, education, participation and research, creative industries, sustainable tourism and peacebuilding (ICCROM 2020).

The latter's goals on heritage are closely linked to those of ICCROM's Collections Matter Project and are underpinned by the realisation that collections and conservation work are an anchor for sustainable development in museums. For instance, goals such as *11.4: Strengthening efforts to protect and safeguard the world's cultural and natural heritage*. While efforts are in place to conserve collections through protection against pest attack at the Natural

History Museum of Zimbabwe, the indiscriminate and extensive use of pesticides on collections threatens their protection as the chemical pesticides can react with the collections resulting in their deterioration. This limits future generations from accessing and utilising clean and safe heritage that is passed on to them contaminated with hazardous pesticides. Goal 3a. highlights that *by 20230 there should be a substantial reduction in the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination*; and goal 4a. aims to *build and upgrade education facilities that are child, disability, and gender-sensitive, and provide safe, non-violent, inclusive, and effective learning environments for all*. The important aspects highlighted in these goals are the reduction of hazardous chemicals and contamination and making education facilities safe and effective learning environments for all. These goals are very vital for the Natural History Museum of Zimbabwe as the widespread use of hazardous pesticides and contamination of collections makes the museum unsafe and exposes staff, researchers and visitors to various ailments caused by hazardous pesticides. As a critical learning resource that supports education and research through its collections, the Natural History Museum should adopt safety protocols for the handling and use of contaminated specimens, accessing contaminated environments and embark on a decontamination exercise of its collections and environments to safeguard the health of people in the museum. This will ensure that the museum and its collections become safe for all and supports learning and research and pass on the collections to future generations in a safe state.

5.9 Chapter Summary

This chapter presented the research finding based on the objectives of the study which were as follows: to investigate chemical residues on collections that could be indicative of pesticide residues of heavy metal and organic compounds on the collections at the Natural History Museum of Zimbabwe; assess the state of conservation of organic collections that have possibly reacted with pesticide contaminants at the Natural History Museum of Zimbabwe; to appraise pest control practices at the Natural History Museum in order to develop protocols that minimise the use of pesticides and ensure the safety of museum staff and visitors from the use of contaminated collections; to determine possible health risks to museum staff, researchers and visitors from accessing contaminated collections and environments in the museum. Data were presented and interpreted in the form of tables, pictures, graphs, and text. This was followed by the discussion of the research findings in light of the theoretical frameworks of the study and literature on pesticide contamination of museum artefacts. The next and final chapter

summarises the study, presents conclusions based on the objectives of the study and provides recommendations on pest control and safety protocols for the protection of museum staff and other users of the artefacts as well as collections from hazardous pesticide contaminants.

Chapter 6

Summary, Conclusions and Recommendations

6.0 Introduction

This chapter concludes the study by presenting the thesis summary; conclusions of the research by presenting the findings based on the objectives of the study and giving recommendations on pest control and safety protocols for access and use of contaminated specimens and environments at the Natural History Museum of Zimbabwe.

6.1 Summary

Chapter 1 introduced the study by highlighting the issue addressed by the study which was to investigate the possible contamination of organic collections from pesticide use at the Natural History Museum of Zimbabwe. Issues discussed in the chapter included the challenges caused by inadequate documentation of pesticide use in museums in determining the chemical contaminants on collections and the significance of the study which included capacitating the Natural History Museum of Zimbabwe by conducting chemical analysis of its collections, which is an expensive undertaking that is not afforded by the museum; suggesting non-pesticides methods of pest control that are safe for collections and humans which make the museum a safe and user-friendly educational resource; and conserving the museum collections for the benefit of future generations. The chapter also presented the problem statement which was the lack of studies on scientific analysis of collections in museums in the global south for the determination of pesticide contaminants. The other aspects addressed by the chapter included the purpose of the study, area of the study, aim and objectives, and limitations of the study which included exorbitant costs in gas chromatography-mass spectrometry analysis and a breakdown of the equipment that resulted in the analysis of only a few samples. Finally, the chapter discussed ethical issues addressed in the conduction of the study that included non-destructive analysis of the specimens, handling collections with care and seeking the consent of research participants at the Natural History Museum of Zimbabwe before the conduction of the study and ensuring their anonymity.

Chapter 2 discussed the theoretical frameworks underpinning the study, which include the “The Planetary Trust: Conservation and Intergenerational Equity” and the Integrated Pest Management concepts. The chapter has demonstrated that museum artefacts across the globe have been treated with various hazardous insecticides from the 18th century up to recent times. It also revealed that these chemicals are not only harmful to humans who access and use

contaminated collections but are also a threat to the conservation of the artefacts as they react with them leading to their deterioration. Apart from these aspects, the chapter highlighted on safety protocols that may be instituted in museums to protect humans from contaminated collections as well as to prevent cross-contamination in artefacts and their deterioration from pesticides.

Chapter 3 discussed the repatriation of possibly contaminated artefacts from museums in the global north to museums in the global south and the weaknesses of legislations in safeguarding recipients of the collections particularly in the global south. The next chapter presents the research methodology.

Chapter 4 discussed the mixed-method triangulation convergence design which was used in the study. It is a research design which mixed quantitative methods that included XRF spectrometry and XRF spectrometry, and qualitative methods that include condition assessments, observations, desktop survey, and semi-structured interviews in data collection. Both quantitative and qualitative methods had equal weighting in data collection. The chapter also highlighted the research population that was purposively sampled and selected from the Natural History Museum of Zimbabwe to participate in the study based on their knowledge of pest control practices at the museum. It also addressed why a limited number of samples had to be selected for quantitative analyses and why. Finally, the chapter addressed adherence to safety protocols in the handling and use of potentially contaminated artefacts at the museum, and the safe use of the XRF spectrometry.

Chapter 5 presented the research finding based on the objectives of the study which were as follows: to investigate chemical residues on collections that could be indicative of pesticide residues of heavy metal and organic compounds on the collections at the Natural History Museum of Zimbabwe; assess the state of conservation of organic collections that have possibly reacted with pesticide contaminants at the Natural History Museum of Zimbabwe; to appraise pest control practices at the Natural History Museum in order to develop protocols that minimise the use of pesticides and ensure the safety of museum staff and visitors from the use of contaminated collections; to determine possible health risks to museum staff, researchers and visitors from accessing contaminated collections and environments in the museum. Data were presented and interpreted in the form of tables, pictures, a graph and text. This was

followed by the discussion of the research findings in light of the theoretical frameworks of the study and literature on pesticide contamination of museum artefacts.

6.2 Conclusions

6.2.1 To investigate chemical residues on collections that could be indicative of pesticide residues of heavy metal and organic compounds on the collections at the Natural History Museum of Zimbabwe.

The research findings established that collections at the Natural History Museum of Zimbabwe are contaminated with hazardous inorganic and organic pesticides. Table 16 shows the pesticide contaminants that were discovered on specimens in the museum and from documents found in the museum.

Table 16 Pesticide contaminants detected on Mammalogy and Ornithology Specimens and from documents at the Natural History Museum of Zimbabwe

Inorganic Pesticides	Source:XRF Spectrometry
Arsenic	XRF Spectrometry
Mercury	XRF Spectrometry
Lead	XRF Spectrometry
Chlorine	XRF Spectrometry
Chrome	XRF Spectrometry
Corrosive sublimate	Desktop Survey
Organic Pesticides	Source:GC-Mass Spectrometry
Naphthalene	GC-Mass Spectrometry
DDT	GC-Mass Spectrometry
1.4 Paradichlorobenzene	GC-Mass Spectrometry
Alum	Desktop Survey
Turpentine	Desktop Survey
Formic Acid	Desktop Survey
Syntan	Desktop Survey
Calcium formate	Desktop Survey
Furliquor	Desktop Survey
Synthetic retan solution	Desktop Survey
Edolan	Desktop Survey
Gamatox	Desktop Survey
Vapona	Desktop Survey
Aluminium Phosphate	Desktop Survey
Methyl Bromide	Desktop Survey
Dichlorvos	Desktop Survey
Permethrin	Desktop Survey
Formalin	Desktop Survey
Isopropyl Alcohol	Desktop Survey

6.2.2 To analyse the state of conservation of organic collections that have been contaminated with pesticides at the Natural History Museum of Zimbabwe.

Research results showed that some collections that were contaminated with pesticide residues were showing signs of deterioration such as brittleness, falling of fur from skins and hides and the total disintegration of the specimens. This was most widespread in mammalogy specimens.

However, some contaminated specimens particularly those from the department of Ornithology were in a good state of conservation.

6.2.3 To appraise pest control practices at the Natural History Museum in order to develop protocols that minimise the use of harmful pesticides and ensure the safety of museum staff and visitors from the use of contaminated collections.

The research findings demonstrated that pesticide use is widespread in the museum, having started from the early years of the inception of the museum in the first half of the 20th century up to the present times. Pesticide application in the museum is outsourced to pest control companies. There is an indiscriminate application of pesticides by the companies with direct application of the pesticides on the specimens and in cabinet drawers. Other non-pesticide methods of pest control used in the museum include freezing of specimens, housekeeping, quarantining specimens affected by pests, and the use of sticky traps. However, these non-pesticides are considered options to complement pesticides in the museum. Freeze is used as a stop-gap measure when there is a heavy infestation of pests in the museum. Freezing is overwhelmed by a large number of specimens in the museum and the available freezers are not enough. The use of sticky traps was a temporary project initiated by the Department of Entomology and has since been stopped.

6.2.4 To assess possible health risks to museum staff, researchers, and visitors from accessing contaminated collections and environments in the museum.

There is a strong smell of chemicals, particularly naphthalene within the museum's premises, especially in storage rooms. At some point, a health emergency was experienced by museum staff from handling contaminated specimens without protective equipment, during the shifting of the specimens from the basement storeroom to the upper storeroom of the Mammalogy department. They got sick, showing symptoms of chemical poisoning such as red eyes, flu-like symptoms, coughing, dizziness, and irritation of the respiratory tract. Some staff members indicated that they experience perpetual headaches, blurred vision, tiredness, and dizziness. These symptoms are indicators of possible underlying health challenges affecting staff in the museum due to exposure to pesticides used in the museum.

6.2 Recommendations

6.2.1 Safety Protocols for Accessing and Use of Contaminated Specimens and Environments

6.3.1 (a) Warning Signage

The following guidelines should be implemented at the Natural History Museum of Zimbabwe. The museum should institute warning signage for contaminated specimens and contaminated environments in storerooms and display areas. The signage should be based on the level of contamination found in specimens and storage and display areas. These can range from a caution for minor contamination; danger for extensive contamination; and extremely dangerous for more extensive contamination. The warning signage can be colour coded from green (caution), red (dangerous) and purple (extremely dangerous). The warning signage should be accompanied by labels that indicate the names of chemicals/pesticides that have contaminated the specimens or storage and display environments (Odegaard 2014). This is very important as it makes museum staff, researchers, and visitors aware of contamination and empowers them to make informed decisions when accessing contaminated specimens and environments.

Barriers should be installed in front of contaminated specimens on display (Odegaard 2014). Alternatively, contaminated specimens can be enclosed in glass display cases to protect staff and visitors from touching contaminated specimens on display. There is no warning signage about the possible contamination of specimens on display in the museum. The museum should put warning signage about possible contamination of specimens on display to protect staff and visitors. As shown in chapter 5, these specimens are taken from heavily contaminated storage environments in the museum and it is probable that the specimens on display could be contaminated with toxic pesticides.

6.3.1 (b) Protective Safety Equipment

Museum staff, researchers and visitors should be provided with protective safety equipment for access and use of contaminated specimens and environments. These include dust coats, overalls, respiratory masks, goggles and nitrile gloves. Additionally, the museum staff, researchers and visitors should thoroughly wash their hands with soap after handling contaminated specimens. They should also wash their overalls, dust coats and respiratory masks after accessing contaminated storerooms and handling contaminated specimens. These safety protocols will protect them from direct contact with harmful pesticide contaminants in

specimens and storage and display areas. There is a need for the establishment of a safety team that coordinates safety issues in the museum. The team's activities should be funded by the museum to ensure the purchasing of adequate safety equipment for use when handling contaminated specimens and accessing contaminated environments. The team should enforce safety protocols for accessing and use of contaminated environments and specimens in the museum. This will ensure the protection of staff, researchers and visitors when using contaminated specimens.

6.3.1 (c) Quarantining of Contaminated Specimens

The museum should quarantine contaminated specimens and close access to them or provide safety measures for accessing them (See sections 6.3.1 (a) & (b)). Quarantining protects staff and visitors from accessing contaminated specimens, and it also aids in the conservation of the specimens by preventing cross-contamination between contaminated and uncontaminated specimens.

6.3.1 (d) Decontamination of Specimens and Environments

The current research was a pilot study that showed that the museum's specimens are indeed contaminated. The museum should take this study further and do an extensive analysis of its collections to determine the level of contamination. This will pave way for the decontamination of its specimens to make them safe for handling and use. Some of the decontamination methods that are recommended include specialised high-efficiency particulate air (HEPA) filtered vacuum or ultra-low penetration air (ULPA), compressed air, washing, ultraviolet light, chemical alteration, freeze-drying, laser cleaning, and microbial detoxification. HEPA and ULPA are recommended for the reduction of lead, asbestos and liquid and granular mercury. A HEPA-filtered vacuum was effective in removing DDT in storage at the Australian Archives (Odegaard 2001). Thus, HEPA and ULPA vacuum would be useful in the reduction of lead, mercury and DDT residues that have contaminated specimens at the Natural History Museum of Zimbabwe. However, care should be taken to prevent the vacuuming from removing fur and feathers from the specimens as this will be against conservation ethics.

Caution must be taken in the use of other methods such as compressed air and washing. Compressed air was tested in the removal of paradichlorobenzene, DDT and naphthalene at the National Museum in Denmark (Glastrup cited in Odegaard 2001). However, results showed that it was not very effective in completely removing the pesticide residues in objects. Washing

using laundering techniques with temperatures of 60°C, heavy-duty detergents and line drying was found partially effective in the removal of pesticide residues from contaminated clothing (Odegaard 2001). However, this method may not be appropriate for ornithology and mammalogy specimens at the Natural History Museum of Zimbabwe as it may lead to the removal of feathers and fur from the specimens. It could work on clothing collections on display in the museum. Analysis has to be conducted first to determine whether the clothing collections are contaminated with pesticide residues.

Ultraviolet (UV) light leads to the reduction of many pesticide residues from organic compounds that are sensitive to ultraviolet light. O' Rourke (2000) cited in Odegaard (2001) reported that organophosphates and carbamate-based pesticide residues on the clothing of agricultural workers degraded and detoxified with exposure to UV light from the sun. However, the application of UV light exposure to cultural objects in museums has not been done (Odegaard 2001). With regards to the use of UV light on specimens at the Natural History Museum of Zimbabwe to decontaminate them, this method may not be appropriate as UV light is a known agent of deterioration of museum collections. If it is to be used at the Natural History Museum, there is a need to strike a balance between detoxifying the specimens from pesticide contaminants and limiting the deterioration of the specimens from exposure to UV light.

With regards to chemical alteration, Hawks and Bell (1999) cited in Odegaard (2001) examined the use of a water-based oxidising agent to remove mercuric chloride stains on herbarium sheets, and results indicated that the process removed the stains. However, they indicated that it is unlikely to remove all the residues. Since mercury residues were detected on specimens at the Natural History Museum of Zimbabwe, this method could be tried to reduce the pesticide residues in the specimens. Precautions have to be taken that ensure that the method is safe for the decontamination of specimens at the museum.

Freeze-drying and laser cleaning are the other decontamination methods for pesticides. However, Odegaard (2001) warns that with regards to freeze-drying there are no reports of its use on museum artefacts for decontamination and that the complex nature of the technique, the stresses it brings on artefacts, the variability of materials in objects and the range of pesticide possibilities makes this method difficult to use on museum artefacts. With regards to laser cleaning, Abraham (1999) cited in Odegaard (2001) warned that there is little evidence on their long-term treatments and the effects caused by localised heating and light irradiation. If the

Natural History Museum of Zimbabwe is to use such decontamination methods, there is a need for extensive consultations with stakeholders in the field of heritage conservation.

Roane and Snelling (2010) investigated the removal of mercury, a persistent heavy metal chemical from museum materials by bacteria. The bacteria act by converting this heavy metal element into a gaseous form thereby removing it from museum materials. Their study indicated that two non-pathogenic bacterial isolates, *arthrobacter* sp. 2604 and *cupriavidus metallidurans* CH34 were capable of reducing 10 mg/L mercury concentrations on museum materials. Elsewhere, Cross *et al* (2010) examined the use of alpha-lipoic acid solutions for the removal of arsenic and mercury from museum objects. Their findings indicated that high concentrations of arsenic and mercury were removed from test samples. They used alpha-lipoic acid in their study as it is a natural chemical that is widely found in mammals and plants and it is environmentally friendly. The Natural History Museum of Zimbabwe should consider using these methods to decontaminate specimens with mercury and arsenic residues. No side effects on the conservation of museum artefacts have been reported and this makes the methods ideal for the decontamination of the specimens.

6.2.2 Non-Pesticide Methods of Pest Control

6.3.2(a) Housekeeping

The Natural History Museum should intensify its housekeeping efforts to lessen the chances of pest attack on its collections. There is a need to establish an integrated pest management (IPM) team. Among other responsibilities, the IPM team should be tasked with enforcing cleanliness in the museum. The team should spearhead the drafting of a housekeeping plan that will help in identifying possible areas that may encourage pest infestation in the museum, and such areas should be prioritised for cleaning. The housekeeping plan should also provide for regular intervals of thorough cleaning using vacuum cleaners in the museum and eliminate any possibilities of pest infestation brought by lack of cleanliness. The plan should also empower the IPM team to enforce the prohibition of food consumption in the museum's storage and display areas to eliminate food sources for pests.

6.3.2(b) Pest Trapping Programme

The IPM team working in collaboration with other staff at the Natural History Museum of Zimbabwe should embark on visual inspection exercises to identify possible pests in storage and display areas. The visual inspection exercises are a precursor to a pest trapping programme. Visual inspections can be done using white acid-free paper that can be lined on drawer bottoms or storage shelves which greatly enhances the visibility of small insect bodies (Strang and Kigawa 2009). The visual inspections should then be followed by a routine pest trapping programme led by the IPM team using adhesive or sticky traps, pheromone traps and UV light traps for insects and rat traps. Trapping can be enhanced through the use of lures such as food sources. These traps would help staff to identify the pests that are prevalent in the museum. The traps should be monitored monthly or bi-monthly (National Museum of the American Indian 2002). The museum is in a better position to implement this programme as it has the department of Entomology that deals with pests. Thus the department should work in collaboration with the IPM team to spearhead this programme which should be routine and establish food sources and feeding patterns of the pests, breeding and their habitats in the museum. Knowledge of these characteristics of pests would help the museum to come up with preventive measures that safeguard the collections against pest attack.

6.3.2(c) Freezing of Specimens

The Natural History Museum should acquire state-of-the-art freezers that can accommodate many specimens. The freezer that is currently in use in the Department of Ornithology is very small such that it only accommodates a few specimens. The museum should use these freezers for a routine freezing programme that can be done at least once a month in various curatorial departments to kill possible pests that could attack the specimens. To achieve the best results, the specimens should be kept in freezers at temperatures ranging from -20°C - 40°C for a week and be allowed to thaw for 24 hours after being removed from freezers (National Museum of the American Indian 2002, Strang and Kigawa 2009).

6.3.2(d) Anoxic Treatment of Pest Infested Artefacts

The Natural History Museum of Zimbabwe should consider anoxic treatment of its pest-infested specimens. With this method infested artefacts are placed in airtight enclosures that are oxygen-free for a recommended minimum treatment period of fourteen days. The atmospheric oxygen in the enclosure is then either removed by placing oxygen absorber packets, such as silica gel with the artefacts and sealing the enclosure, or flushed out by passing

through an externally supplied nitrogen gas. These anoxic environments will kill pests by depriving them of the oxygen that they need for their survival.

The enclosures that are used for the anoxic killing of pests in museum artefacts include small and large plastic bags, in small (10 cubic metres) or commercial fumigation tents (30 or more cubic metres) or in stationary rigid chambers (ranging from a volume of 2-3 to many cubic metres). The use of oxygen absorber packets only applies to small plastic enclosures, whereas for large enclosures, the air is displaced by passing nitrogen gas through them from cylinders or other nitrogen sources. The nitrogen flow is continued until the oxygen level decreases below 0.3% Nitrogen is recommended as it is an inert gas and does not react with any museum materials at any temperature (Maekawa and Elert 2003).

Since plastic bags are not durable, the Natural History Museum should consider using large tents and rigid chambers that can accommodate its large number of collections. Although this is an expensive undertaking for the museum in the initial setup and labour intensive in setting up large tents and rigid chambers, the benefits of this method far outweigh the costs as it will help the museum to move away from its overreliance on pesticides for pest control. The museum will need to embark on fundraising campaigns to raise the money to invest in anoxic treatments for its collections.

6.3.2(e) Placing of Specimens Covered with Polyethylene Sheets in the Sun to Kill Pests

The Natural History Museum should consider this method as it is relatively cheap compared to all the pest control methods mentioned above. The museum can wrap its specimens in black polyethylene plastic sheets and place them in the sun. The black polyethylene sheets will trap the heat from the sun for a prolonged period, causing the pests to suffocate and killing them. This method has been applied with success at the National Gallery of Zimbabwe in exhibition preparation (Chiwara 2022). It is an environmentally friendly method that does not cause harm to humans and the collections. It is very much suited to the summer weather experienced in Zimbabwe where maximum temperatures range between 25°C-33°C. However, this method is seasonal as it mostly works in summer with sunny and hot conditions. It may not be effective in winter where temperatures drop with limited time of sunshine. It should also be noted that this method is not 100% effective in killing pests.

6.3.2(f) Sealing of Crevices and Entry Points Used by Pests to Enter the Museum

This method can help prevent pests from entering the museum and attacking collections by closing all the crevices and other points of entry into the museum such as windows, doors and the roof. This can be achieved by repairing foundation cracks, sealing gaps between continuous sheet flooring walls, application of blade seals around opening windows and under doors, and attaching mesh wire to exterior vents (1mm mesh to restrict most insect pests) (Strang and Kigawa 2009). The interior of the museum building should be caulked by focusing on electrical outlet areas and drainpipes (National Museum of the American Indian 2002). These measures could require an extensive redesigning of the museum building to seal off all entry points used by the pests into the museum such as the roof, windows and doors. The sealing of the crevices and entry points to make the museum building pest-proof could be an expensive undertaking and the museum may need to embark on fundraising campaigns to raise the money for the redesigning of its building.

6.3.2(g) Indigenous Methods of Pest Control

The Natural History Museum of Zimbabwe should consider using indigenous methods of pest control over hazardous synthetic chemical pesticides. Some of the indigenous methods that have been used for pest control in Zimbabwe include tobacco leaves or powder and cinnamon. The advantage of using these is that they are found abundantly in Zimbabwe. The smell of these plants can repel or kill pests. Tobacco is widely grown in Zimbabwe, and this makes it easier for the Natural History Museum of Zimbabwe to acquire it. However, tobacco can have an unpleasant smell that can be uncomfortable for some people. Cinnamon is a spice that is used as an ingredient in confectionery and various food and recipes. It is also effective in killing or repelling pests such as ants, spider mites, whiteflies, silverfish, mice, midges and fungus gnats. The researcher has used cinnamon powder domestically with success for the control of ants. It is a multipurpose spice that is useful in the control of pests. It is cheap and it is not harmful to people and collections.

The other indigenous method of pest control which could be used by the Natural History Museum of Zimbabwe is the burning of chilli in charcoal. The method produces smoke that kills or repels pests. This method was adopted by the Batonga Community Museum in Zimbabwe to repel bats that had become a threat to the museum's organic artefacts. Many species of birds and bats build their nests on buildings. This in turn supports the infestation of

protein-eating pests. Further, exposure to avian source dusts created from faeces, feathers and nesting materials may lead to the development of bacteria and viruses, as well as cause chronic diseases (Strang and Kigawa 2009). The excretions (guano and urine) of the bats (guano) were falling directly on artefacts on display thereby staining and reacting with them causing deterioration. Further, the excretions attracted pests such as cockroaches, bat bugs, and mites that in turn caused damage to organic artefacts in the museum by feeding on them. The Batonga Community Museum provided a favourable environment for the bats on a thatched roof that was suitable for roosting of the bats. All the bats that had nested in the museum left because of the effect of the smoke of the burnt chilli (Chitima and Ndlovu 2017). However, the effect of the smoke on the conservation of collections in the museum needs to be established, as the smoke may react with the collections resulting in their deterioration.

Ash from burnt wood is another method that has traditionally been used for pest control in Zimbabwe, particularly in preserving grains. For instance, ash from burnt *Isihaqa* trees has been used by indigenous Batonga communities in Zimbabwe to kill pests such as ants and termites (Chitima and Ndlovu 2017). The Natural History Museum of Zimbabwe can also adopt this method, and carefully place the ash in the crevices and cracks, windows and entrance and exit points of the museum building. The ash repels the pests away.

Herbal plant extracts have also been used traditionally to repel or kill pests. Plant-based extracts from walnut fruit, *Artemisia* oil, cinnamon oil, equisetum stem, circium roots, rhizophora leaf, and beggar-tick plant oil were used effectively in protecting artefacts against pest attack in India. These plant extracts are environmentally friendly, are not hazardous to humans and do not cause damage to museum collections (Sharma *et al.* 2018). Further, plant materials from *Arctium lappa* L (bardana – burdock) and *Centaurea cyanus* L (garden cornflower) have been used for the control of micro-organisms that affect organic artefacts at the National Archive of the Republic of Cuba and the Historical Archive of the Museum of La Plata, Argentina (Saravia *et al.* 2008). If available, the Natural History Museum of Zimbabwe should consider using these plant-based extracts for pest control.

The use of all these methods in combination will make a massive difference in pest control and eliminate the need for pesticide use at the Natural History Museum. The adoption of these pest control methods adds more work pressure for museum staff. To improve efficiency in the implementation of these methods and to lessen the burden on individuals, the museum should

consider establishing teams that spearhead these pest control initiatives such as the safety and integrated pest management teams.

6.4 Recommendations for Further Research

Due to funding challenges and time constraints, a limited number of specimens were analysed for chemical contamination. There is a need for extensive analysis of collections at the Natural History Museum of Zimbabwe to get a clear picture of the extent of contamination of collections in the museum. The analysis of chemical contamination needs to be expanded from a focus on collection contamination to environmental contamination by analysing the air in storage and display cases. This will help to determine if the air in the museum environment is contaminated by toxic pesticides. There is a need to conduct clinical tests on staff in the museum to determine whether they have been exposed to the hazardous pesticides that have been applied in the museum for a period spanning over a century of years. Further, the research on pesticide contamination needs to be expanded across Africa to determine the state of contamination of collections in museums and to establish safety protocols for accessing and using them.

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Appendix 1. Ethics Clearance Letter, UP Ethics Committee



Faculty of Humanities

Fakulteit Geesteswetenskappe
Lefapha la Bomotheo



11 November 2020

Dear Mr D Chiwara

Project Title: Collections Conservation Practices and Possibilities of Contamination by Hazardous Pesticides: Towards a Non-Pesticide Approach of Conserving Organic Collections at the Natural History Museum of Zimbabwe.
Researcher: Mr D Chiwara
Supervisor(s): Prof SE O'Connell
Department: Historical and Heritage Studies
Reference number: 19214686 (HUM030/1020)
Degree: Doctoral

I have pleasure in informing you that the above application was **approved** by the Research Ethics Committee on 11 November 2020. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

We wish you success with the project.

Sincerely,

Prof Innocent Pikirayi
Deputy Dean: Postgraduate Studies and Research Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: PGHumanities@up.ac.za

Fakulteit Geesteswetenskappe
Lefapha la Bomotheo

Research Ethics Committee Members: Prof I Pikirayi (Deputy Dean); Prof KL Hamis; Mr A. Bizo; Dr A. M. de Beer; Dr A. de Santos; Ms KT Govender; Andrew; Dr P. Bule; Dr T. Johnson; Prof D. Mase; Mr A. Mohamed; Dr I. Nkomo; Dr G. Buthe; Prof D. Beynon; Prof M. Sene; Prof E. Tshabangu; Prof V. Tshabe; Ms B. Tshabe; Ms D. Mkalapa

Appendix 2. Research Permission Letter, Natural History Museum of Zimbabwe



National Museums and Monuments of Zimbabwe

ALL COMMUNICATIONS SHOULD BE
ADDRESSED TO THE REGIONAL DIRECTOR

Natural History Museum of Zimbabwe
P.O. Box 240
Bulawayo
Zimbabwe
Tel: 29-2234019/29-2235627
Fax: 2250045
Email: natimuse@netconnect.co.zw

06 July 2020

TO WHOM IT MAY CONCERN

This letter serves to notify Davison Chiwara from the University of Pretoria, South Africa, Registration Number U19214686 that permission has been granted to carry out research at the Natural History Museum, titled Conservation Practises and Possibilities of Contamination by Hazardous Pesticides: Towards a Non-Pesticide Approach of Conserving Organic Artefacts at the Natural History Museum of Zimbabwe. The above student should therefore send his full proposal and timetable of data collection prior to his visits.

Yours sincerely



Dr FitzPatrick
Regional Director
Natural History Museum



Appendix 3. Letter of Informed Consent



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Pretoria 0002 Republic of South Africa
<http://www.up.ac.za>
Tel 012-420-2323

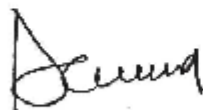
Faculty of Humanities
Historical and Heritage Studies
12 July 2020

Letter of Informed Consent

I, Davison Chiwara (student number: U19214686) am currently enrolled for a PhD in Heritage and Museum Studies in the Department of Historical and Heritage Studies at the University of Pretoria. I am doing a thesis entitled "Collections Conservation Practises and Possibilities of Contamination by Hazardous Pesticides: Towards a Non-Pesticide Approach of Conserving Organic Artefacts at the Natural History Museum of Zimbabwe." For the purposes of this study I need to complete certain field research which will take the form of open-ended interviews with individuals with first-hand or expert knowledge of information relevant to my thesis. This will form part of my primary research as oral evidence and complies with the accepted standards within the department of Historical and Heritage Studies. I hereby wish to obtain permission to interview you.

Your input will be acknowledged according to the footnoting system prescribed by the Department of Historical and Heritage Studies. If specifically requested, participants may request to remain anonymous. Your interview will be recorded in writing / tape recorder and will be stored in electronic format for a period of 15 years in compliance with the policy of the University Faculty of Humanities. This material may also be used for other research by the candidate. Your participation is entirely voluntary and you may choose to withdraw from the interview at any stage.

Yours sincerely
Davison Chiwara



I, Phetulo N. Tshabangu (the undersigned) agree to participate in the Doctoral research project of Mr Davison Chiwara, (student number U19214686) at the University of Pretoria.

I have read his letter of introduction and agree that my information may be acknowledged according to the prescribed Departmental footnote reference system.

☒	I give permission for my name to be used in this research.
☐	I wish to remain anonymous in this research.

Yours sincerely

Signed Phetulo N. Tshabangu Date 22-07-2020

Appendix 4. Signed Consent

I, Charity Nyathi (the undersigned) agree to participate in the Doctoral research project of Mr Davison Chikwara, (student number U19214686) at the University of Pretoria.

I have read his letter of introduction and agree that my information may be acknowledged according to the prescribed Departmental footnote reference system.

☐	I give permission for my name to be used in this research.
☐	I wish to remain anonymous in this research.

Yours sincerely

Signed Charity Nyathi

Date 20-7-2020

Appendix 5. Signed Consent

I, Lovemore Temba (the undersigned) agree to participate in the Doctoral research project of Mr Davison Chiwara, (student number U19214686) at the University of Pretoria.

I have read his letter of introduction and agree that my information may be acknowledged according to the prescribed Departmental footnote reference system.

☒	I give permission for my name to be used in this research.
☐	I wish to remain anonymous in this research.

Yours sincerely

Signed



Date

23/07/2020

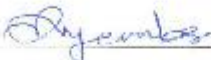
Appendix 6. Signed Consent

I, VIOLAH MAKUVAZA (the undersigned) agree to participate in the Doctoral research project of Mr Davison Ukwara, (student number U19214686) at the University of Pretoria.

I have read his letter of introduction and agree that my information may be acknowledged according to the prescribed Departmental footnote reference system.

☒	I give permission for my name to be used in this research.
☐	I wish to remain anonymous in this research.

Yours sincerely

Signed  Date 23/07/2020

Appendix 7. Interview Schedule



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Pretoria 0002 Republic of South Africa
<http://www.up.ac.za>
Tel 012-420-2323

Faculty of Humanities
Historical and Heritage Studies

Interview Schedule

1. Do you know of any chemicals that have been used by the museum for pest control, both historically and currently?
2. Who is responsible for the application of pesticides in the museum and how are the pesticides applied?
3. How often are pesticides applied in the museum?
4. Have there been any collections that have reacted with chemical pesticides? If so, have you observed any changes in appearance of collections owing to pesticide use?
5. What precautionary measures are taken by the museum to prevent pesticide contamination of artefacts during the application of pesticides?
6. Do you systematically document the pesticides that are used in the museum? If so, how do you document the pesticides?
7. Apart from pesticides, do you have any other means of controlling pests in the museum?
8. When you access specimens in storage and display areas, is there any smell of chemicals that you encounter?
9. Are there any safety measures that are in place to protect museum staff, researchers and visitors from possibly contaminated collections or environments in the museum?

Appendix 8. Observation Guide



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Pretoria 0002 Republic of South Africa
<http://www.up.ac.za>
Tel 012-420-2323

Faculty of Humanities
Historical and Heritage Studies

Observation Guide: Pesticide Contamination at the Natural History Museum of Zimbabwe.

1. Is there any presence of pesticide residues (whitish, grey or any other powder or crystalline particles) that can be seen by the naked eye in organic collections, and pesticides within storage and display areas?
2. Is there any smell of chemical odours in the museum's environments?
3. How are the people doing condition assessments and chemical analysis of artefacts reacting to the chemical odours in the museum's environments?
4. What is the state of ventilation in the museum's storerooms and office space?
5. Are there enough windows in the museum's storerooms and office space to allow for free air circulation?

Appendix 9. Condition Assessment Form

Condition Assessment Form: Mammalogy and Ornithology Collections (Natural History Museum of Zimbabwe)

Name of Object/Specimen:

Description:

Accession Date:

Accession Number:

Old Accession Number:

Assessment Date:

Assessed by:

Contact Details of Assessor: Cell:

email:

Object/Specimen Photo:

Type of Material:

Dimensions: Height.....

Width.....

Depth.....

Weight.....

Conservation Condition Rating: Excellent ☐

Good ☐

Fair ☐

Poor ☐

Stability: Stable ☐

Potentially unstable ☐

Unstable ☐

Highly unstable ☐

Treatment Proposal: No further action ☐

Preventive Conservation¹ ☐

Remedial Conservation² ☐

Priority Rating: Urgent ☐

Necessary ☐

Desirable ☐

No treatment ☐

Access Proposal: Open access ☐

Controlled access with precautions ☐

Quarantine & closed access ☐

Damage Description:

Chemical Damage

Powdery deposits ☐

Crystalline deposits ☐

Stains⁴ ☐

Pigment loss ☐

Odour ☐

Physical Damage

Structural weaknesses ☐

Loss of parts (Feathers, fur, skin) ☐

Detaching (Feathers, fur, skin) ☐

Biological Damage: Pests

Surface loss ☐

Holes³ ☐

Examination & Analysis

Visual analysis ☐

XRF analysis ☐

Chromatography ☐

UV analysis ☐

Infrared (IR) spectroscopy ☐

¹ Indirect measures for safeguarding artefacts against deterioration caused by chemical contamination such as repackaging, quarantining and non-pesticide methods of pest control.

² Direct measures for safeguarding artefacts against deterioration caused by chemical contamination such as decontamination, surface cleaning etc.

³ Openings on artefacts caused by pest activity

⁴ A change of colour caused by a chemical agent reacting with a material

Artefact Condition Assessment Framework

ACCESS	Open access	Controlled access with Precautions	Quarantine and closed access	
Definition	Artefacts are not contaminated with pesticides and access to them is unlimited	Artefacts are partially contaminated with pesticides and access to them is limited while observing safety protocols	Artefacts are overly contaminated with pesticides and they are not accessible. They are quarantined in safe storage to prevent cross contamination with unaffected artefacts as well as preventing harm to humans.	
STABILITY	Stable	Potentially unstable	Unstable/steady deterioration	Highly unstable
Definition	Condition not expected to deteriorate within the next 10+ years	Condition not expected to deteriorate within next 3-10 years	Change in condition likely to be evident between 1-3 years	Change in condition likely to be evident within 1 year
CONDITION	Excellent	Good	Fair	Poor
Definition	Little or no damage evident.	Minor amount of damage and/or loss of original and added material, or with light discolouration from chemical agents	Noticeable damage and loss and appears discoloured with visible chemical residues.	Considerable and/or significant loss of original material. May be endangering other artefacts through cross contamination and posing danger to human health.
TREATMENT PRIORITY	Urgent	Necessary	Desirable	No Treatment
Definition	Conservation treatment required to prevent significant deterioration in condition of object and/or loss of significance (evidential or artistic value). This may include structural vulnerability, risk of total loss of entire object or part of object, or risk of harm to visitors/users	Conservation treatment necessary to avoid further deterioration, loss or undesirable strain on an object and/or loss of significance (evidential or artistic value).	Conservation treatment desirable but not necessary to ensure the long term stability of the object. For instance, conservation treatment may be required for curatorial reasons	Conservation treatment not required beyond routine maintenance

Appendix 10. XRF Analysis

File #	DateTime	Name	ID	Field1	Field2	Time	MgO	Al2O3	SiO2	P
1	01-31-2022 15:39	Instrument Check	CS-M2	Spot 1		90	1.63	12.87	71.86	< LOD
2	01-31-2022 15:58	Ornithology	86350	Spot 1		90	< LOD	< LOD	0.96	0.12
3	01-31-2022 16:03	Ornithology	86351	Spot 2		90	< LOD	< LOD	0.34	0.06
4	01-31-2022 16:05	Ornithology	86352	Spot 3		90	< LOD	< LOD	0.82	0.04
5	01-31-2022 16:17	Ornithology	70514	Spot 2		30				
6	01-31-2022 16:18	Ornithology	70515	Spot 2		30				
7	01-31-2022 16:19	Ornithology	70516	Spot 3		30				
8	01-31-2022 16:25	Ornithology	70513	spot 1		2	3.00			
9	01-31-2022 16:26	Check sample	CS-M2	spot 1		90	1.56	12.34	70.14	< LOD
10	01-31-2022 16:33	Ornithology	51630	spot 1		90	< LOD	< LOD	1.53	0.05
11	01-31-2022 16:35	Ornithology	51631	spot 2		30				
12	01-31-2022 16:37	Ornithology	51632	spot 3		90	< LOD	< LOD	1.02	0.03
13	01-31-2022 16:42	Ornithology	9818	spot 1		90	< LOD	< LOD	1.44	0.08
14	01-31-2022 16:44	Ornithology	9819	spot 1		90	< LOD	< LOD	1.57	0.13
15	01-31-2022 16:47	Ornithology	9820	spot 3		30				
16	02-01-2022 10:56	Instrument Check	CS-M2	spot 1		90	< LOD	12.73	70.55	< LOD
17	02-01-2022 11:10	Mammology	68099	spot 1 inside	furs	30				
18	02-01-2022 11:12	Mammology	68100	spot 1 inside	furs	60	1.84	< LOD	0.59	0.09
19	02-01-2022 11:24	Mammology	4362	spot 1 inside	furs	30				
20	02-01-2022 11:58	Instrument Check	CS-M2			90	1.80	12.30	69.49	< LOD
21	02-01-2022 12:05	Mammography	4771	Field mouse		31				
22	02-01-2022 12:07	Mammography 1	4771	Field mouse	Spot 2 back	90	< LOD	< LOD	1.01	0.05
23	02-01-2022 12:14	Mammography 2	50743	Field mouse	Spot 1 tummy	30				
24	02-01-2022 12:16	Mammography 3	50743	Field mouse	Spot 1 tummy	30				
25	02-01-2022 12:19	Mammography 4	52866	Field mouse	Spot 1 tummy	30				
26	02-01-2022 12:23	Mammography 5	52866	Field mouse	Spot 1 tummy	30				
27	02-01-2022 12:25	Mammography 6	52866	Field mouse	Spot 2 back	90	3.31	< LOD	0.50	0.07
28	02-01-2022 12:30	Mammography 7	54709	Field mouse	Spot 2 back	30				
29	02-01-2022 12:33	Mammography 8	58132	Field mouse	Spot 1 tummy	30				
30	02-01-2022 12:34	Mammography 9	58132	Field mouse	Spot 2 back	30				
31	02-01-2022 12:36	Mammography 10	50838	Field mouse	Spot 1 tummy	30				

File #	DateTime	Name	ID	Field1	Field2	Time	MgO	Al2O3	SiO2	P
32	02-01-2022 12:38	Mammography 11	50838	Field mouse	Spot 2 back	30				
33	02-01-2022 12:40	Mammography 12	77938	Field mouse	Spot 1 tummy	30				
34	02-01-2022 12:41	Mammography 13	77938	Field mouse	Spot 2 back	30				
35	02-01-2022 12:56	Mammography 14	5892	Squirrels	Spot 1 tummy	90	3.19	< LOD	0.60	0.12
36	02-01-2022 12:58	Mammography 15	5892	Squirrels	Spot 2 back	30				
37	02-01-2022 13:01	Mammography 16	17675	Squirrels	Spot 1 tummy	90	< LOD	< LOD	0.63	0.06
38	02-01-2022 13:04	Mammography 17	17675	Squirrels	Spot 2 back	90	< LOD	< LOD	0.32	0.10
39	02-01-2022 13:09	Mammography 18	3472	Squirrels	Spot 1 tummy	90	< LOD	< LOD	4.65	0.16
40	02-01-2022 13:11	Mammography 19	3472	Squirrels	Spot 2 back	30				
41	02-01-2022 13:18	Mammography 20	4788	Squirrels	Spot 1 front	30				
42	02-01-2022 13:19	Mammography 21	4788	Squirrels	Spot 2 back	30				
43	02-01-2022 13:23	Mammography 22	69155	Squirrels	Spot 1 front	30				
44	02-01-2022 13:24	Mammography 23	69155	Squirrels	Spot 2 back	90	2.94	< LOD	0.17	0.17
45	02-01-2022 13:48	Mammography 24	26615	furs	Spot 1 underside	30				
46	02-01-2022 13:51	Mammography 25	55119	furs	Spot 1 underside	30				
47	02-01-2022 13:54	Mammography 26	55115	furs	Spot 1 skinside	30				
48	02-01-2022 13:55	Mammography 27	55115	furs	Spot 2 furside	1				
49	02-01-2022 13:56	Mammography 28	55086	furs	spot 1 skinside	30				
50	02-01-2022 13:57	Mammography 29	55086	furs	spot 2 furside	30				
51	02-01-2022 14:06	Mammography 30	55107	furs	spot 1 skin side	30				
52	02-01-2022 14:07	Mammography 31	55107	furs	spot 2 fur side	30				
53	02-01-2022 14:08	Mammography 32	55051	furs	spot 1 skin side	30				
54	02-01-2022 14:10	Mammography 33	55051	furs	spot 2 fur side	30				
55	02-01-2022 14:24	Mammography 34	4760	vervet monkeys	spot 1 belly down	30				
56	02-01-2022 14:25	Mammography 35	4760	vervet monkeys	spot 2 back	15				
57	02-01-2022 14:29	Mammography 36	4411	vervet monkeys	spot 1 belly	75	1.40	< LOD	1.69	0.09
58	02-01-2022 14:32	Mammography 37	4411	vervet monkeys	spot 2 back	75	< LOD	< LOD	0.45	0.10
59	02-01-2022 14:34	Mammography 38	4405	vervet monkeys	spot 1 front	15				
60	02-01-2022 14:35	Mammography 39	4405	vervet monkeys	spot 2 back	15				
61	02-01-2022 14:50	Mammography 40	56488	otter furs	spot 2 furside	15				
62	02-01-2022 14:52	Mammography 41	68605	otter furs	spot 1skin	75	2.59	< LOD	1.17	0.11
63	02-01-2022 14:56	Mammography 42	56376	otter furs	spot 1 skin side	15				

File #	DateTime	Name	ID	Field1	Field2	Time	MgO	Al2O3	SiO2	P
64	02-01-2022 14:57	Mammography 43	56376	otter furs	spot 2 fur side	15				
65	02-01-2022 14:59	Mammography 44	68613	otter furs	spot 1 skin side	15				
66	02-01-2022 15:00	Mammography 45	68613	otter furs	spot 2 fur side	15				
67	02-01-2022 15:16	Mammography 46	68685	Dassies	Spot 1 belly	15				
68	02-01-2022 15:17	Mammography 47	68685	Dassies	Spot 2 back	15				
69	02-01-2022 15:20	Mammography 48	68723	Dassies	Spot 1 belly	15				
70	02-01-2022 15:21	Mammography 49	68723	Dassies	Spot 2 back	15				
71	02-01-2022 15:23	Mammography 50	68728	Dassies	Spot 2 back	15				
72	02-01-2022 15:24	Mammography 51	68728	Dassies	Spot 2 back	15				
73	02-01-2022 15:25	Mammography 52	68760	Dassies	Spot 1 belly	15				
74	02-01-2022 15:26	Mammography 53	68760	Dassies	Spot 2 back	15				
75	02-01-2022 15:36	Mammography 54	60585	Spring hare fur	Spot 2 fur	15				
76	02-01-2022 15:59	Mammography 55	1318	Mongoose fur	Spot 1 skin	15				
77	02-02-2022 10:58	Instrument Check	CS-M2			75	1.80	11.73	68.66	0.04
78	02-02-2022 11:05	Mammalogy	5218	Skin side	Fur	15				
79	02-02-2022 11:08	Mammalogy 1	1318	skin side	Fur	15				
80	02-02-2022 11:14	Mammalogy 2	4293	tummy side	Spotted Genet	15				
81	02-02-2022 11:16	Mammalogy 3	2081	tummy side	Spotted Genet	15				
82	02-02-2022 11:17	Mammalogy 4	2081	back side	Spotted Genet	15				
83	02-02-2022 11:20	Mammalogy 5	7481	tummy side	Spotted Genet	6				
84	02-02-2022 11:21	Mammalogy 6	7481	back side	Spotted Genet	28				
85	02-02-2022 11:27	Mammalogy 7	945	tummy side	Spotted Genet	15				
86	02-02-2022 11:28	Mammalogy 8	945	back side	Spotted Genet	75	1.62	< LOD	0.54	0.09
87	02-02-2022 11:32	Mammalogy 9	27921	tummy side	Spotted Genet	15				
88	02-02-2022 12:38	Skins	54193	skin side	Porcupine	15				
89	02-02-2022 12:49	Skins 1	27413	spot 2	Papio Ursinus	5				
90	02-02-2022 12:50	Skins 2	27413	spot 2	Papio Ursinus	15				
91	02-02-2022 12:54	Skins 3	27968	skin side	Baboon	75	2.10	< LOD	0.68	0.08
92	02-02-2022 12:57	Skins 4	27968	fur side	Baboon	15				
93	02-02-2022 13:01	Skins 5	56396	scaly side	Pangolin	75	1.60	0.33	3.49	0.08
94	02-02-2022 13:08	Skins 6	56293	skin side	Brown Hyena	75	2.14	< LOD	1.49	0.13
95	02-02-2022 13:10	Skins 7	56293	fur side	Brown Hyena	75	1.26	< LOD	0.36	0.07

File #	DateTime	Name	ID	Field1	Field2	Time	MgO	Al2O3	SiO2	P
96	02-02-2022 13:15	Skins 8	2578	skin side	Leopard cub	32				
97	02-02-2022 13:17	Skins 9	2578	fur ide	Leopard cub	75	< LOD	< LOD	0.57	0.09
98	02-02-2022 13:20	Skins 10	28766	skin side	Leopard cub	75	1.53	< LOD	1.95	0.18
99	02-02-2022 13:22	Skins 11	28766	fur side	Leopard cub	75	1.32	< LOD	0.44	0.11
100	02-02-2022 13:26	Skins 12	2648	skin side	Painted hunting dog	75	1.88	< LOD	1.80	0.20
101	02-02-2022 13:28	Skins 13	2648	fur side	Painted hunting dog	15				
102	02-02-2022 13:31	Skins 14	33365	skin side	Spotted Hyena	75	2.00	< LOD	0.46	0.05
103	02-02-2022 13:34	Skins 15	33365	fur side	Spotted Hyena	75	< LOD	< LOD	0.33	0.11
104	02-02-2022 13:38	Skins 16	table			75	< LOD	0.60	1.85	0.12
105	02-02-2022 13:42	Skins 17	56740	skin side	cheetah	75	1.43	< LOD	1.97	0.12
106	02-02-2022 13:44	Skins 18	56740	fur side	cheetah	38				
107	02-02-2022 13:53	Skins 19	TG255	skin side	Ant eater	75	1.55	< LOD	1.18	0.18
108	02-02-2022 13:55	Skins 20	TG255	fur side	Ant eater	75	2.65	< LOD	1.08	0.22
109	02-02-2022 14:05	Skins 21	TNL10	skin side	Impala	55	1.53	< LOD	1.57	0.09
110	02-02-2022 14:08	Skins 22	TNL10	fur side	Impala	55	< LOD	< LOD	0.28	0.09
111	02-02-2022 14:13	Skins 23	11563	skin side	Letchwe	55	2.08	< LOD	2.05	0.16
112	02-02-2022 14:15	Skins 24	11563	fur side	Letchwe	55	1.77	< LOD	3.38	0.51
113	02-02-2022 14:18	Skins 25	MSA67	skin side		55	2.50	< LOD	1.05	0.07
114	02-02-2022 14:20	Skins 26	MSA67	fur side		55	2.01	< LOD	1.22	0.09
115	02-02-2022 14:24	Skins 27	TNL4949	skin side	springbok	55	1.66	< LOD	2.09	0.23
116	02-02-2022 14:26	Skins 28	TNL4949	fur side	springbok	55	< LOD	< LOD	0.19	0.10
117	02-02-2022 14:41	Skins 29	189	fur	tatty skin	15				
118	02-02-2022 14:43	Skins 30	nm3365	skun	tatty skin	55	2.14	< LOD	0.63	0.05
119	02-02-2022 14:45	Skins 31	nm3365	fur	tatty skin	55	< LOD	< LOD	1.89	0.04
120	02-02-2022 14:54	Skins 32	59200	fur	kobus leche	55	1.59	< LOD	1.06	0.11
121	02-02-2022 14:56	Skins 33	59200	fur	kobus leche	55	1.68	< LOD	0.39	0.06
122	02-02-2022 15:08	Skins 34	20539	skin side	warthog	16				
123	02-02-2022 15:08	Skins 35	20539	hairy side	warthog	25				
124	02-02-2022 15:12	Skins 36	25865	skin side	warthog	15				
125	02-02-2022 15:13	Skins 37	25865	fur side	warthog	42	< LOD	< LOD	2.03	0.07
126	02-02-2022 15:16	Skins 38	25909	skin side		55	< LOD	1.49	5.46	0.18
127	02-02-2022 15:17	Skins 39	25909	fur side		55	< LOD	< LOD	1.67	0.23

File #	DateTime	Name	ID	Field1	Field2	Time	MgO	Al2O3	SiO2	P
128	02-02-2022 15:22	Skins 40	25923	skin side		55	< LOD	< LOD	1.68	0.19
129	02-02-2022 15:23	Skins 41	25923	fur side		55	< LOD	< LOD	2.38	0.14
130	02-02-2022 15:27	Skins 42	59314	skin side		55	1.80	< LOD	1.06	0.12
131	02-02-2022 15:29	Skins 43	59314	fur side		55	< LOD	< LOD	0.56	0.13
132	02-02-2022 16:13	Skins 44	56283	skin	cheetah	55	< LOD	< LOD	1.77	0.12
133	02-02-2022 16:15	Skins 45	56283	fur	cheetah	55	< LOD	< LOD	0.19	0.10
134	02-02-2022 16:21	Skins 46	5014	skin	baby zebra	55	< LOD	< LOD	1.87	0.11
135	02-02-2022 16:23	Skins 47	5014	fur	baby zebra	15	0.04	< LOD	< LOD	0.03
136	02-02-2022 16:26	Skins 48	5014	fur	baby zebra	55	< LOD	< LOD	0.38	0.10
137	02-02-2022 16:29	Skins 49	54716	fur	buffalo	55	< LOD	< LOD	0.48	0.06
138	02-02-2022 16:33	Skins 50	2071	skin	kudu	15				
139	02-02-2022 16:35	Skins 51	2071	fur	kudu	55	2.63	< LOD	0.99	0.17
140	02-02-2022 16:40	Skins 52	21854	skin	duiker	55	1.66	< LOD	0.91	0.03
141	02-02-2022 16:42	Skins 53	21854	fur	duiker	15				
142	02-02-2022 16:44	Skins 54	4044	skin	klipspringer	55	< LOD	< LOD	0.58	0.05
143	02-02-2022 16:45	Skins 55	4044	fur	klipspringer	55	< LOD	< LOD	< LOD	0.10
144	02-02-2022 16:48	Skins 56	21960	skin	oribi	55	< LOD	0.49	0.80	0.06
145	02-02-2022 16:50	Skins 57	21960	fur	oribi	55	< LOD	0.38	1.18	0.06
146	02-03-2022 10:53	Ornithology	34543	tummy	1876 Eagle	15				
147	02-03-2022 10:55	Ornithology 1	34543	tummy	1876 Eagle	35	2.21	< LOD	1.05	0.03
148	02-03-2022 10:58	Ornithology 2	34543	back	1876 Eagle	15				
149	02-03-2022 10:58	Ornithology 3	34543	back	1876 Eagle	35	1.79	< LOD	0.54	0.03
150	02-03-2022 11:07	Ornithology 4	34530	tummy	1876 Falcon	55	< LOD	< LOD	0.70	0.09
151	02-03-2022 11:09	Ornithology 5	34530	back	1876 Falcon	15				
152	02-03-2022 11:15	Ornithology 6	34532	back	Goshawk	15				
153	02-03-2022 11:16	Ornithology 7	34532	tummy	Goshawk	55	< LOD	< LOD	0.55	0.03
154	02-03-2022 11:19	Ornithology 8	34531	tummy	Goshawk	55	< LOD	< LOD	0.48	0.07
155	02-03-2022 11:21	Ornithology 9	34531	back	Goshawk	55	< LOD	< LOD	0.40	0.06
156	02-03-2022 11:29	Ornithology 10	34534	tummy	bird	55	3.01	< LOD	2.50	0.05
157	02-03-2022 11:32	Ornithology 11	34534	back	bird	55	1.57	< LOD	0.45	0.03
158	02-03-2022 11:34	Ornithology 12	86148	tummy	bird	55	< LOD	< LOD	0.33	0.05
159	02-03-2022 11:37	Ornithology 13	86148	back	bird	55	8.77	< LOD	0.13	0.04

File #	DateTime	Name	ID	Field1	Field2	Time	MgO	Al2O3	SiO2	P
160	02-03-2022 11:54	Ornithology 14	34528	tummy	bird	15				
161	02-03-2022 11:57	Ornithology 15	34529	tummy	bird	2				
162	02-03-2022 11:59	Ornithology 16	34529	back	bird	15				
163	02-03-2022 12:01	Ornithology 17	85520	tummy	bird	55	4.07	< LOD	0.27	0.05
164	02-03-2022 12:02	Ornithology 18	85520	back	bird	55	< LOD	< LOD	0.67	0.07
165	02-03-2022 12:23	Ornithology 19	72401	tummy	bird (Ardeola Grayii)	55	< LOD	< LOD	0.39	0.06
166	02-03-2022 12:24	Ornithology 20	72401	back	bird (Ardeola Grayii)	55	< LOD	< LOD	0.44	0.15
167	02-03-2022 12:31	Ornithology 21	72403	tummy	bird (Butorides Virescens)	55	3.06	< LOD	0.45	0.05
168	02-03-2022 12:33	Ornithology 22	72403	back	bird (Butorides Virescens)	55	2.77	< LOD	0.59	0.05
169	02-03-2022 12:40	Ornithology 23	85537	Back	bird (RissaTridactyla)	55	< LOD	< LOD	0.37	0.05
170	02-03-2022 12:45	Ornithology 24	85531	Tummy	bird (Limosa Haemastica)	55	< LOD	< LOD	1.29	0.05
171	02-03-2022 12:48	Ornithology 25	85531	Back	bird (Limosa Haemastica)	55	< LOD	< LOD	0.67	0.06
172	02-03-2022 12:54	Ornithology 26	72410	Tummy	bird (Capella Delicate)	55	< LOD	< LOD	2.65	0.06
173	02-03-2022 12:57	Ornithology 27	72410	Back	bird (Capella Delicate)	55	2.46	< LOD	1.24	0.03
174	02-03-2022 13:05	Ornithology 28	72413	Tummy	bird (Capella Stenura)	55	< LOD	< LOD	3.14	0.31
175	02-03-2022 13:07	Ornithology 29	72413	Back	bird (Capella Stenura)	55	< LOD	< LOD	1.24	0.08
176	02-03-2022 13:30	Ornithology 30	73455	Tummy	bird (Heterotrogon Vittatum)	15				
177	02-03-2022 13:31	Ornithology 31	73455	Back	bird (Heterotrogon Vittatum)	15				
178	02-03-2022 13:35	Ornithology 32	70507	Tummy	bird (Trogon Citrealus)	55	5.02	< LOD	1.37	0.09
179	02-03-2022 13:37	Ornithology 33	70507	back	bird (Trogon Citrealus)	55	5.86	< LOD	0.40	0.09
180	02-03-2022 13:57	Ornithology 34	63628	Tummy	bird (Apus Pallidus)	15				
181	02-03-2022 13:58	Ornithology 35	63628	Back	bird (Apus Pallidus)	55	2.76	0.38	3.05	0.10
182	02-03-2022 14:04	Ornithology 36	95952	Tummy	bird	55	7.55	< LOD	3.29	0.07
183	02-03-2022 14:07	Ornithology 37	95952	Back	bird	55	6.01	< LOD	3.50	0.05
184	02-03-2022 14:11	Ornithology 38	26480	Tummy	bird	55	< LOD	< LOD	3.09	0.08
185	02-03-2022 14:14	Ornithology 39	26480	back	bird	55	< LOD	< LOD	2.28	0.05
186	02-03-2022 14:19	Ornithology 40	46580	Tummy	bird	15				
187	02-03-2022 14:20	Ornithology 41	46580	Back	bird	55	2.82	< LOD	2.82	0.34
188	02-03-2022 14:26	Ornithology 42	63948	Tummy	bird (Apus apus apus)	55	2.49	< LOD	1.11	0.06
189	02-03-2022 14:29	Ornithology 43	63948	Back	bird (Apus apus apus)	6				
190	02-03-2022 14:30	Ornithology 44	63948	Back	bird (Apus apus apus)	55	< LOD	< LOD	1.36	0.05
191	02-03-2022 14:48	Ornithology 45	Indian Minah	Belly	No pesticides only borax	15				

File #	DateTime	Name	ID	Field1	Field2	Time	MgO	Al2O3	SiO2	P
192	02-03-2022 14:49	Ornithology 46	Indian Minah	Belly	No pesticides only borax	35	< LOD	< LOD	1.97	0.07
193	02-03-2022 14:50	Ornithology 47	Indian Minah	feathers	No pesticides only borax	35	< LOD	< LOD	1.41	0.02
194	02-03-2022 15:01	Ornithology 48	81231	Tummy	Bird (Chaetura sabini)	35	< LOD	< LOD	0.88	0.06
195	02-03-2022 15:03	Ornithology 49	81231	Back	Bird (Chaetura sabini)	35	2.05	< LOD	0.30	0.10
196	02-03-2022 15:10	Ornithology 50	66616	Tummy	Bird (Chaetura Pellagica)	35	1.60	< LOD	0.93	0.13
197	02-03-2022 15:12	Ornithology 51	66616	Back	Bird (Chaetura Pellagica)	35	1.60	< LOD	0.50	0.07
198	02-03-2022 15:17	Ornithology 52	77650	Tummy	Bird	35	< LOD	< LOD	1.01	0.06
199	02-03-2022 15:24	Ornithology 53	77650	Back	Bird	35	< LOD	< LOD	0.80	0.05
200	02-03-2022 15:26	Ornithology 54	66845	Tummy	Bird	35	< LOD	< LOD	1.05	0.11
201	02-03-2022 15:28	Ornithology 55	66845	Back	Bird	35	< LOD	< LOD	1.02	0.07
202	02-03-2022 15:34	Ornithology 56	70505	Tummy	Bird	35	< LOD	< LOD	2.75	0.23
203	02-03-2022 15:37	Ornithology 57	70505	Back	Bird	35	< LOD	< LOD	2.09	0.12
204	02-03-2022 15:57	Ornithology 58	86715	Tummy	Bird	35	1.67	< LOD	0.39	0.22
205	02-03-2022 15:59	Ornithology 59	86715	Back	Bird	35	2.80	< LOD	0.65	0.25
206	02-03-2022 16:04	Ornithology 60	81221	Tummy	Bird	1	3.00			
207	02-03-2022 16:10	Ornithology 61	92471	Tummy	Bird	35	1.76	< LOD	1.15	0.06
208	02-03-2022 16:12	Ornithology 62	92471	Tummy	Bird	35	2.36	< LOD	1.28	0.06
209	02-03-2022 16:14	Ornithology 63	92471	Back	Bird	35	1.95	< LOD	0.89	0.04
210	02-03-2022 16:17	Ornithology 64	89233	Tummy	Bird	35	< LOD	< LOD	0.50	0.04
211	02-03-2022 16:19	Ornithology 65	89233	Back	Bird	2	3.00			
212	02-03-2022 16:19	Ornithology 66	89233	Back	Bird	1	3.00			
213	02-03-2022 16:22	Ornithology 67	3771	Tummy	Bird	35	< LOD	< LOD	1.45	0.06
214	02-03-2022 16:24	Ornithology 68	3771	Back	Bird	35	2.12	< LOD	2.00	0.04
215	02-03-2022 16:29	Ornithology 69	22127	Tummy	Bird	35	3.41	< LOD	2.78	0.08
216	02-03-2022 16:30	Ornithology 70	22127	Back	Bird	35	1.71	1.46	4.92	0.06
217	02-03-2022 16:34	Ornithology 71	89210	Tummy	Bird	35	< LOD	< LOD	2.33	0.09
218	02-03-2022 16:39	Ornithology 72	93045	Tummy	Bird	35	< LOD	< LOD	5.44	0.14
219	02-03-2022 16:41	Ornithology 73	93045	Back	Bird	35	1.50	< LOD	2.09	0.18
220	02-03-2022 16:53	Ornithology 74	13827	tummy	Hooded vulture	35	2.97	< LOD	3.06	0.09
221	02-03-2022 16:55	Ornithology 75	13827	back	Hooded vulture	35	3.26	< LOD	1.66	0.08
222	02-03-2022 17:05	Ornithology 76	B827	Tummy	Pseudo gyps africanus	35	2.60	< LOD	5.36	0.14
223	02-03-2022 17:06	Ornithology 77	B827	back	Pseudo gyps africanus	35	1.55	< LOD	4.85	0.06
224	02-03-2022 17:09	Ornithology 78	89050	back	Lappet face Vulture	35	4.56	< LOD	2.01	0.02

File #	S	Cl	K2O	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As
1	0.156	< LOD	4.48	0.60	0.16	< LOD	0.00	0.09	1.42	< LOD		0.02	0.06	< LOD	0.00
2	10.1582	0.17	0.68	0.53	0.02	< LOD	< LOD	0.00	0.16	< LOD		0.01	0.03	< LOD	0.84
3	11.1098	< LOD	0.67	0.52	0.01	< LOD	< LOD	0.00	0.09	< LOD	< LOD	0.01	0.05	< LOD	1.54
4	9.0389	< LOD	0.28	0.33	0.02	< LOD	< LOD	0.00	0.10	< LOD	< LOD	0.00	0.04	< LOD	1.29
5				0.24	0.01	< LOD	< LOD	0.00	< LOD	0.00		< LOD	0.05	< LOD	
6				0.23	0.01	< LOD	< LOD	0.00	0.01	< LOD		< LOD	0.05	< LOD	
7				0.18	0.01	< LOD	< LOD	0.00	0.04	< LOD	< LOD	< LOD	0.10	< LOD	
8															
9	0.1893	< LOD	4.29	0.60	0.16	< LOD	0.00	0.09	1.38	< LOD		0.02	0.06	< LOD	< LOD
10	11.7812	1.84	0.25	0.58	0.02	< LOD	< LOD	0.00	0.13	< LOD		0.01	0.04	< LOD	4.14
11				0.58	0.01	< LOD	< LOD	0.00	0.11	< LOD		0.00	0.02	< LOD	
12	6.4714	1.46	0.17	0.38	0.02	< LOD	< LOD	0.00	0.08	< LOD		0.00	0.01	< LOD	2.00
13	10.6866	1.45	0.39	0.17	0.02	< LOD	< LOD	0.00	0.19	< LOD		0.00	0.03	< LOD	0.95
14	12.4331	1.47	0.40	0.26	0.02	< LOD	< LOD	0.00	0.17	< LOD		0.00	0.05	< LOD	1.73
15				0.17	0.03	< LOD	< LOD	0.01	0.21	< LOD		< LOD	0.04	< LOD	
16	0.1686	< LOD	4.44	0.58	0.17	< LOD	0.00	0.10	1.40	< LOD		0.02	0.06	< LOD	0.00
17				0.06	0.01	< LOD	0.69	< LOD	0.03	< LOD	< LOD	0.00	0.00	< LOD	
18	2.706	0.28	< LOD	0.06	0.01	< LOD	0.71	< LOD	0.03	< LOD	< LOD	0.00	0.00	< LOD	
19				0.09	0.02	< LOD	1.93	< LOD	0.13	< LOD		0.01	0.01	< LOD	
20	0.1894	< LOD	4.30	0.59	0.15	< LOD	0.00	0.09	1.40	< LOD		0.02	0.06	< LOD	0.00
21				0.22	0.01	< LOD	< LOD	0.01	0.08	< LOD		< LOD	0.01	< LOD	1.13
22	11.8721	1.21	0.93	0.49	0.03	< LOD	< LOD	0.01	0.36	< LOD		0.01	0.04	< LOD	1.56
23				0.15	0.01	< LOD	< LOD	0.00	0.84	< LOD	< LOD	< LOD	1.47	< LOD	
24				0.19	0.01	< LOD	< LOD	0.00	0.06	< LOD		< LOD	0.08	< LOD	
25				0.29	0.01	< LOD	< LOD	0.00	0.06	< LOD		< LOD	0.02	< LOD	
26				0.30	0.01	< LOD	< LOD	0.00	0.05	< LOD		< LOD	0.02	< LOD	
27	11.1778	0.75	1.48	0.37	0.02	< LOD	< LOD	0.00	0.13	< LOD		0.01	0.03	< LOD	2.52
28				0.24	0.01	< LOD	0.00	0.00	0.03	< LOD		< LOD	0.03	< LOD	
29				0.19	0.06	< LOD	< LOD	0.00	0.69	< LOD	< LOD	< LOD	0.49	< LOD	
30				0.22	0.06	< LOD	< LOD	0.00	0.26	< LOD		< LOD	0.36	< LOD	
31				0.10	0.01	< LOD	< LOD	< LOD	0.23	< LOD	< LOD	< LOD	0.24	< LOD	

File #	S	Cl	K2O	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As
32				0.11	0.01	<LOD	<LOD	0.00	0.15	<LOD		<LOD	0.20	<LOD	
33				0.12	0.04	<LOD	0.00	0.00	0.53	<LOD	<LOD	<LOD	1.07	<LOD	
34				0.25	0.01	<LOD	<LOD	0.00	0.06	<LOD	<LOD	0.00	0.04	<LOD	
35	5.3386	0.32	1.18	0.59	0.04	<LOD	<LOD	0.01	0.14	<LOD		0.01	0.02	<LOD	3.28
36				0.20	0.02	<LOD	<LOD	0.00	0.11	<LOD		<LOD	0.02	<LOD	
37	2.2038	0.12	5.29	0.93	0.03	<LOD	<LOD	0.00	0.11	<LOD		0.01	0.02	<LOD	21.90
38	7.5622	0.39	1.14	0.20	0.01	<LOD	<LOD	0.00	0.10	<LOD		0.00	0.02	<LOD	1.26
39	8.9007	1.04	0.82	0.86	0.07	<LOD	0.01	0.02	0.88	<LOD		0.01	0.06	<LOD	1.45
40				0.25	0.02	<LOD	<LOD	0.01	0.14	<LOD		<LOD	0.03	<LOD	
41				0.11	0.01	<LOD	<LOD	0.00	0.04	<LOD		<LOD	0.02	<LOD	
42				0.13	0.02	<LOD	0.00	0.00	0.11	<LOD		<LOD	0.02	<LOD	
43				0.11	0.01	<LOD	<LOD	0.00	0.03	<LOD		<LOD	0.03	<LOD	
44	11.3472	0.38	0.45	0.18	0.01	<LOD	<LOD	0.00	0.08	<LOD		0.00	0.05	<LOD	0.03
45				0.07	0.01	<LOD	0.08	<LOD	0.03	<LOD		<LOD	0.04	<LOD	
46				0.05	0.01	<LOD	1.29	<LOD	0.09	<LOD		0.00	0.01	<LOD	
47				0.02	0.01	<LOD	0.97	<LOD	0.04	<LOD		0.00	0.01	<LOD	
48															
49				0.19	0.01	<LOD	1.59	<LOD	0.11	<LOD		0.00	0.00	<LOD	
50				0.09	0.01	<LOD	0.18	0.00	0.02	<LOD	<LOD	0.01	0.01	<LOD	
51				0.13	0.02	<LOD	1.41	<LOD	0.22	<LOD		<LOD	0.01	<LOD	
52				0.15	0.01	<LOD	0.22	0.00	0.06	<LOD		0.01	0.01	<LOD	
53				0.17	0.01	<LOD	3.72	<LOD	0.09	<LOD	<LOD	0.01	0.05	<LOD	
54				0.12	0.01	<LOD	0.45	<LOD	0.05	<LOD		0.01	0.06	<LOD	
55				0.28	0.02	<LOD	<LOD	0.00	0.25	<LOD		<LOD	0.44	<LOD	
56				0.19	0.01	<LOD	0.00	0.00	0.06	<LOD	<LOD	<LOD	0.12	<LOD	
57	9.3603	0.74	0.18	0.30	0.03	<LOD	<LOD	0.00	0.19	<LOD	<LOD	0.01	0.05	<LOD	1.33
58	14.0132	0.85	0.09	0.15	0.02	<LOD	0.00	0.00	0.18	<LOD	<LOD	0.01	0.07	<LOD	1.76
59				0.13	0.02	<LOD	<LOD	0.00	0.07	<LOD		<LOD	0.13	<LOD	
60				0.16	0.01	<LOD	<LOD	0.00	0.05	<LOD	<LOD	<LOD	0.32	<LOD	
61				0.04	0.01	<LOD	0.06	0.01	<LOD	0.00		<LOD	0.03	<LOD	
62	3.4379	2.84	0.03	0.11	0.01	<LOD	0.88	<LOD	0.10	<LOD	<LOD	0.00	0.01	<LOD	0.05
63				0.02	0.01	<LOD	0.86	<LOD	0.05	<LOD	<LOD	0.00	0.00	<LOD	

File #	S	Cl	K2O	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As
64				0.09	0.01	<LOD	0.06	0.01	<LOD	0.00		<LOD	0.03	<LOD	
65				0.03	0.01	<LOD	1.58	<LOD	0.05	<LOD	<LOD	0.00	0.00	<LOD	
66				0.05	0.01	<LOD	0.15	<LOD	0.02	<LOD	<LOD	<LOD	0.01	<LOD	
67				0.12	0.03	<LOD	0.00	0.02	0.18	<LOD		<LOD	0.04	<LOD	
68				0.31	0.01	<LOD	<LOD	0.01	0.11	<LOD		<LOD	0.05	<LOD	
69				0.09	0.01	<LOD	<LOD	0.00	<LOD	0.00	<LOD	<LOD	0.05	<LOD	
70				0.16	0.01	<LOD	<LOD	0.01	<LOD	<LOD	<LOD	<LOD	0.07	<LOD	
71				0.15	0.01	<LOD	0.01	0.01	<LOD	0.01		<LOD	0.04	<LOD	
72				0.19	0.01	<LOD	0.01	0.01	<LOD	0.01	<LOD	<LOD	0.05	<LOD	
73				0.18	0.02	<LOD	<LOD	0.00	0.06	<LOD	<LOD	<LOD	0.04	<LOD	
74				0.29	0.02	<LOD	<LOD	0.01	0.18	<LOD	<LOD	<LOD	0.08	<LOD	
75				0.05	0.01	<LOD	0.04	0.00	<LOD	<LOD	<LOD	<LOD	0.14	<LOD	
76	0.6178			0.03	0.01	<LOD	0.93	<LOD	0.05	<LOD	<LOD	0.00	0.00	<LOD	
77		<LOD	4.33	0.54	0.14	<LOD	<LOD	0.09	1.42	<LOD		0.02	0.06	<LOD	<LOD
78				0.02	0.01	<LOD	2.24	<LOD	0.05	<LOD		0.00	0.01	<LOD	
79				0.02	0.01	<LOD	0.89	<LOD	0.05	<LOD	<LOD	0.00	0.00	<LOD	
80				0.20	0.01	<LOD	<LOD	0.00	0.08	<LOD		<LOD	0.11	<LOD	
81				0.19	0.02	<LOD	<LOD	0.00	0.19	<LOD		<LOD	0.06	<LOD	
82				0.15	0.01	<LOD	<LOD	0.00	0.15	<LOD		<LOD	0.05	<LOD	
83				0.27	0.02	<LOD	<LOD	0.01	0.23	<LOD		<LOD	0.05	<LOD	
84				0.16	0.02	<LOD	<LOD	0.00	0.20	<LOD		<LOD	0.06	<LOD	0.08
85	13.9959			0.13	0.01	<LOD	<LOD	0.01	<LOD	0.01		<LOD	0.03	<LOD	
86		0.91	0.32	0.27	0.01	<LOD	<LOD	0.01	0.15	<LOD		0.00	0.09	<LOD	0.60
87				0.22	0.02	<LOD	0.00	0.00	0.22	<LOD	<LOD	<LOD	0.08	<LOD	
88				0.07	0.01	<LOD	0.59	<LOD	0.07	<LOD		<LOD	0.02	<LOD	
89				0.05	<LOD	<LOD	0.83	<LOD	0.05	<LOD	<LOD	0.00	0.02	<LOD	
90	6.3917			0.02	0.01	<LOD	0.38	0.01	<LOD	<LOD		<LOD	0.01	<LOD	
91		1.01	0.01	0.11	0.01	<LOD	2.57	<LOD	0.10	<LOD	<LOD	0.01	0.02	<LOD	<LOD
92	9.0377			0.05	0.01	<LOD	0.07	<LOD	0.02	<LOD	<LOD	0.00	0.02	<LOD	<LOD
93	5.0452	1.67	0.06	0.15	0.02	<LOD	0.08	<LOD	0.11	<LOD	<LOD	0.01	0.10	<LOD	0.00
94	11.7853	2.56	0.04	0.10	0.02	<LOD	2.73	<LOD	0.37	<LOD	<LOD	0.00	0.07	<LOD	0.02
95		2.66	<LOD	0.06	<LOD	<LOD	0.21	0.02	0.10	<LOD	<LOD	0.00	0.07	<LOD	0.05

File #	S	Cl	K2O	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As
96	14.542			0.09	0.02	<LOD	5.00	<LOD	0.51	<LOD	<LOD	0.01	0.14	<LOD	0.04
97	10.9362	1.07	0.10	0.26	0.02	<LOD	1.65	0.06	0.53	<LOD		0.04	0.37	<LOD	0.05
98	16.0581	3.26	0.08	0.19	0.01	<LOD	2.25	<LOD	0.21	<LOD		0.01	0.03	<LOD	0.04
99	5.3916	3.36	0.04	0.15	0.01	<LOD	0.30	0.02	0.12	<LOD	<LOD	0.01	0.04	<LOD	0.04
100		4.58	0.05	0.14	0.01	<LOD	4.56	<LOD	0.40	<LOD	<LOD	<LOD	1.03	<LOD	<LOD
101	7.2179			0.10	0.04	<LOD	2.74	<LOD	0.40	<LOD	<LOD	0.01	0.07	0.00	
102	16.7706	2.03	0.05	0.39	<LOD	<LOD	1.95	0.01	0.14	<LOD	<LOD	0.00	0.05	<LOD	<LOD
103	4.6717	2.28	0.02	0.07	<LOD	<LOD	0.77	0.03	0.21	<LOD	<LOD	0.01	0.15	<LOD	<LOD
104	6.4478	0.21	0.03	0.85	10.75	<LOD	0.60	0.11	9.86	<LOD	<LOD	0.01	0.99	<LOD	0.24
105		5.05	0.12	0.09	0.01	<LOD	3.36	<LOD	0.29	<LOD	<LOD	0.00	0.10	<LOD	<LOD
106	4.5308			0.11	0.01	<LOD	0.86	<LOD	0.13	<LOD		0.02	0.02	<LOD	0.00
107	5.5555	2.55	0.35	0.12	0.02	<LOD	1.37	<LOD	0.45	<LOD	<LOD	0.01	0.02	<LOD	0.00
108	8.4554	1.41	0.13	0.16	0.01	<LOD	0.69	0.01	0.05	<LOD	<LOD	0.01	0.03	<LOD	0.00
109	13.157	3.33	0.06	0.43	0.02	<LOD	3.20	<LOD	0.26	<LOD	<LOD	0.01	0.01	<LOD	0.00
110	7.0587	3.73	0.02	0.08	0.01	<LOD	0.90	0.03	0.08	<LOD	<LOD	0.03	0.02	0.00	0.01
111	9.0179	2.62	0.04	0.14	0.02	<LOD	2.82	<LOD	0.24	<LOD	<LOD	0.03	0.03	0.00	0.00
112	2.7106	2.04	0.06	0.27	0.02	<LOD	2.07	<LOD	0.27	<LOD	<LOD	0.04	0.05	0.00	0.00
113	13.173	3.82	<LOD	0.08	0.01	<LOD	1.08	<LOD	0.07	<LOD	<LOD	0.01	0.01	<LOD	<LOD
114	6.408	3.84	0.02	0.15	0.01	<LOD	0.41	0.01	0.13	<LOD	<LOD	0.01	0.02	0.00	<LOD
115	12.7857	2.83	0.02	0.08	0.02	<LOD	1.73	<LOD	0.16	<LOD	<LOD	0.01	0.27	<LOD	0.03
116		2.59	<LOD	0.06	0.01	<LOD	0.13	0.01	0.07	<LOD	<LOD	0.02	0.08	<LOD	0.02
117	5.6294			0.08	0.02	<LOD	0.19	<LOD	0.01	<LOD		0.00	0.01	<LOD	
118	9.6622	5.77	0.02	0.16	0.02	<LOD	0.95	<LOD	0.14	<LOD	<LOD	0.00	0.01	<LOD	0.01
119	3.1794	4.91	0.07	0.14	0.03	<LOD	0.44	0.01	0.21	<LOD		0.01	0.02	<LOD	0.02
120	11.0135	2.67	0.03	0.08	0.01	<LOD	3.57	<LOD	0.10	<LOD	<LOD	0.00	0.03	<LOD	0.01
121		2.08	0.01	0.09	0.01	<LOD	1.18	0.04	0.07	<LOD	<LOD	0.01	0.10	<LOD	0.01
122				0.10	0.02	<LOD	1.31	<LOD	0.25	<LOD	<LOD	0.00	<LOD	<LOD	<LOD
123				0.04	0.02	<LOD	0.33	<LOD	0.15	<LOD		0.00	0.00	<LOD	0.01
124	1.9943			0.09	0.02	<LOD	1.27	<LOD	0.25	<LOD	<LOD	0.01	0.01	<LOD	
125	4.7396	1.76	0.04	0.07	0.02	<LOD	0.37	0.01	0.16	<LOD	<LOD	0.00	0.01	<LOD	0.00
126	5.4296	4.18	0.17	0.09	0.03	<LOD	2.02	<LOD	0.43	<LOD	<LOD	0.01	0.02	<LOD	0.00
127	3.2259	3.85	0.03	0.10	0.02	<LOD	1.02	0.02	0.25	<LOD	<LOD	0.01	0.01	<LOD	0.00

File #	S	Cl	K2O	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As
128	4.1728	11.60	0.01	0.19	0.11	<LOD	0.30	<LOD	0.14	<LOD	<LOD	0.01	0.01	<LOD	0.00
129	5.281	10.79	0.02	0.14	0.40	<LOD	0.74	<LOD	0.16	<LOD	<LOD	0.01	0.01	<LOD	0.01
130	14.7856	11.71	0.02	0.09	0.35	<LOD	2.06	<LOD	0.14	<LOD	<LOD	0.00	0.01	<LOD	0.03
131	6.0373	7.40	0.04	0.07	0.37	<LOD	0.17	0.01	0.07	<LOD	<LOD	0.01	0.06	<LOD	0.05
132	18.3994	3.70	0.03	0.10	0.01	<LOD	0.97	<LOD	0.16	<LOD	<LOD	0.01	0.02	<LOD	0.04
133	5.5862	5.11	0.01	0.04	<LOD	<LOD	0.03	0.00	0.07	<LOD	<LOD	0.02	0.06	<LOD	0.04
134	0.0038	3.54	0.04	0.06	0.01	<LOD	0.73	<LOD	0.18	<LOD	<LOD	0.01	0.01	<LOD	0.01
135	13.9208	<LOD	0.00	<LOD	<LOD	0.01	<LOD	<LOD	<LOD	<LOD					
136	8.3402	4.27	0.01	0.05	<LOD	<LOD	0.04	0.00	0.09	<LOD	<LOD	0.01	0.03	<LOD	0.01
137		1.85	<LOD	0.09	0.00	<LOD	0.20	<LOD	0.12	<LOD	<LOD	0.01	0.02	<LOD	0.05
138	6.1757			0.08	<LOD	<LOD	0.57	<LOD	0.04	<LOD	<LOD	<LOD	0.01	<LOD	
139	2.9235	3.24	0.04	0.11	0.01	<LOD	1.39	<LOD	0.11	<LOD	<LOD	0.01	0.03	<LOD	0.00
140		1.16	0.01	0.07	<LOD	<LOD	1.29	<LOD	0.06	<LOD	<LOD	0.02	0.01	0.00	<LOD
141	3.9015			0.08	0.01	<LOD	0.34	0.01	0.02	<LOD	<LOD	<LOD	0.04	<LOD	
142	11.305	3.15	<LOD	0.02	0.00	<LOD	0.47	<LOD	0.02	<LOD	<LOD	0.01	0.01	<LOD	0.01
143	7.1314	1.72	<LOD	0.20	<LOD	<LOD	0.27	<LOD	0.04	<LOD		0.01	0.03	<LOD	0.01
144	9.8527	0.49	<LOD	0.07	<LOD	<LOD	2.80	<LOD	0.03	<LOD	<LOD	0.00	0.02	<LOD	0.00
145		0.58	<LOD	0.39	0.01	<LOD	1.64	<LOD	0.16	<LOD	<LOD	0.01	0.16	<LOD	0.00
146	9.7214			0.49	0.01	<LOD	<LOD	<LOD	0.07	<LOD		<LOD	0.02	<LOD	
147		0.72	0.24	0.50	0.01	<LOD	<LOD	0.00	0.08	<LOD		0.00	0.02	<LOD	
148	9.2076			0.30	0.01	<LOD	<LOD	0.00	0.03	<LOD		<LOD	0.03	<LOD	
149	13.1732	0.47	0.10	0.29	0.01	<LOD	<LOD	0.00	0.05	<LOD		0.00	0.03	<LOD	
150		1.13	0.21	0.31	0.01	<LOD	<LOD	0.00	0.16	<LOD		0.01	0.03	<LOD	0.43
151				0.29	0.01	<LOD	<LOD	<LOD	0.07	<LOD		<LOD	0.06	<LOD	
152	10.0635			0.13	0.01	<LOD	<LOD	<LOD	0.05	<LOD		<LOD	0.03	<LOD	
153	12.068	0.45	0.09	0.28	<LOD	<LOD	<LOD	<LOD	0.12	<LOD		0.01	0.05	<LOD	6.38
154	10.0637	0.96	0.14	0.16	<LOD	<LOD	<LOD	<LOD	0.40	<LOD	<LOD	0.01	0.04	<LOD	2.90
155	7.0749	0.36	0.14	0.21	0.01	<LOD	<LOD	0.00	0.09	<LOD		0.01	0.05	<LOD	7.97
156	7.6041	0.60	1.02	0.78	0.01	<LOD	<LOD	0.00	0.16	<LOD		0.03	0.04	<LOD	1.64
157	10.5003	0.18	0.12	0.18	0.01	<LOD	<LOD	<LOD	0.04	<LOD		0.00	0.04	<LOD	3.42
158	8.3024	0.98	0.09	1.62	<LOD	<LOD	<LOD	<LOD	0.08	<LOD		0.01	0.03	<LOD	11.15
159		0.14	0.06	0.56	<LOD	<LOD	<LOD	<LOD	0.03	<LOD		0.01	0.05	<LOD	4.81

File #	S	Cl	K2O	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As
160				0.45	0.01	< LOD	< LOD	0.02	< LOD	< LOD		< LOD	0.03	< LOD	
161															
162	11.059			0.26	0.01	< LOD	< LOD	0.01	< LOD	< LOD		< LOD	0.05	< LOD	
163	8.3221	1.30	0.05	0.09	< LOD	< LOD	< LOD	< LOD	0.02	< LOD		0.00	0.03	< LOD	1.51
164	9.8879	1.13	0.48	0.20	< LOD	< LOD	< LOD	0.00	0.06	< LOD		0.01	0.05	< LOD	9.42
165	11.7311	0.60	0.83	0.13	0.00	< LOD	< LOD	< LOD	0.04	< LOD		0.01	0.02	< LOD	2.89
166	8.903	0.21	0.12	0.16	< LOD	< LOD	< LOD	0.00	0.06	< LOD		0.01	0.06	< LOD	3.38
167	10.1451	0.24	0.03	0.37	< LOD	< LOD	< LOD	< LOD	0.04	< LOD		0.01	0.04	< LOD	2.49
168	12.5818	0.43	0.05	0.43	< LOD	< LOD	< LOD	< LOD	0.05	< LOD		0.01	0.07	< LOD	2.72
169	13.3837	2.32	0.10	0.08	< LOD	< LOD	< LOD	0.00	0.01	< LOD	< LOD	0.01	0.04	< LOD	0.79
170	12.5734	1.12	0.25	0.28	0.01	< LOD	< LOD	0.01	0.12	< LOD		0.01	0.06	< LOD	6.47
171	11.8137	1.46	0.17	0.20	0.01	< LOD	< LOD	< LOD	0.05	< LOD	< LOD	0.01	0.05	< LOD	3.29
172	9.9139	2.80	0.15	1.10	0.01	< LOD	< LOD	0.01	0.13	< LOD		0.01	0.04	< LOD	2.59
173	11.2871	0.52	0.11	0.63	0.01	< LOD	0.00	0.00	0.08	< LOD		0.01	0.04	< LOD	3.04
174	7.9983	1.07	1.20	0.41	0.02	< LOD	< LOD	0.00	0.23	< LOD		0.01	0.06	< LOD	3.72
175		0.30	1.46	0.46	0.01	< LOD	< LOD	0.01	0.15	< LOD		0.01	0.05	< LOD	13.92
176				0.21	0.00	< LOD	< LOD	0.00	0.01	< LOD		< LOD	0.05	< LOD	
177	7.0753			0.12	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	0.04	< LOD	
178	6.8472	0.52	0.17	0.19	0.01	< LOD	< LOD	< LOD	0.07	< LOD		0.01	0.03	< LOD	6.35
179		0.18	0.09	0.11	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	0.03	< LOD	1.89
180	14.1086			4.34	0.02	< LOD	< LOD	0.00	0.19	< LOD		0.00	0.04	< LOD	
181	11.6253	0.43	0.33	3.84	0.02	< LOD	< LOD	0.00	0.26	< LOD	< LOD	0.01	0.06	< LOD	0.14
182	10.3144	0.36	0.33	1.67	0.01	< LOD	< LOD	0.00	0.13	< LOD		0.00	0.03	< LOD	4.36
183	10.8565	0.11	0.48	1.50	0.02	< LOD	< LOD	0.00	0.22	< LOD		0.01	0.05	< LOD	5.14
184	12.0257	1.32	0.38	0.45	0.03	< LOD	< LOD	0.01	1.48	< LOD	< LOD	0.03	0.39	< LOD	2.80
185		0.51	0.31	0.29	0.01	< LOD	< LOD	0.01	0.16	< LOD	< LOD	0.01	0.04	< LOD	1.76
186	9.6345			2.88	0.02	< LOD	< LOD	0.02	0.41	< LOD		0.01	0.03	< LOD	
187	12.405	0.74	2.06	4.57	0.03	< LOD	< LOD	0.02	0.42	< LOD		0.01	0.04	< LOD	0.06
188		0.54	0.14	0.49	0.01	< LOD	< LOD	0.00	0.17	< LOD		0.00	0.06	< LOD	2.27
189	12.2983			0.36	< LOD	< LOD	< LOD	< LOD	0.13	< LOD		< LOD	0.09	< LOD	
190		0.25	0.09	0.39	0.01	< LOD	< LOD	0.00	0.20	< LOD		0.01	0.10	< LOD	7.84
191	12.2833			0.54	0.03	< LOD	< LOD	0.01	0.12	< LOD		< LOD	0.09	< LOD	

File #	S	Cl	K2O	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As
192	11.7457	0.33	0.13	0.54	0.04	< LOD	< LOD	0.01	0.15	< LOD		0.00	0.08	< LOD	
193	12.5181	0.13	0.10	0.67	0.01	< LOD	< LOD	0.00	0.09	< LOD		0.01	0.09	< LOD	
194	10.8781	0.81	0.17	0.17	0.01	< LOD	< LOD	0.00	0.19	< LOD		0.01	0.02	< LOD	
195	11.5936	0.26	0.15	0.11	0.00	< LOD	< LOD	< LOD	0.06	< LOD		0.00	0.03	< LOD	
196	11.9952	0.67	0.42	0.27	< LOD	< LOD	< LOD	0.00	0.04	< LOD		0.01	0.11	< LOD	
197	12.9842	0.15	0.25	0.10	< LOD	< LOD	< LOD	0.00	0.02	< LOD		0.00	0.05	< LOD	
198	12.5625	0.52	0.22	0.14	0.00	< LOD	< LOD	0.00	0.04	< LOD		< LOD	0.03	< LOD	
199	14.4024	0.21	0.14	0.13	0.00	< LOD	< LOD	0.00	0.02	< LOD		0.00	0.03	< LOD	
200	12.3049	0.95	0.14	0.12	0.00	< LOD	< LOD	< LOD	0.03	< LOD		0.00	0.06	< LOD	
201	10.7522	0.30	0.10	0.13	0.00	< LOD	< LOD	< LOD	0.03	< LOD	< LOD	0.00	0.04	< LOD	
202	12.5067	0.81	0.55	0.12	< LOD	< LOD	< LOD	< LOD	0.09	< LOD	< LOD	0.00	0.03	< LOD	
203	4.3792	0.55	0.26	0.14	0.00	< LOD	< LOD	< LOD	0.05	< LOD		0.00	0.04	< LOD	
204	5.8879	1.47	0.48	0.07	< LOD	< LOD	< LOD	< LOD	0.03	< LOD		0.00	0.01	< LOD	
205		0.98	0.55	0.10	0.00	< LOD	< LOD	< LOD	0.05	< LOD		0.01	0.05	< LOD	
206	3.7826														
207	3.8525	0.19	0.11	0.20	0.01	< LOD	< LOD	0.00	0.13	< LOD	< LOD	0.00	0.03	< LOD	
208	8.0093	0.18	0.12	0.23	0.01	< LOD	< LOD	0.00	0.13	< LOD	< LOD	0.01	0.03	< LOD	
209	10.6593	0.72	0.06	0.13	< LOD	< LOD	< LOD	0.00	0.07	< LOD		0.00	0.03	< LOD	
210		0.71	0.07	0.11	0.00	< LOD	< LOD	< LOD	0.03	< LOD	< LOD	0.01	0.04	< LOD	
211															
212	11.3123														
213	8.8326	0.94	0.22	0.22	0.01	< LOD	< LOD	0.00	0.15	< LOD		0.01	0.04	< LOD	
214	4.9408	0.41	0.16	0.10	0.01	< LOD	< LOD	0.00	0.18	< LOD		0.01	0.08	< LOD	
215	8.0663	0.67	1.81	0.98	0.01	< LOD	< LOD	0.00	0.20	< LOD		0.00	0.03	< LOD	
216	9.8053	0.70	0.28	0.38	0.01	< LOD	< LOD	0.01	0.21	< LOD		0.00	0.05	< LOD	
217	5.9527	0.80	0.26	0.11	0.01	< LOD	< LOD	0.00	0.13	< LOD		0.01	0.03	< LOD	
218	7.9893	0.14	0.46	0.16	0.02	< LOD	< LOD	0.00	0.29	< LOD	< LOD	0.01	0.03	< LOD	
219	6.0197	0.26	0.52	0.35	0.01	< LOD	< LOD	0.01	0.11	< LOD		0.00	0.04	< LOD	
220	9.3885	0.69	0.41	0.35	0.03	< LOD	0.00	0.01	0.29	< LOD		0.02	0.07	< LOD	
221	6.1637	1.34	0.59	0.50	0.02	< LOD	< LOD	0.01	0.16	< LOD		0.10	0.16	< LOD	
222	7.7884	2.95	0.66	0.50	0.10	< LOD	< LOD	0.01	0.85	< LOD	< LOD	0.01	0.03	< LOD	
223	9.7764	0.86	0.15	0.40	0.03	< LOD	< LOD	0.01	0.34	< LOD		0.00	0.04	< LOD	
224		0.65	0.13	0.30	0.02	< LOD	< LOD	0.01	0.25	< LOD		0.00	0.07	< LOD	

File #	Se	Rb	Sr	Zr	Nb	Mo		Rh	Pd	Ag	Cd	Sn	Sb	Te
1	0.00	0.01	0.01	0.02	0.00	< LOD		< LOD			< LOD	< LOD	0.01	< LOD
2	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD
3	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
4	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
5														
6														
7														
8														
9	< LOD	0.01	0.01	0.02	0.00	< LOD		< LOD		< LOD	< LOD	< LOD	0.01	< LOD
10	0.00	< LOD	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
11														
12	0.00	< LOD	0.00	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
13	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
14	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD			< LOD	0.02	< LOD	< LOD
15														
16	< LOD	0.01	0.01	0.02	0.00	< LOD		< LOD			< LOD	< LOD	0.01	< LOD
17														
18														
19														
20	< LOD	0.01	0.01	0.02	0.00	< LOD		< LOD		< LOD	< LOD	< LOD	0.01	< LOD
21	0.00	< LOD	< LOD	< LOD	0.01	0.03		< LOD	0.00	0.04	0.00	0.08	0.02	0.01
22	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
23														
24														
25														
26														
27	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD
28														
29														
30														
31														

File #	Se	Rb	Sr	Zr	Nb	Mo		Rh	Pd	Ag	Cd	Sn	Sb	Te
32														
33														
34														
35	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	0.01	< LOD
36														
37	0.01	< LOD	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	0.04	< LOD
38	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD
39	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD		< LOD	0.01	< LOD	< LOD
40														
41														
42														
43														
44	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
45														
46														
47														
48														
49														
50														
51														
52														
53														
54														
55														
56														
57	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
58	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
59														
60														
61														
62	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
63														

File #	Se	Rb	Sr	Zr	Nb	Mo		Rh	Pd	Ag	Cd	Sn	Sb	Te
64														
65														
66														
67														
68														
69														
70														
71														
72														
73														
74														
75														
76														
77	< LOD	0.01	0.01	0.02	0.00	< LOD		< LOD	< LOD		< LOD	< LOD	0.01	< LOD
78														
79														
80														
81														
82														
83														
84	0.00	0.00	0.00	< LOD	< LOD	0.01		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
85														
86	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
87														
88														
89														
90														
91	0.00	< LOD	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
92	< LOD	< LOD	3.00											
93	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
94	< LOD	0.00	0.00	0.00	0.00	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
95	< LOD	0.00	0.00	< LOD	0.00	< LOD		< LOD	< LOD	< LOD		0.04	< LOD	< LOD

File #	Se	Rb	Sr	Zr	Nb	Mo		Rh	Pd	Ag	Cd	Sn	Sb	Te
96	0.00	0.00	0.00	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
97	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
98	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
99	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
100	0.00	0.00	0.00	0.00	0.00	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
101														
102	< LOD	0.00	0.00	0.00	0.00	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
103	< LOD	0.00	0.00	0.00	0.00	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
104	< LOD	0.00	0.01	0.01	0.01	< LOD		< LOD	< LOD		< LOD	0.03	< LOD	< LOD
105	< LOD	0.00	0.00	0.00	0.00	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
106	0.00	0.00	< LOD	< LOD	< LOD	0.01		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
107	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
108	< LOD	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
109	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.05	< LOD	< LOD
110	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.04	< LOD	< LOD
111	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	0.06	< LOD	< LOD
112	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.04	< LOD	< LOD
113	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
114	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
115	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
116	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.04	< LOD	< LOD
117														
118	< LOD	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
119	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
120	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	0.00	< LOD	< LOD	0.02	< LOD	< LOD
121	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD		0.00	< LOD	0.02	< LOD	< LOD
122	0.00	< LOD	< LOD	< LOD	< LOD			< LOD	< LOD	0.01	< LOD	< LOD	< LOD	< LOD
123	0.00	0.00	< LOD	< LOD	< LOD	0.03		< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
124														
125	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
126	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
127	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	0.00	< LOD	< LOD	0.04	< LOD	< LOD

File #	Se	Rb	Sr	Zr	Nb	Mo		Rh	Pd	Ag	Cd	Sn	Sb	Te
128	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.04	< LOD	< LOD
129	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	0.00	< LOD	< LOD	0.06	< LOD	< LOD
130	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.05	< LOD	< LOD
131	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.04	< LOD	< LOD
132	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD		< LOD	0.05	< LOD	< LOD
133	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	0.00	< LOD	< LOD	0.02	< LOD	< LOD
134	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
135														
136	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	0.04	< LOD	< LOD
137	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD
138														
139	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
140	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
141														
142	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD		< LOD	0.03	< LOD	< LOD
143	0.00	0.00	0.00	< LOD	< LOD	< LOD	< LOD	< LOD			< LOD	< LOD	< LOD	< LOD
144	0.00	0.00	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD			< LOD	< LOD	< LOD	< LOD
145	0.00	0.00	0.00	< LOD	< LOD	< LOD	< LOD	< LOD			< LOD	0.04	< LOD	< LOD
146														
147														
148														
149														
150	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD			< LOD	0.02	< LOD	< LOD
151														
152														
153	0.00	< LOD	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
154	0.00	< LOD	< LOD	0.00	< LOD	< LOD		< LOD	< LOD		< LOD	0.02	< LOD	< LOD
155	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
156	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
157	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
158	0.01	< LOD	0.03	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
159	0.00	< LOD	0.00	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD

File #	Se	Rb	Sr	Zr	Nb	Mo		Rh	Pd	Ag	Cd	Sn	Sb	Te
160														
161														
162														
163	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD
164	0.01	< LOD	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
165	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD		0.01	< LOD	< LOD
166	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
167	0.00	< LOD	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	0.01	< LOD	< LOD
168	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD
169	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
170	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
171	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
172	0.00	0.00	0.00	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
173	0.00	< LOD	0.00	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.02	< LOD	< LOD
174	0.00	0.00	< LOD	< LOD	< LOD	< LOD		< LOD		< LOD	< LOD	0.03	< LOD	< LOD
175	0.01	< LOD	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
176														
177														
178	0.00	< LOD	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
179	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
180														
181	< LOD	0.00	0.07	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
182	0.00	< LOD	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
183	0.00	< LOD	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
184	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
185	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
186														
187	0.00	0.00	0.04	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
188	0.00	0.00	< LOD	0.00	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD
189														
190	0.00	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
191														

File #	Se	Rb	Sr	Zr	Nb	Mo		Rh	Pd	Ag	Cd	Sn	Sb	Te
192														
193														
194														
195														
196														
197														
198														
199														
200														
201														
202														
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219														
220														
221														
222														
223														
224														

File #	Ba	La	Ce	Hf	Ta	W	Pt	Hg	Tl	Pb	Bi	Th	U
1	0.09	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	0.07	< LOD	< LOD	< LOD
2	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.01	< LOD	0.00	< LOD
3	< LOD	< LOD	0.02	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.00	< LOD	0.00	< LOD
4	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	0.00	< LOD	0.00	< LOD
5				< LOD	< LOD				< LOD				
6				< LOD	< LOD				< LOD				
7				< LOD	< LOD				< LOD				
8													
9	0.10	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.08	< LOD	< LOD	< LOD
10	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.04	< LOD	< LOD	< LOD	0.00	< LOD
11				< LOD	< LOD				< LOD				
12	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD	< LOD	0.00	< LOD
13	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.01	< LOD	0.00	< LOD	0.00	< LOD
14	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.00	< LOD	0.00	< LOD
15		< LOD	< LOD	< LOD	3.00								
16	0.09	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	0.08	< LOD	< LOD	< LOD
17				< LOD	< LOD				< LOD				
18				< LOD	< LOD				< LOD				
19				< LOD	< LOD	< LOD	3.00						
20	0.09	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.08	< LOD	< LOD	< LOD
21	0.04	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD
22	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.00	< LOD	0.00	< LOD
23				< LOD	< LOD				< LOD				
24				< LOD	< LOD				< LOD				
25				< LOD	< LOD				< LOD				
26				< LOD	< LOD				< LOD				
27	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.02	< LOD	< LOD	< LOD	0.00	< LOD
28				< LOD	< LOD				< LOD				
29				< LOD	< LOD				< LOD				
30				< LOD	< LOD				< LOD				
31				< LOD	< LOD				< LOD				

File #	Ba	La	Ce	Hf	Ta	W	Pt	Hg	Tl	Pb	Bi	Th	U
32				< LOD	< LOD				< LOD				
33				< LOD	< LOD				< LOD				
34				< LOD	< LOD				< LOD				
35	0.07	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.03	< LOD	< LOD	< LOD	0.01	< LOD
36				< LOD	< LOD	< LOD	3.00						
37	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD		0.06	< LOD	< LOD	< LOD	0.01	< LOD
38	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	0.00	< LOD
39	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.01	< LOD	0.00	< LOD
40				< LOD	< LOD				< LOD				
41				< LOD	< LOD				< LOD				
42				< LOD	< LOD				< LOD				
43				< LOD	< LOD				< LOD				
44	< LOD	< LOD	0.06	< LOD	< LOD	0.01	< LOD		< LOD	0.01	< LOD	< LOD	< LOD
45					< LOD				< LOD				
46					< LOD				< LOD				
47					< LOD				< LOD				
48													
49					< LOD				< LOD				
50					< LOD				< LOD				
51					< LOD				< LOD				
52					< LOD				< LOD				
53					< LOD				< LOD				
54					< LOD				< LOD				
55					< LOD				< LOD				
56					< LOD				< LOD				
57	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.01	< LOD	0.00	< LOD	0.00	< LOD
58	< LOD	< LOD	0.03	< LOD	< LOD	0.02	< LOD	0.01	< LOD	0.00	< LOD	0.00	< LOD
59				< LOD	< LOD				< LOD				
60				< LOD	< LOD				< LOD				
61				< LOD	< LOD				< LOD				
62	< LOD	< LOD	0.03	< LOD	< LOD	0.01	< LOD		< LOD	0.00	< LOD	0.00	< LOD
63				< LOD	< LOD				< LOD				

File #	Ba	La	Ce	Hf	Ta	W	Pt	Hg	Tl	Pb	Bi	Th	U
64				< LOD	< LOD				< LOD				
65				< LOD	< LOD				< LOD				
66				< LOD	< LOD				< LOD				
67				< LOD	< LOD				< LOD				
68				< LOD	< LOD				< LOD				
69				< LOD	< LOD				< LOD				
70				< LOD	< LOD				< LOD				
71				< LOD	< LOD				< LOD				
72				< LOD	< LOD				< LOD				
73				< LOD	< LOD				< LOD				
74				< LOD	< LOD				< LOD				
75				< LOD	< LOD				< LOD				
76				< LOD	< LOD				< LOD				
77	0.11	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.08	< LOD	< LOD	< LOD
78				< LOD	< LOD				< LOD				
79				< LOD	< LOD				< LOD				
80				< LOD	< LOD				< LOD				
81				< LOD	< LOD				< LOD				
82				< LOD	< LOD				< LOD				
83				0.00	< LOD				< LOD				
84	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
85				< LOD	< LOD				< LOD				
86	< LOD	< LOD	0.06	< LOD	< LOD	0.01	< LOD	0.01	< LOD	0.00	< LOD	< LOD	< LOD
87				< LOD	< LOD				< LOD				
88				< LOD	< LOD				< LOD				
89				< LOD	< LOD				< LOD				
90				< LOD	< LOD				< LOD				
91	< LOD	< LOD	0.10	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	0.05	< LOD	< LOD	< LOD
92													
93	< LOD	< LOD	0.36	< LOD	< LOD	0.02	< LOD		< LOD	< LOD	< LOD	< LOD	< LOD
94	< LOD	< LOD	0.09	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.20	< LOD	< LOD	< LOD
95	0.05	< LOD	0.18	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.26	< LOD	< LOD	< LOD

File #	Ba	La	Ce	Hf	Ta	W	Pt	Hg	Tl	Pb	Bi	Th	U
96	<LOD	<LOD	0.03	<LOD	<LOD	0.02	<LOD		<LOD	0.12	<LOD	<LOD	<LOD
97	<LOD	<LOD	0.13	<LOD	<LOD	0.02	<LOD	<LOD	<LOD	0.01	<LOD	<LOD	<LOD
98	<LOD	<LOD	0.20	<LOD	<LOD	0.01	<LOD		<LOD	0.00	<LOD	0.00	<LOD
99	<LOD	<LOD	0.18	<LOD	<LOD	0.01	<LOD	<LOD	<LOD	0.00	<LOD	<LOD	<LOD
100	0.03	<LOD	0.13	<LOD	<LOD	0.03	<LOD	<LOD	<LOD	0.23	<LOD	<LOD	<LOD
101					<LOD				<LOD				
102	0.05	<LOD	0.18	<LOD	<LOD	0.01	<LOD	<LOD	<LOD	0.22	<LOD	<LOD	<LOD
103	0.06	<LOD	0.18	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.55	<LOD	<LOD	<LOD
104	0.15	<LOD	<LOD	0.01	<LOD	<LOD	<LOD		<LOD	1.50	<LOD	<LOD	<LOD
105	0.05	<LOD	0.13	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.36	<LOD	<LOD	<LOD
106	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD		<LOD	0.01	<LOD	<LOD	<LOD
107	<LOD	<LOD	0.18	<LOD	<LOD	0.01	<LOD		<LOD	0.00	<LOD	<LOD	<LOD
108	<LOD	<LOD	0.22	<LOD	<LOD	<LOD	<LOD		<LOD	<LOD	<LOD	<LOD	<LOD
109	<LOD	<LOD	0.23	<LOD	<LOD	0.01	<LOD		<LOD	0.01	<LOD	<LOD	<LOD
110	<LOD	<LOD	0.27	<LOD	<LOD	<LOD	<LOD		<LOD	0.01	<LOD	<LOD	<LOD
111	<LOD	<LOD	0.21	<LOD	<LOD	<LOD	<LOD		<LOD	<LOD	<LOD	<LOD	<LOD
112	<LOD	<LOD	0.22	<LOD	<LOD	<LOD	<LOD		<LOD	0.00	<LOD	<LOD	<LOD
113	<LOD	<LOD	0.16	<LOD	<LOD	0.01	<LOD		<LOD	0.00	<LOD	<LOD	<LOD
114	<LOD	<LOD	0.22	<LOD	<LOD	<LOD	<LOD		<LOD	0.00	<LOD	<LOD	<LOD
115	<LOD	<LOD	0.28	<LOD	<LOD	<LOD	<LOD		<LOD	0.01	<LOD	<LOD	<LOD
116	<LOD	<LOD	0.30	<LOD	<LOD	<LOD	<LOD		<LOD	0.01	<LOD	<LOD	<LOD
117				<LOD	<LOD				<LOD				
118	<LOD	<LOD	0.14	<LOD	<LOD	<LOD	<LOD		<LOD	<LOD	<LOD	0.00	<LOD
119	<LOD	<LOD	0.22	<LOD	<LOD	<LOD	<LOD		<LOD	0.00	<LOD	<LOD	<LOD
120	<LOD	<LOD	0.19	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00	<LOD	0.00	<LOD
121	<LOD	<LOD	0.15	<LOD	<LOD	<LOD	<LOD		<LOD	0.01	<LOD	<LOD	<LOD
122	<LOD	<LOD	0.13	<LOD	<LOD	<LOD	<LOD		<LOD	<LOD	<LOD	<LOD	<LOD
123	<LOD	<LOD	0.05	<LOD	<LOD	<LOD	<LOD		<LOD	<LOD	<LOD	<LOD	<LOD
124				<LOD	<LOD				<LOD				
125	<LOD	<LOD	0.06	<LOD	<LOD	0.01	<LOD	<LOD	<LOD	0.00	<LOD	<LOD	<LOD
126	<LOD	<LOD	0.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00	<LOD	<LOD	<LOD
127	<LOD	<LOD	0.10	<LOD	<LOD	<LOD	<LOD		<LOD	0.00	<LOD	<LOD	<LOD

File #	Ba	La	Ce	Hf	Ta	W	Pt	Hg	Tl	Pb	Bi	Th	U
128	<LOD	<LOD	0.20	<LOD	<LOD	0.01	<LOD	<LOD	<LOD	0.03	<LOD	<LOD	<LOD
129	<LOD	<LOD	0.32	<LOD	<LOD	<LOD	<LOD		<LOD	<LOD	<LOD	<LOD	<LOD
130	<LOD	<LOD	0.30	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00	<LOD
131	<LOD	<LOD	0.27	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.00	<LOD	<LOD	<LOD
132	<LOD	<LOD	0.28	<LOD	<LOD	<LOD	<LOD		<LOD	0.00	<LOD	<LOD	<LOD
133	<LOD	<LOD	0.13	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.12	<LOD	<LOD	<LOD
134	<LOD	<LOD	0.12	<LOD	<LOD	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
135													
136	<LOD	<LOD	0.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.01	<LOD	<LOD	<LOD
137	<LOD	<LOD	0.07	<LOD	<LOD	0.01	<LOD	<LOD	<LOD	0.00	<LOD	<LOD	<LOD
138				<LOD	<LOD				<LOD				
139	<LOD	<LOD	0.07	<LOD	<LOD	0.01	<LOD		<LOD	<LOD	<LOD	<LOD	<LOD
140	<LOD	<LOD	0.17	<LOD	<LOD	0.02	<LOD		<LOD	0.00	<LOD	<LOD	<LOD
141				<LOD	<LOD				<LOD				
142	<LOD	<LOD	0.22	<LOD	<LOD	0.01	<LOD		<LOD	0.00	<LOD	<LOD	<LOD
143	<LOD	<LOD	0.08	<LOD	<LOD	0.01	<LOD		<LOD	0.02	<LOD	<LOD	<LOD
144	<LOD	<LOD	0.14	<LOD	<LOD	0.02	<LOD		<LOD	<LOD	<LOD	0.00	<LOD
145	<LOD	<LOD	0.24	<LOD	<LOD	<LOD	<LOD		<LOD	0.01	<LOD	<LOD	<LOD
146				<LOD	<LOD				<LOD				
147					<LOD				<LOD				
148				<LOD	<LOD				<LOD				
149					<LOD				<LOD				
150	<LOD	<LOD	0.02	<LOD	<LOD	0.01	<LOD	0.05	<LOD	0.01	<LOD	0.00	<LOD
151				<LOD	<LOD				<LOD				
152				<LOD	<LOD				<LOD				
153	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.06	<LOD	0.01	<LOD	0.01	<LOD
154	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.05	<LOD	0.02	<LOD	0.01	<LOD
155	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.10	<LOD	0.01	<LOD	0.00	<LOD
156	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.06	<LOD	0.01	<LOD	0.00	<LOD
157	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.12	<LOD	0.00	<LOD	0.00	<LOD
158	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.03	<LOD	<LOD	<LOD	0.01	<LOD
159	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.04	<LOD	<LOD	<LOD	0.00	<LOD

File #	Ba	La	Ce	Hf	Ta	W	Pt	Hg	Tl	Pb	Bi	Th	U
160				< LOD	< LOD				< LOD				
161													
162				< LOD	< LOD				< LOD				
163	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	0.00	< LOD
164	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.05	< LOD	< LOD	< LOD	0.01	< LOD
165	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD	< LOD	0.01	< LOD
166	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	0.01	< LOD
167	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	0.00	< LOD	0.00	< LOD
168	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.11	< LOD	0.00	< LOD	0.01	< LOD
169	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD	< LOD	< LOD	< LOD	0.00	< LOD
170	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.05	< LOD	0.00	< LOD	0.01	< LOD
171	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.04	< LOD	< LOD	< LOD	0.01	< LOD
172	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.14	< LOD	0.01	< LOD	0.00	< LOD
173	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.10	< LOD	0.01	< LOD	0.00	< LOD
174	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.03	< LOD	0.01	< LOD	0.00	< LOD
175	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.13	< LOD	0.02	< LOD	0.01	< LOD
176				< LOD	< LOD				< LOD				
177				< LOD	< LOD				< LOD				
178	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.05	< LOD	< LOD	< LOD	0.00	< LOD
179	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD	< LOD	0.00	< LOD
180				< LOD	< LOD				< LOD				
181	< LOD	< LOD	0.05	< LOD	< LOD	< LOD	< LOD		< LOD	0.13	< LOD	< LOD	< LOD
182	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.03	< LOD	0.00	< LOD	0.00	< LOD
183	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.03	< LOD	0.01	< LOD	0.00	< LOD
184	< LOD	< LOD	0.06	< LOD	< LOD	< LOD	< LOD	0.03	< LOD	0.00	< LOD	0.00	< LOD
185	< LOD	< LOD	0.05	< LOD	< LOD	0.02	< LOD	0.03	< LOD	0.00	< LOD	0.00	< LOD
186				< LOD	< LOD				< LOD				
187	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.00	< LOD	< LOD	< LOD
188	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	0.00	< LOD
189				< LOD	< LOD				< LOD				
190	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.04	< LOD	< LOD	< LOD	0.01	< LOD
191													

File #	Ba	La	Ce	Hf	Ta	W	Pt	Hg	Tl	Pb	Bi	Th	U
192				< LOD	< LOD				< LOD				
193				Hf	Ta				Tl				
194				< LOD	< LOD				< LOD				
195				< LOD	< LOD				< LOD				
196				< LOD	< LOD				< LOD				
197				< LOD	< LOD				< LOD				
198				< LOD	< LOD				< LOD				
199				< LOD	< LOD				< LOD				
200				< LOD	< LOD				< LOD				
201				< LOD	< LOD				< LOD				
202				Hf	Ta				Tl				
203				< LOD	< LOD				< LOD				
204				Hf	Ta				Tl				
205				< LOD	< LOD				< LOD				
206				< LOD	< LOD				< LOD				
207													
208													
209				< LOD	< LOD				< LOD				
210				Hf	Ta				Tl				
211				Hf	Ta				Tl				
212				< LOD	< LOD				< LOD				
213				Hf	Ta				Tl				
214				< LOD	< LOD				< LOD				
215				< LOD	< LOD				< LOD				
216				< LOD	< LOD				< LOD				
217				< LOD	< LOD				< LOD				
218				Hf	Ta				Tl				
219				Hf	Ta				Tl				
220				< LOD	< LOD				< LOD				
221				< LOD	< LOD				< LOD				
222				Hf	Ta				Tl				
223				Hf	Ta				Tl				
224				< LOD	< LOD				< LOD				

Appendix 11. XRF Ornithology Data

ID	Collection Date & Origin	Spot	Scientific name	MgO	Al2O3	SiO2	P	S	Cl	K2O	Ca	Ti	Cr	Mn	Fe	As	Hg	Pb
86350	1901 (India)	Spot 1	Megalaima australis	< LOD	< LOD	0.96	0.12	10.16	0.17	0.68	0.53	0.019	< LOD	0.004	0.16	0.84	0.009	0.009
86350	1901 (India)	Spot 2	Megalaima australis	< LOD	< LOD	0.34	0.06	11.11	< LOD	0.67	0.52	0.014	< LOD	0.002	0.09	1.54	0.009	0.004
86350	1901 (India)	Spot 3	Megalaima australis	< LOD	< LOD	0.82	0.04	9.04	< LOD	0.28	0.33	0.016	< LOD	0.002	0.10	1.29	< LOD	0.005
70514	16/06/ 1967 (Peru, Los Angeles State University)	Spot 1	Capito niger								0.24	0.012	< LOD	0.003	< LOD			
70514	16/06/ 1967 (Peru, Los Angeles State University)	Spot 2	Capito niger								0.23	0.011	< LOD	0.002	0.01			
70515	24/06/1962 (Peru, Los Angeles State University)	Spot 1	Capito niger auratus								0.18	0.015	< LOD	0.004	0.04			
70513	1968 (Peru, (Los Angeles State University)	spot 1	Capito aurovrens	3.00														
51630	18/01/1956 (Somalia)	Spot 1	Trachyphonus margaritatus	< LOD	< LOD	1.53	0.05	11.78	1.84	0.25	0.58	0.020	< LOD	0.004	0.13	4.14	0.044	< LOD
51630	18/01/1956 (Somalia)	Spot 2	Trachyphonus margaritatus								0.58	0.015	< LOD	0.003	0.11			
51630	18/01/1956 (Somalia)	Spot 3	Trachyphonus margaritatus	< LOD	< LOD	1.02	0.03	6.47	1.46	0.17	0.38	0.016	< LOD	0.002	0.08	2.00	0.019	< LOD
9818	12/8/1951 (Tanzania)	Spot 1	Trachyphonus darnandii usambiro	< LOD	< LOD	1.44	0.08	10.69	1.45	0.39	0.17	0.024	< LOD	0.004	0.19	0.95	0.008	0.001
9818	12/8/1951 (Tanzania)	Spot 2	Trachyphonus darnandii usambiro	< LOD	< LOD	1.57	0.13	12.43	1.47	0.40	0.26	0.022	< LOD	0.004	0.17	1.73	0.013	0.001
9818	12/8/1951 (Tanzania)	Spot 3	Trachyphonus darnandii usambiro								0.17	0.030	< LOD	0.006	0.21			
34543	20/04/1876 (Pemerania, Norwich Castle Museum)	Spot 1: Tummy	Aquila pomarina brehm								0.49	0.009	< LOD	< LOD	0.07			
34543	20/04/1876 (Pemerania, Norwich Castle Museum)	Spot 2: Back	Aquila pomarina brehm	2.21	< LOD	1.05	0.03	9.72	0.72	0.24	0.50	0.011	< LOD	0.002	0.08			
34543	20/04/1876 (Pemerania, Norwich Castle Museum)	Spot 1: Tummy	Aquila pomarina brehm								0.30	0.005	< LOD	0.002	0.03			
34543	20/04/1876 (Pemerania, Norwich Castle Museum)	Spot 2: Back	Aquila pomarina brehm	1.79	< LOD	0.54	0.03	9.21	0.47	0.10	0.29	0.005	< LOD	0.002	0.05			
34530	July 1876 (Scotland, Norwich Castle)	Spot 1: Tummy	Accipiter nisus linn	< LOD	< LOD	0.70	0.09	13.17	1.13	0.21	0.31	0.008	< LOD	0.003	0.16	0.43	0.048	0.008
34530	July 1876 (Scotland, Norwich Castle)	Spot 2: Back	Accipiter nisus linn								0.29	0.005	< LOD	< LOD	0.07			
34532	N.d. (Norfolk, Norwich Castle Museum)	Spot 1: Back	Accipiter nisus linn								0.13	0.006	< LOD	< LOD	0.05			
34532	N.D (Norfolk, Norwich Castle Museum)	Spot 2: Tummy	Accipiter nisus linn	< LOD	< LOD	0.55	0.03	10.06	0.45	0.09	0.28	< LOD	< LOD	< LOD	0.12	6.38	0.058	0.006
34531	N.d. (Northrepps, Norfolk, Norwich Castle Museum)	Spot 1: Tummy	Accipiter nisus linn	< LOD	< LOD	0.48	0.07	12.07	0.96	0.14	0.16	< LOD	< LOD	< LOD	0.40	2.90	0.050	0.019
34531	N.d. (Northrepps, Norfolk, Norwich Castle Museum)	Spot 2: Back	Accipiter nisus linn	< LOD	< LOD	0.40	0.06	10.06	0.36	0.14	0.21	0.007	< LOD	0.003	0.09	7.97	0.099	0.01
34534	1868 (Beirut, Norwich Castle Museum)	Spot 1: Tummy	Sceloporus brevipes (sen)	3.01	< LOD	2.50	0.05	7.07	0.60	1.02	0.78	0.012	< LOD	0.003	0.16	1.64	0.060	0.013
34534	1868 (Beirut, Norwich Castle Museum)	Spot 2: Back	Sceloporus brevipes (sen)	1.57	< LOD	0.45	0.03	7.60	0.18	0.12	0.18	0.006	< LOD	< LOD	0.04	3.42	0.116	0.004
86148	27/08/1891 (Suffolk, UK)	Spot 1: Tummy	Accipiter nisus	< LOD	< LOD	0.33	0.05	10.50	0.98	0.09	1.62	< LOD	< LOD	< LOD	0.08	11.15	0.032	< LOD
86148	27/08/1891 (Suffolk, UK)	Spot 2: Back	Accipiter nisus	8.77	< LOD	0.13	0.04	8.30	0.14	0.06	0.56	< LOD	< LOD	< LOD	0.03	4.81	0.044	< LOD
34528	23/04/1879 (India, British Museum; Norwich Castle Museum)	Spot 1: Tummy	Circus aeruginosus								0.45	0.009	< LOD	0.020	< LOD			

ID	Collection Date & Origin	Spot	Scientific name	MgO	Al2O3	SiO2	P	S	Cl	K2O	Ca	Ti	Cr	Mn	Fe	As	Hg	Pb
34529	12/12/1864(Maunbhoom,British Museum;NorwichCastleMus	Spot 1: Tummy	Circus aeruginosus															
34529	12/12/1864(Maunbhoom,British Museum;NorwichCastleMus	Spot 2: Back	Circus aeruginosus								0.26	0.005	< LOD	0.007	< LOD			
85520	20/12/1897 (Denmark)	Spot 1: Tummy	Buteo lagonus	4.07	< LOD	0.27	0.05	11.06	1.30	0.05	0.09	< LOD	< LOD	< LOD	0.02	1.51	0.012	< LOD
85520	20/12/1897 (Denmark)	Spot 2: Back	Buteo lagonus	< LOD	< LOD	0.67	0.07	8.32	1.13	0.48	0.20	< LOD	< LOD	0.004	0.06	9.42	0.048	< LOD
72401	17/11/1892 (India)	Spot 1: Tummy	(Ardeola Grayii)	< LOD	< LOD	0.39	0.06	9.89	0.60	0.83	0.13	0.004	< LOD	< LOD	0.04	2.89	0.029	< LOD
72401	17/11/1892 (India)	Spot 2: Back	(Ardeola Grayii)	< LOD	< LOD	0.44	0.15	11.73	0.21	0.12	0.16	< LOD	< LOD	0.005	0.06	3.38	0.014	< LOD
72403	19/03/1857 (California, Museum of Zoology Cambridge	Spot 1: Tummy	Butorides Virescens	3.06	< LOD	0.45	0.05	8.90	0.24	0.03	0.37	< LOD	< LOD	< LOD	0.04	2.49	0.022	0.005
72403	19/03/1857 (California, Museum of Zoology Cambridge	Spot 2: Back	Butorides Virescens	2.77	< LOD	0.59	0.05	10.15	0.43	0.05	0.43	< LOD	< LOD	< LOD	0.05	2.72	0.114	0.004
85537	29/05/1896 (Copenhagen Museum of Zoology, Denmark)	Spot 1: Back	RissaTridactyla	< LOD	< LOD	0.37	0.05	12.58	2.32	0.10	0.08	< LOD	< LOD	0.003	0.01	0.79	< LOD	< LOD
85531	01/05/1886 (Fort Cosmos, USA)	Spot 1: Tummy	Limosa Haemastica	< LOD	< LOD	1.29	0.05	13.38	1.12	0.25	0.28	0.006	< LOD	0.006	0.12	6.47	0.051	0.002
85531	01/05/1886 (Fort Cosmos, USA)	Spot 2: Back	Limosa Haemastica	< LOD	< LOD	0.67	0.06	12.57	1.46	0.17	0.20	0.006	< LOD	< LOD	0.05	3.29	0.041	< LOD
72410	19/12/1857 (Museum of Zoology, University of Cambridge,UK	Spot 1:Tummy	Capella delicate	< LOD	< LOD	2.65	0.06	11.81	2.80	0.15	1.10	0.006	< LOD	0.008	0.13	2.59	0.139	0.008
72410	19/12/1857 (UK, Museum of Zoology, University of Cambridge	Spot 2: Back	Capella delicate	2.46	< LOD	1.24	0.03	9.91	0.52	0.11	0.63	0.005	0.00	0.003	0.08	3.04	0.096	0.006
72413	1872 (Museum of Zoology, University of Cambridge, UK)	Spot 1: Tummy	Capella Stenura	< LOD	< LOD	3.14	0.31	11.29	1.07	1.20	0.41	0.016	< LOD	0.005	0.23	3.72	0.034	0.012
72413	1872 (UK, Museum of Zoology, University of Cambridge)	Spot 2: Back	Capella Stenura	< LOD	< LOD	1.24	0.08	8.00	0.30	1.46	0.46	0.010	< LOD	0.007	0.15	13.92	0.128	0.016
73455	19/11/1970 (Malawi)	Spot 1: Tummy	Heterotrogon Vittatum								0.21	0.004	< LOD	0.002	0.01			
73455	19/11/1970 (Malawi)	Spot 2: Back	Heterotrogon Vittatum								0.12	< LOD	< LOD	< LOD	< LOD			
70507	31/1/1961 (Mexico, Los Angeles State Museum)	Spot 1: Tummy	Trogon Citrealus	5.02	< LOD	1.37	0.09	7.08	0.52	0.17	0.19	0.012	< LOD	< LOD	0.07	6.35	0.046	< LOD
70507	31/1/1961 (Mexico, Los Angeles State Museum)	Spot 2: Back	Trogon Citrealus	5.86	< LOD	0.40	0.09	6.85	0.18	0.09	0.11	< LOD	< LOD	< LOD	0.01	1.89	0.016	< LOD
63628	June/1910 (Tunisia,Natural History Museum in Wien,Austria	Spot 1: Tummy	Apus Pallidus								4.34	0.021	< LOD	0.002	0.19			
63628	June/1910 (Tunisia,Natural History Museum in Wien,Austria	Spot 2: Back	Apus Pallidus	2.76	0.381	3.05	0.10	14.11	0.43	0.33	3.84	0.017	< LOD	0.003	0.26	0.14		0.132
95952	17/6/1909 (China, American Museum of Natural History)	Spot 1: Tummy	Apus apus pekinensis	7.55	< LOD	3.29	0.07	11.63	0.36	0.33	1.67	0.014	< LOD	0.002	0.13	4.36	0.033	0.005
95952	17/6/1909 (China, American Museum of Natural History)	Spot 2: Back	Apus apus pekinensis	6.01	< LOD	3.50	0.05	10.31	0.11	0.48	1.50	0.019	< LOD	0.005	0.22	5.14	0.029	0.008
26480	21/06/1955 (Sweden) Malmo Museum of Natural History	Spot 1:Tummy	Apus apus apus	< LOD	< LOD	3.09	0.08	10.86	1.32	0.38	0.45	0.031	< LOD	0.009	1.48	2.80	0.034	0.002
26480	21/06/1955 (Sweden) Malmo Museum of Natural History	Spot 2: Back	Apus apus apus	< LOD	< LOD	2.28	0.05	12.03	0.51	0.31	0.29	0.014	< LOD	0.006	0.16	1.76	0.026	0.002
46580	9/6/1937 (Afghanistan, American Museum of Natural History	Spot 1:Tummy	Apus apus pekinensis								2.88	0.022	< LOD	0.020	0.41			
46580	9/6/1937 (Afghanistan, American Museum of Natural History	Spot 2: Back	Apus apus pekinensis	2.82	< LOD	2.82	0.34	9.63	0.74	2.06	4.57	0.026	< LOD	0.023	0.42	0.06	< LOD	0.002
63948	10/05/1933 (Austria,Natural History Museum in Wien)	Spot 1:Tummy	Apus apus apus	2.49	< LOD	1.11	0.06	12.41	0.54	0.14	0.49	0.011	< LOD	0.004	0.17	2.27	0.011	< LOD
63948	10/05/1933 (Austria,Natural History Museum in Wien)	Spot 2: Back	Apus apus apus								0.36	< LOD	< LOD	< LOD	0.13			
63948	10/05/1933 (Austria,Natural History Museum in Wien)	Spot 3: Back	Apus apus apus	< LOD	< LOD	1.36	0.05	12.30	0.25	0.09	0.39	0.015	< LOD	0.003	0.20	7.84	0.045	< LOD

ID	Collection Date & Origin	Spot	Scientific name	MgO	Al2O3	SiO2	P	S	Cl	K2O	Ca	Ti	Cr	Mn	Fe	As	Hg	Pb
Indian Minah		Spot 1: Tummy	No pesticides only borax								0.54	0.031	< LOD	0.007	0.12	< LOD	< LOD	< LOD
Indian Minah		Spot 2: Tummy	No pesticides only borax	< LOD	< LOD	1.97	0.07	12.28	0.33	0.13	0.54	0.039	< LOD	0.007	0.15	< LOD	< LOD	< LOD
Indian Minah		Spot 3: Tummy	No pesticides only borax	< LOD	< LOD	1.41	0.02	11.75	0.13	0.10	0.67	0.008	< LOD	0.004	0.09	< LOD	< LOD	< LOD
81231	14/06/1965 (Kenya,U.S Nat Museum of the Smithsonian Institution)	Spot 1: Tummy	Chaetura sabini	< LOD	< LOD	0.88	0.06	12.52	0.81	0.17	0.17	0.006	< LOD	0.004	0.19	< LOD	< LOD	< LOD
81231	14/06/1965 (Kenya,U.S Nat Museum of the Smithsonian Institution)	Spot 2: Back	Chaetura sabini	2.05	< LOD	0.30	0.10	10.88	0.26	0.15	0.11	0.003	< LOD	< LOD	0.06	< LOD	< LOD	< LOD
66616	24/5/1941 (USA,Texas Cooperative)	Spot 1: Tummy	Chaetura Pellagica	1.60	< LOD	0.93	0.13	11.59	0.67	0.42	0.27	< LOD	< LOD	0.002	0.04	< LOD	< LOD	< LOD
66616	24/5/1941 (USA,Texas Cooperative)	Spot 2: Back	Chaetura pellagica	1.60	< LOD	0.50	0.07	12.00	0.15	0.25	0.10	< LOD	< LOD	0.002	0.02	< LOD	< LOD	< LOD
77650	11/06/1945 (USA)	Spot 1: Tummy	Cypseloides n.borealis	< LOD	< LOD	1.01	0.06	12.98	0.52	0.22	0.14	0.004	< LOD	0.002	0.04	< LOD	< LOD	< LOD
77650	11/06/1945 (USA)	Spot 2: Back	Cypseloides n.borealis	< LOD	< LOD	0.80	0.05	12.56	0.21	0.14	0.13	0.003	< LOD	0.002	0.02	< LOD	< LOD	< LOD
66845	01/05/1954 (USA, University of Oklahoma, Museum of Zoology)	Spot 1: Tummy	Chaetura pellagica	< LOD	< LOD	1.05	0.11	14.40	0.95	0.14	0.12	0.004	< LOD	< LOD	0.03	< LOD	< LOD	< LOD
66845	01/05/1954 (USA, University of Oklahoma, Museum of Zoology)	Spot 2: Back	Chaetura pellagica	< LOD	< LOD	1.02	0.07	12.30	0.30	0.10	0.13	0.004	< LOD	< LOD	0.03	< LOD	< LOD	< LOD
70505	07/02/1965 (Costa Rica,Los Angeles State University, Museum of Zoology)	Spot 1: Tummy	Chaetura vauxi	< LOD	< LOD	2.75	0.23	10.75	0.81	0.55	0.12	< LOD	< LOD	< LOD	0.09	< LOD	< LOD	< LOD
70505	07/02/1965 (Costa Rica,Los Angeles State University, Museum of Zoology)	Spot 2: Back	Chaetura vauxi	< LOD	< LOD	2.09	0.12	12.51	0.55	0.26	0.14	0.005	< LOD	< LOD	0.05	< LOD	< LOD	< LOD
86715	16 March 1978 (Zimbabwe)	Spot 1: Tummy	Thraskiornis aethiopicus	1.67	< LOD	0.39	0.22	4.38	1.47	0.48	0.07	< LOD	< LOD	< LOD	0.03	< LOD	< LOD	< LOD
86715	16 March 1978 (Zimbabwe)	Spot 2: Back	Thraskiornis aethiopicus	2.80	< LOD	0.65	0.25	5.89	0.98	0.55	0.10	0.004	< LOD	< LOD	0.05	< LOD	< LOD	< LOD
B1221	05/04/1949 (Zambia)	Spot 1: Tummy	Hagedashie hagedash	3.00												< LOD	< LOD	< LOD
92471	16/03/1990 (Zimbabwe)	Spot 1:Tummy	Milvus migrans	1.76	< LOD	1.15	0.06	3.78	0.19	0.11	0.20	0.011	< LOD	0.003	0.13	< LOD	< LOD	< LOD
92471	16/03/1990 (Zimbabwe)	Spot 2: Tummy	Milvus migrans	2.36	< LOD	1.28	0.06	3.85	0.18	0.12	0.23	0.008	< LOD	0.004	0.13	< LOD	< LOD	< LOD
92471	16/03/1990 (Zimbabwe)	Spot 3: Back	Milvus migrans	1.95	< LOD	0.89	0.04	8.01	0.72	0.06	0.13	< LOD	< LOD	0.002	0.07	< LOD	< LOD	< LOD
89233	08/01/1974 (Botswana)	Spot 1: Tummy	Milvus migrans	< LOD	< LOD	0.50	0.04	10.66	0.71	0.07	0.11	0.004	< LOD	< LOD	0.03	< LOD	< LOD	< LOD
89233	08/01/1974 (Botswana)	Spot 2: Back	Milvus migrans	3.00												< LOD	< LOD	< LOD
89233	08/01/1974 (Botswana)	Spot 3: Back	Milvus migrans	3.00												< LOD	< LOD	< LOD
3771	15/2/1950 (Zimbabwe)	Spot 1: Tummy	Platalea alba	< LOD	< LOD	1.45	0.06	11.31	0.94	0.22	0.22	0.010	< LOD	0.003	0.15	< LOD	< LOD	< LOD
3771	15/2/1950 (Zimbabwe)	Spot 2: Back	Platalea alba	2.12	< LOD	2.00	0.04	8.83	0.41	0.16	0.10	0.012	< LOD	0.003	0.18	< LOD	< LOD	< LOD
22127	23/1/1956 (Zimbabwe)	Spot 1:Tummy	Ciconia abdimii	3.41	< LOD	2.78	0.08	4.94	0.67	1.81	0.98	0.013	< LOD	0.003	0.20	< LOD	< LOD	< LOD
22127	23/1/1956 (Zimbabwe)	Spot 2: Back	Ciconia abdimii	1.71	1.465	4.92	0.06	8.07	0.70	0.28	0.38	0.013	< LOD	0.006	0.21	< LOD	< LOD	< LOD
89210	9/12/1982 (Zimbabwe)	Spot 1: Tummy	Ciconia abdimii	< LOD	< LOD	2.33	0.09	9.81	0.80	0.26	0.11	0.006	< LOD	0.002	0.13	< LOD	< LOD	< LOD
93045	06/01/1998 (Zimbabwe)	Spot 1: Tummy	Ciconia abdimii	< LOD	< LOD	5.44	0.14	5.95	0.14	0.46	0.16	0.022	< LOD	0.003	0.29	< LOD	< LOD	< LOD
93045	06/01/1998 (Zimbabwe)	Spot 2: Back	Ciconia abdimii	1.50	< LOD	2.09	0.18	7.99	0.26	0.52	0.35	0.012	< LOD	0.008	0.11	< LOD	< LOD	< LOD
13827	(Zimbabwe)	Spot 1: Tummy	Necrosyrtes monachus(Hooded vulture)	2.97	< LOD	3.06	0.09	6.02	0.69	0.41	0.35	0.034	0.00	0.009	0.29	< LOD	< LOD	< LOD
13827	(Zimbabwe)	Spot 2: Back	Necrosyrtes monachus (Hooded vulture)	3.26	< LOD	1.66	0.08	9.39	1.34	0.59	0.50	0.021	< LOD	0.013	0.16	< LOD	< LOD	< LOD
B827	(Zimbabwe)	Spot 1: Tummy	Pseudo gyps africanus	2.60	< LOD	5.36	0.14	6.16	2.95	0.66	0.50	0.097	< LOD	0.014	0.85	< LOD	< LOD	< LOD
B827	(Zimbabwe)	Spot 2: Back	Pseudo gyps africanus	1.55	< LOD	4.85	0.06	7.79	0.86	0.15	0.40	0.025	< LOD	0.012	0.34	< LOD	< LOD	< LOD
89050	(Zimbabwe)	back	Torgos tracheliotos (Lappet face Vulture)	4.56	< LOD	2.01	0.02	9.78	0.65	0.13	0.30	0.015	< LOD	0.007	0.25	< LOD	< LOD	< LOD

Appendix 12. XRF Skins Data

ID	Collection Date & Origin	Field1	Scientific name	MgO	Al2O3	SiO2	P	S	Cl	K2O	Ca	Ti	Cr	Mn	Fe	As	Hg	Pb
54193	1952 (Zimbabwe)	Spot 1: Skin	Hystrix Africae Australis (Pocupine)								0.07	0.014	0.59	< LOD	0.07			
27413	08/05/1964 (Zimbabwe)	spot 1: Skin	Papio Ursinus								0.05	< LOD	0.83	< LOD	0.05			
27413	08/05/1964 (Zimbabwe)	spot 2: Fur	Papio Ursinus								0.02	0.008	0.38	0.01	< LOD			
27968	29/01/1965 (Kasane, Botswana)	Spot 1: Skin	Papio Ursinus	2.10	< LOD	0.68	0.08	6.39	1.01	0.01	0.11	0.008	2.57	< LOD	0.10	< LOD	< LOD	0.054
27968	29/01/1965 (Kasane, Botswana)	Spot 2: Fur	Papio Ursinus								0.05	0.008	0.07	< LOD	0.02	< LOD		
56396	21/01/1976 (Zimbabwe)	Spot 1: Skin (sc)	Manis temminick	1.60	0.33	3.49	0.08	9.04	1.67	0.06	0.15	0.024	0.08	< LOD	0.11	0.001		< LOD
56293	16/10/1969 (Botswana)	Spot 1: Skin	Hyaena Brunnea	2.14	< LOD	1.49	0.13	5.05	2.56	0.04	0.10	0.015	2.73	< LOD	0.37	0.022	< LOD	0.205
56293	16/10/1969 (Botswana)	Spot 2: Fur	Hyaena Brunnea	1.26	< LOD	0.36	0.07	11.79	2.66	< LOD	0.06	< LOD	0.21	0.02	0.10	0.054	< LOD	0.263
2578	October 1948 (Zambia)	Spot 1: Skin	Panthera Pardus								0.09	0.023	5.00	< LOD	0.51	0.038		0.125
2578	October 1948 (Zambia)	Spot 2: Fur	Panthera Pardus	< LOD	< LOD	0.57	0.09	14.54	1.07	0.10	0.26	0.017	1.65	0.06	0.53	0.054	< LOD	0.012
28766	02/09/1965 (Botswana)	Spot 1: Skin	Panthera Pardus	1.53	< LOD	1.95	0.18	10.94	3.26	0.08	0.19	0.012	2.25	< LOD	0.21	0.041		0.004
28766	02/09/1965 (Botswana)	Spot 2: Fur	Panthera Pardus	1.32	< LOD	0.44	0.11	16.06	3.36	0.04	0.15	0.008	0.30	0.02	0.12	0.043	< LOD	0.003
2648	19/09/1949 (Zambia)	Spot 1: Skin	Lycaon Pictus	1.88	< LOD	1.80	0.20	5.39	4.58	0.05	0.14	0.011	4.56	< LOD	0.40	< LOD	< LOD	0.225
2648	19/09/1949 (Zambia)	Spot 2: Fur	Lycaon Pictus								0.10	0.039	2.74	< LOD	0.40			
33365	12/12/1966 (Zimbabwe)	Spot 1: Skin	Crocota Crocuta	2.00	< LOD	0.46	0.05	7.22	2.03	0.05	0.39	< LOD	1.95	0.01	0.14	< LOD	< LOD	0.221
33365	12/12/1966 (Zimbabwe)	Spot 2: Fur	Crocota Crocuta	< LOD	< LOD	0.33	0.11	16.77	2.28	0.02	0.07	< LOD	0.77	0.03	0.21	< LOD	< LOD	0.548
56740	No date and locality	Spot 1: Skin	Acinonyx Jubatus (cheetah)	1.43	< LOD	1.97	0.12	6.45	5.05	0.12	0.09	0.009	3.36	< LOD	0.29	< LOD	< LOD	0.362
56740	No date and locality	Spot 2: Fur	Acinonyx Jubatus (cheetah)								0.11	0.008	0.86	< LOD	0.13	0.005		0.007
TG255	No date and locality	Spot 1: Skin	Vermilingua (Ant eater)	1.55	< LOD	1.18	0.18	4.53	2.55	0.35	0.12	0.017	1.37	< LOD	0.45	0.002		0.002
TG255	No date and locality	Spot 2: Fur	Vermilingua (Ant eater)	2.65	< LOD	1.08	0.22	5.56	1.41	0.13	0.16	0.015	0.69	0.01	0.05	0.002		< LOD
TNL10	10/12/1968 (Botswana)	Spot 1: Skin	Aepyceros Melampus (Impala)	1.53	< LOD	1.57	0.09	8.46	3.33	0.06	0.43	0.018	3.20	< LOD	0.26	0.003		0.008
TNL10	10/12/1968 (Botswana)	Spot 2: Fur	Aepyceros Melampus (Impala)	< LOD	< LOD	0.28	0.09	13.16	3.73	0.02	0.08	0.010	0.90	0.03	0.08	0.007		0.010
11563	08/11/1962 (Botswana)	Spot 1: Skin	Kobus Vardonii	2.08	< LOD	2.05	0.16	7.06	2.62	0.04	0.14	0.016	2.82	< LOD	0.24	0.005		< LOD
11563	08/11/1962 (Botswana)	Spot 2: Fur	Kobus Vardonii	1.77	< LOD	3.38	0.51	9.02	2.04	0.06	0.27	0.016	2.07	< LOD	0.27	0.004		0.003
MSA67	August 1968 (Botswana)	Spot 1: Skin	Orycteropus Afer	2.50	< LOD	1.05	0.07	2.71	3.82	< LOD	0.08	0.013	1.08	< LOD	0.07	< LOD		0.002
MSA67	August 1968 (Botswana)	Spot 2: Fur	Orycteropus Afer	2.01	< LOD	1.22	0.09	13.17	3.84	0.02	0.15	0.012	0.41	0.01	0.13	< LOD		0.002
TNL4949	09/02/1970 (Botswana)	Spot 1: Skin	Aepyceros Melampus	1.66	< LOD	2.09	0.23	6.41	2.83	0.02	0.08	0.018	1.73	< LOD	0.16	0.026		0.010
TNL4949	09/02/1970 (Botswana)	Spot 2: Fur	Aepyceros Melampus	< LOD	< LOD	0.19	0.10	12.79	2.59	< LOD	0.06	0.009	0.13	0.01	0.07	0.023		0.012
0189	17/01/1965 (Zimbabwe)	Spot 1: Fur	Redunca Arundinum								0.08	0.015	0.19	< LOD	0.01			
nm3365	07/01/1965 (Zimbabwe)	Spot 1: Skin	Redunca (Reed Buck)	2.14	< LOD	0.63	0.05	5.63	5.77	0.02	0.16	0.016	0.95	< LOD	0.14	0.007		< LOD
nm3365	07/01/1965 (Zimbabwe)	Spot 2: Fur	Redunca (Reed Buck)	< LOD	< LOD	1.89	0.04	9.66	4.91	0.07	0.14	0.026	0.44	0.01	0.21	0.017		0.002
59200	06/12/1981 (Botswana)	Spot 1: Skin	Kobus leche	1.59	< LOD	1.06	0.11	3.18	2.67	0.03	0.08	0.013	3.57	< LOD	0.10	0.006	< LOD	0.002
59200	06/12/1981 (Botswana)	Spot 2: Fur	Kobus leche	1.68	< LOD	0.39	0.06	11.01	2.08	0.01	0.09	0.008	1.18	0.04	0.07	0.008		0.006
20539	26/01/1963 (Zimbabwe)	Spot 1: Skin	Potamochoerus Porcus								0.10	0.018	1.31	< LOD	0.25	< LOD		< LOD
20539	26/01/1963 (Zimbabwe)	Spot 2: Fur	Potamochoerus Porcus								0.04	0.019	0.33	< LOD	0.15	0.006		< LOD
25865	October 1962 (Zimbabwe)	Spot 1: Skin	Phacochoerus africanus (warthog)								0.09	0.024	1.27	< LOD	0.25			
25865	October 1962 (Zimbabwe)	Spot 2: Fur	Phacochoerus africanus (warthog)	< LOD	< LOD	2.03	0.07	1.99	1.76	0.04	0.07	0.023	0.37	0.01	0.16	0.001	< LOD	0.002

ID	Collection Date & Origin	Field1	Scientific name	MgO	Al2O3	SiO2	P	S	Cl	K2O	Ca	Ti	Cr	Mn	Fe	As	Hg	Pb
25909	12/04/1963 (Zimbabwe)	Spot 1: Skin	Potamochoerus Porcus	< LOD	1.49	5.46	0.18	4.74	4.18	0.17	0.09	0.034	2.02	< LOD	0.43	0.005	< LOD	0.002
25909	12/04/1963 (Zimbabwe)	Spot 2: Fur	Potamochoerus Porcus	< LOD	< LOD	1.67	0.23	5.43	3.85	0.03	0.10	0.018	1.02	0.02	0.25	0.003		0.003
25923	05/05/1963 (Zimbabwe)	Spot 1: Skin	Phacochoerus africanus (Wartt)	< LOD	< LOD	1.68	0.19	3.23	11.60	0.01	0.19	0.109	0.30	< LOD	0.14	0.002	< LOD	0.032
25923	05/05/1963 (Zimbabwe)	Spot 2: Fur	Phacochoerus africanus (Wartt)	< LOD	< LOD	2.38	0.14	4.17	10.79	0.02	0.14	0.400	0.74	< LOD	0.16	0.005		< LOD
59314	05/11/1981 (Zimbabwe)	Spot 1: Skin	Acinonyx Jubatus (Cheetah)	1.80	< LOD	1.06	0.12	5.28	11.71	0.02	0.09	0.349	2.06	< LOD	0.14	0.033	< LOD	< LOD
59314	05/11/1981 (Zimbabwe)	Spot 2: Fur	Acinonyx Jubatus (Cheetah)	< LOD	< LOD	0.56	0.13	14.79	7.40	0.04	0.07	0.375	0.17	0.01	0.07	0.052	< LOD	0.003
56283	22/04/1973 (Zimbabwe)	Spot 1: Skin	Acinonyx Jubatus (Cheetah)	< LOD	< LOD	1.77	0.12	6.04	3.70	0.03	0.10	0.005	0.97	< LOD	0.16	0.042		0.004
56283	22/04/1973 (Zimbabwe)	Spot 2: Fur	Acinonyx Jubatus (Cheetah)	< LOD	< LOD	0.19	0.10	18.40	5.11	0.01	0.04	< LOD	0.03	0.00	0.07	0.035	< LOD	0.123
5014	21/08/1955 (Zambia)	Spot 1: Skin	Equus Buchelli (Zebra)	< LOD	< LOD	1.87	0.11	5.59	3.54	0.04	0.06	0.007	0.73	< LOD	0.18	0.008	< LOD	< LOD
5014	21/08/1955 (Zambia)	Spot 2: Fur	Equus Buchelli (Zebra)	0.04	< LOD	< LOD	0.03	0.00	< LOD	0.00	< LOD	< LOD	< LOD	< LOD	< LOD			
5014	21/08/1955 (Zambia)	Spot 3: Fur	Equus Buchelli (Zebra)	< LOD	< LOD	0.38	0.10	13.92	4.27	0.01	0.05	< LOD	0.04	0.00	0.09	0.006	< LOD	0.005
54716	29/11/1973 (Zimbabwe)	Spot 1: Fur	Syncerus Caffer (Buffalo)	< LOD	< LOD	0.48	0.06	8.34	1.85	< LOD	0.09	0.004	0.20	< LOD	0.12	0.054	< LOD	0.002
2071	01/11/1949 (Zimbabwe)	Spot 1: Skin	Tragelaphus strepsiceros (Kudu)								0.08	< LOD	0.57	< LOD	0.04			
2071	01/11/1949 (Zimbabwe)	Spot 2: Fur	Tragelaphus strepsiceros (Kudu)	2.63	< LOD	0.99	0.17	6.18	3.24	0.04	0.11	0.006	1.39	< LOD	0.11	0.002		< LOD
21854	29/03/1962 (Zambia)	Spot 1: Skin	Sylvicapra Grimmia (Duiker)	1.66	< LOD	0.91	0.03	2.92	1.16	0.01	0.07	< LOD	1.29	< LOD	0.06	< LOD		0.002
21854	29/03/1962 (Zambia)	Spot 2: Fur	Sylvicapra Grimmia (Duiker)								0.08	0.006	0.34	0.01	0.02			
4044	21/11/1951 (Zambia)	Spot 1: Skin	Oreotragus Oreotragus (Klipspruit)	< LOD	< LOD	0.58	0.05	3.90	3.15	< LOD	0.02	0.004	0.47	< LOD	0.02	0.014		0.003
4044	21/11/1951 (Zambia)	Spot 2: Fur	Oreotragus Oreotragus (Klipspruit)	< LOD	< LOD	< LOD	0.10	11.31	1.72	< LOD	0.20	< LOD	0.27	< LOD	0.04	0.007		0.017
21960	12/07/1962 (Zimbabwe)	Spot 1: Skin	Ourebia Ourebi	< LOD	0.49	0.80	0.06	7.13	0.49	< LOD	0.07	< LOD	2.80	< LOD	0.03	0.001		< LOD
21960	12/07/1962 (Zimbabwe)	Spot 2: Fur	Ourebia Ourebi	< LOD	0.38	1.18	0.06	9.85	0.58	< LOD	0.39	0.014	1.64	< LOD	0.16	0.004		0.007

Appendix 13. XRF Mammalogy Data

ID	Collection Date & Origin	Spot	Scientific name	MgO	Al ₂ O ₃	SiO ₂	P	S	Cl	K ₂ O	Ca	Ti	Cr	Mn	Fe	As	Hg	Pb
68088	7/12/1965 (Botswana)	Spot 1: Skin	Otocyon megalotis								0.0552	0.0095	0.6889	< LOD	0.0327			
68088	7/12/1965 (Botswana)	Spot 2: Fur	Otocyon megalotis	1.844	< LOD	0.5857	0.0912	2.706	0.2762	< LOD	0.0572	0.0077	0.7066	< LOD	0.0336			
4362	10/06/1951 (Botswana)	Spot 1: Skin	Otocyon megalotis								0.087	0.0151	1.9271	< LOD	0.1317			
4771	05/08/1953 (Zimbabwe)	Spot 1: Tummy	Mus musculus								0.2197	0.0062	< LOD	0.0079	0.0815	1.1264	< LOD	< LOD
4771	05/08/1953 (Zimbabwe)	Spot 2: Back	Mus musculus	< LOD	< LOD	1.0128	0.0538	11.8721	1.2096	0.9268	0.4937	0.0284	< LOD	0.0069	0.3576	1.562	0.0097	0.0025
50743	23/12/1976 (Zimbabwe)	Spot 1: Tummy	Mus musculus								0.1518	0.0111	< LOD	0.0027	0.8373			
50743	23/12/1976 (Zimbabwe)	Spot 2: Back	Mus musculus								0.1935	0.0105	< LOD	0.0014	0.0561			
52866	30/03/1949 (Zimbabwe)	Spot 1: Tummy	Mus musculus								0.2863	0.0128	< LOD	0.0028	0.0569			
52866	30/03/1949 (Zimbabwe)	Spot 2: Tummy	Mus musculus								0.3005	0.0127	< LOD	0.0036	0.0498			
52866	30/03/1949 (Zimbabwe)	Spot 3: Back	Mus musculus	3.3102	< LOD	0.4987	0.0729	11.1778	0.7464	1.4822	0.3716	0.019	< LOD	0.0038	0.1255	2.5167	0.0191	< LOD
54079	13/01/1978 (Zimbabwe)	Spot 1: Back	Mus musculus								0.237	0.0095	0.001	0.0021	0.0343			
58132	20/04/1981 (Zimbabwe)	Spot 1: Tummy	Mus musculus								0.1883	0.0645	< LOD	0.0034	0.6914			
58132	20/04/1981 (Zimbabwe)	Spot 2: Back	Mus musculus								0.2188	0.059	< LOD	0.0014	0.2635			
50838	April 1977 (Zimbabwe)	Spot 1: Tummy	Mus musculus								0.0963	0.0106	< LOD	< LOD	0.2315			
50838	April 1977 (Zimbabwe)	Spot 2: Back	Mus musculus								0.1103	0.0097	< LOD	0.0011	0.1533			
77938	23/7/1985 (Zimbabwe)	Spot 1: Tummy	Mus musculus								0.1207	0.0395	0.0021	0.0019	0.5325			
77938	23/7/1985 (Zimbabwe)	Spot 2: Back	Mus musculus								0.2467	0.0095	< LOD	0.001	0.062			
5892	02/06/1956 (Tanzania)	Spot 1: Tummy	Paraxerus cepapi	3.1854	< LOD	0.6042	0.1235	5.3386	0.3223	1.1796	0.5876	0.0363	< LOD	0.0104	0.1365	3.2809	0.0343	< LOD
5892	02/06/1956 (Tanzania)	Spot 2: Back	Paraxerus cepapi								0.203	0.0191	< LOD	0.0024	0.1074			
17675	20/10/1958 (Malawi)	Spot 1: Tummy	Paraxerus cepapi	< LOD	< LOD	0.6276	0.0641	2.2038	0.118	5.2902	0.9269	0.0323	< LOD	0.003	0.1102	21.9031	0.0555	< LOD
17675	20/10/1958 (Malawi)	Spot 2: Back	Paraxerus cepapi	< LOD	< LOD	0.3237	0.1032	7.5622	0.386	1.1405	0.2047	0.0128	< LOD	0.0025	0.1042	1.2623	0.0092	< LOD
3472	8/7/1950 (Zimbabwe)	Spot 1: Tummy	Paraxerus cepapi	< LOD	< LOD	4.6533	0.1604	8.9007	1.0374	0.8195	0.8585	0.0717	0.0062	0.0154	0.8774	1.4499	0.0127	0.0076
3472	8/7/1950 (Zimbabwe)	Spot 2: Back	Paraxerus cepapi								0.2466	0.0163	< LOD	0.0053	0.1424			
4788	11/09/1952 (Zimbabwe)	Spot 1: Tummy	Paraxerus cepapi								0.1087	0.0136	< LOD	0.0025	0.0353			
4788	11/09/1952 (Zimbabwe)	Spot 2: Back	Paraxerus cepapi								0.13	0.0155	0.0026	0.0027	0.112			
69155	10/12/1972 (Zimbabwe)	Spot 1: Tummy	Paraxerus cepapi								0.1058	0.0108	< LOD	0.0017	0.0291			
69155	10/12/1972 (Zimbabwe)	Spot 2: Back	Paraxerus cepapi	2.944	< LOD	0.1665	0.1656	11.3472	0.3836	0.4521	0.1833	0.0125	< LOD	0.0022	0.0779	0.0252		0.0068
26615	10/02/1962 (Botswana)	Spot 1: Skin	Felis lybica								0.0658	0.0118	0.0767	< LOD	0.0302			
55119	24/11/1964 (Botswana)	Spot 1: Skin	Felis lybica								0.0538	0.0103	1.2905	< LOD	0.0922			
55115	10/02/1964 (Botswana)	Spot 1: Skin	Felis lybica								0.023	0.0102	0.967	< LOD	0.0433			
55115	10/02/1964 (Botswana)	Spot 2: Fur	Felis lybica															
55086	20/08/1971 (Zimbabwe)	Spot 1: Skin	Felis lybica								0.1929	0.0109	1.5874	< LOD	0.1132			
55086	20/08/1971 (Zimbabwe)	Spot 2: Fur	Felis lybica								0.0947	0.0084	0.1789	0.0046	0.0173			
55107	14/01/1969 (Zimbabwe)	Spot 1: Skin	Felis lybica								0.1331	0.0248	1.4107	< LOD	0.2203			
55107	14/01/1969 (Zimbabwe)	Spot 2: Fur	Felis lybica								0.1479	0.0116	0.2168	0.0043	0.0559			

ID	Collection Date & Origin	Spot	Scientific name	MgO	Al ₂ O ₃	SiO ₂	P	S	Cl	K ₂ O	Ca	Ti	Cr	Mn	Fe	As	Hg	Pb
55051	17/04/ 1963 (Zimbabwe)	Spot 1: Skin	Felis lybica								0.1727	0.011	3.7229	< LOD	0.0862			
55051	17/04/ 1963 (Zimbabwe)	Spot 2: Fur	Felis lybica								0.1218	0.0149	0.4469	< LOD	0.047			
4760	23/07/1952 (Namibia)	Spot 1: Skin	Cercopithecus aethiops								0.2832	0.0154	< LOD	0.0028	0.2547			
4760	23/07/1952 (Namibia)	Spot 1: Fur	Cercopithecus aethiops								0.1854	0.0118	0.002	0.0016	0.0564			
4411	23/07/1951 (Namibia)	Spot 1: Skin	Cercopithecus aethiops	1.3979	< LOD	1.6944	0.0866	9.3603	0.7368	0.179	0.3036	0.0263	< LOD	0.0033	0.193	1.3297	0.0145	0.0022
4411	23/07/1951 (Namibia)	Spot 2: Fur	Cercopithecus aethiops	< LOD	< LOD	0.4511	0.1037	14.0132	0.8468	0.0923	0.1544	0.0179	0.0027	0.0031	0.1806	1.759	0.0129	0.0033
4405	26/07/1950 (Mozambique)	Spot 1: Skin	Cercopithecus aethiops								0.1288	0.0156	< LOD	0.0029	0.0688			
4405	26/07/1950 (Mozambique)	Spot 2: Fur	Cercopithecus aethiops								0.1557	0.0099	< LOD	0.0025	0.0495			
56488	30/05/1929 (Zimbabwe)	Spot 1: Fur	Aonyx capensis								0.0394	0.0098	0.0626	0.0051	< LOD			
68605	27/02/1976 (Zimbabwe)	Spot 1: Skin	Aonyx capensis	2.5906	< LOD	1.1655	0.1088	3.4379	2.8364	0.0254	0.1091	0.0136	0.8802	< LOD	0.1021	0.0511		0.002
56376	06/09/1979 (Zimbabwe)	Spot 1: Tummy	Aonyx capensis								0.0215	0.0083	0.8575	< LOD	0.051			
56376	06/09/1979 (Zimbabwe)	Spot 2: Back	Aonyx capensis								0.0879	0.0109	0.0593	0.0076	< LOD			
68613	4/4/1978 (Zimbabwe)	Spot 1: Tummy	Aonyx capensis								0.0277	0.0103	1.5849	< LOD	0.0548			
68613	4/4/1978 (Zimbabwe)	Spot 2: Back	Aonyx capensis								0.0502	0.009	0.151	< LOD	0.021			
68685	20/06/1970 (Zimbabwe)	Spot 1: Tummy	Procavia capensis								0.1184	0.0338	0.0039	0.0181	0.1804			
68685	20/06/1970 (Zimbabwe)	Spot 2: Back	Procavia capensis								0.3139	0.0142	< LOD	0.0103	0.1054			
68723	04/06/1970 (Zimbabwe)	Spot 1: Tummy	Procavia capensis								0.0885	0.011	< LOD	0.0039	< LOD			
68723	04/06/1970 (Zimbabwe)	Spot 2: Back	Procavia capensis								0.1567	0.0131	< LOD	0.0066	< LOD			
68728	October/1970 (Zimbabwe)	Spot 1: Tummy	Procavia capensis								0.149	0.01	0.0083	0.0099	< LOD			
68728	October/1970 (Zimbabwe)	Spot 2: Back	Procavia capensis								0.1871	0.0119	0.0075	0.0111	< LOD			
68760	30/06/1967 (Zimbabwe)	Spot 1: Tummy	Procavia capensis								0.1763	0.0194	< LOD	0.0038	0.0631			
68760	30/06/1967 (Zimbabwe)	Spot 2: Back	Procavia capensis								0.2855	0.023	< LOD	0.0125	0.1772			
60585	24/03/1982 (Zimbabwe)	Spot 1: Tummy	Pedetes capensis								0.0539	0.0073	0.0354	0.0041	< LOD			
1318	22/01/1949 (Zambia)	Spot 1: Tummy	Ichneumia albicauda								0.0279	0.0097	0.9284	< LOD	0.0452			
5218	November/1949 (Zambia)	Spot 1: Skin	Ichneumia albicauda								0.0248	0.0125	2.2368	< LOD	0.0511			
1318	22/01/1949 (Zambia)	Spot 2: Back	Ichneumia albicauda								0.0187	0.0097	0.8871	< LOD	0.0491			
4293	09/12/1952 (Zimbabwe)	Spot 1: Tummy	Genetta genetta								0.2011	0.0106	< LOD	0.0024	0.0822			
2081	04/10/1949 (Zimbabwe)	Spot 1: Tummy	Genetta genetta								0.1917	0.0167	< LOD	0.0039	0.1872			
2081	04/10/1949 (Zimbabwe)	Spot 2: Back	Genetta genetta								0.1499	0.0142	< LOD	0.0035	0.1472			
7481	03/03/1958 (Zimbabwe)	Spot 1: Tummy	Genetta genetta								0.2736	0.023	< LOD	0.0082	0.2251			
7481	03/03/1958 (Zimbabwe)	Spot 2: Back	Genetta genetta								0.1572	0.0176	< LOD	0.0038	0.1989	0.0842		< LOD
945	18/03/1949 (Zimbabwe)	Spot 1: Tummy	Genetta genetta								0.1275	0.0142	< LOD	0.0064	< LOD			
945	18/03/1949 (Zimbabwe)	Spot 2: Back	Genetta genetta	1.6151	< LOD	0.5372	0.0868	13.9959	0.9077	0.3208	0.2695	0.0113	< LOD	0.0058	0.1543	0.6035	0.0056	0.0012
27921	26/01/1948 (Zimbabwe)	Spot 1: Tummy	Genetta genetta								0.2198	0.0162	0.0022	0.0041	0.2199			

Appendix 14. Condition Assessments

NAME	ACCESSION NUMBER	LOCATION	COLLECTION DATE & ORIGIN	CONDITION	ASSESSMENT DATE	VISUAL	ASSESSOR
1. Megalaima australis (bird)		86350 Drawer No. 64/2 Ornithology	1901 (India)	Good	Apr-21	✓	Davison Chiwara
2. Capito niger auratus (bird)	70515 (Old A.N 28332)	Drawer No. 64/2 Ornithology	24/06/1962 (Collected from Peru for Los Angeles State Univ)	Good	Apr-21	✓	Davison Chiwara
3. Capito niger (bird)	70514 (Old A.N 62226)	Drawer No. 64/2 Ornithology	16/06/ 1967 (Peru Collected for Los Angeles State University)	Good	2021/04/20	✓	Davison Chiwara
4. Capito aurovrens (bird)	70513(Old A.N 64047)	Drawer No. 64/2 Ornithology	1968 (Peru Collected for Los Angeles State University)	Good	2021/04/20	✓	Davison Chiwara
5. Trachyphonus margaritatus (bird)		51630 Drawer No. 64/2 Ornithology	18/01/1956 (Somalia)	Good	2021/04/20	✓	Davison Chiwara
6. Trachyphonus darnandii usambiro (bird)		9818 Drawer No. 64/2 Ornithology	12/8/1951 (Tanzania)	Good	2021/04/20	✓	Davison Chiwara
7. Trachylaemus purporatus purporatus (bird)	70294 (Old A.N) 29437	Drawer No. 64/2 Ornithology	20/08/1969 (Angola)	Good	20/04/2021	✓	Davison Chiwara
8. Upupa epops (bird)		84781 Drawer No. 50/3 Ornithology	9/4/1958 (Cyprus, British Museum)	Good	2021/04/20	✓	Davison Chiwara
9. Trogon citrealus (bird)	70507 (Old A.N 7152)	Drawer No. 50/3 Ornithology	31/1/1961 (Mexico, Los Angeles State Museum)	Good	2021/04/20	✓	Davison Chiwara
10. Heterotrogon vittatum (bird)		73455 Drawer No. 50/3 Ornithology	19/11/1970 (Malawi)	Good	2021/04/20	✓	Davison Chiwara
11. Apus apus pekinensis (bird)	46580 (Old A.N) 465348	Drawer No.52/3 Ornithology	9/6/1937 (Afghanistan, American Museum of Natural History)	Good	2021/04/20	✓	Davison Chiwara
12. Apus apus pekinensis (bird)	46579 (Old A.N) 95952	Drawer No.52/3 Ornithology	17/6/1909 (China, American Museum of Natural History)	Good	2021/04/20	✓	Davison Chiwara
13. Apus apus apus (bird)		26480 Drawer No.52/3 Ornithology	21/06/1955 (Sweden) Malmo Museum of Natural History	Good	2021/04/20	✓	Davison Chiwara
14. Apus apus apus (bird)	26948/63948	Drawer No.52/3 Ornithology	10/05/1933 (Austria,Natural History Museum in Wien)	Good	2021/04/20	✓	Davison Chiwara
15. Apus pallidus brehmorum hartert (bird)		63628 Drawer No.52/3 Ornithology	June/1910 (Tunisia,Natural History Museum in Wien,Austria)	Good	2021/04/20	✓	Davison Chiwara
16. Chaetura sabini (bird)	81231 (Old A.N.) 1891	Drawer No.52/3 Ornithology	14/06/1965 (Kenya,U.S Nat Museum of the Smithsonian Insti)	Good	2021/04/20	✓	Davison Chiwara
17. Chaetura pelagica (bird)	66845 (Old A.N) 1156	Drawer No.52/3 Ornithology	01/05/1954 (USA, University of Oklahoma, Museum of Zoolog	Good	20/04/2021	✓	Davison Chiwara
18. Chaetura vauxi (bird)	70505 (Old A.N) 34947	Drawer No.52/3 Ornithology	07/02/1965 (Costa Rica,Los Angeles State University, Museun	Good	2021/04/20	✓	Davison Chiwara
19. Chaetura pelagica (bird)	70504 (Old A.N) 62852	Drawer No.52/3 Ornithology	19/10/1966 (USA, Los Angeles State University, Museum of Z	Good	2021/04/20	✓	Davison Chiwara
20. Chaetura pelagica (bird)	66616 (Old A. N) 2570	Drawer No.52/3 Ornithology	24/5/1941 (USA,Texas Cooperative Research)	Good	2021/04/20	✓	Davison Chiwara
21. Cypseloides n.borealis (bird)	77650 (Old A.N) 83665	Drawer No.52/3 Ornithology	11/06/1945 (USA)	Good	2021/04/20	✓	Davison Chiwara
22. Aeronautes soxatalis soxatalis (bird)	70506 (Old A.N) 40084	Drawer No.52/3 Ornithology	01/01/1953 (USA, Los Angels State University, Museum of Zo	Good	2021/04/20	✓	Davison Chiwara
23. Streptoprocne zonaris mexicano (bird)	70503 (Old A.N) 40066	Drawer No.52/3 Ornithology	23/3/1960(Mexico, Los Angels State University, Museum of Z	Good	2021/04/21	✓	Davison Chiwara
24. Athene noctua somaliensis (bird)		51622 Drawer No.52/2 Ornithology	27/02/1955 (Somalia) British Museum	Good	2021/04/21	✓	Davison Chiwara
25. Speotyto cunicularia (bird)	(Old A.N) 205	Drawer No.52/2 Ornithology	09/06/1935 (USA) University of Carlifornia Dept of Zoology	Good	2021/04/21	✓	Davison Chiwara
26. Athene noctua (bird)		86320 Drawer No.52/2 Ornithology	24/02/1963 UK	Good	2021/04/21	✓	Davison Chiwara
27. Platalea alba (bird)		3771 Drawer No.84/2 Ornithology	15/2/1950 (Zimbabwe)	Good	2021/04/21	✓	Davison Chiwara
28. Platalea alba (bird)		3771 Drawer No.84/2 Ornithology	06/04/1949 (Caprivi)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
29. Hagedashie hagedash (bird)	B12. 21	Drawer No.84/2 Ornithology	05/04/1949 (Zambia)	Good	2021/04/21	✓	Davison Chiwara
30. Hagedashie hagedash (bird)		87231 Drawer No.84/2 Ornithology	12/12/1978 (South Africa)	Good	2021/04/21	✓	Davison Chiwara
31. Thraskiornis aethiopicus (bird)		86715 Drawer No.84/2 Ornithology	16 March 1978 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
32. Geronticus calvus (bird)		72499 Drawer No.84/2 Ornithology	27/09/1970 (South Africa)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
33. Ciconia abdimii (bird)		93045 Drawer No.84/2 Ornithology	06/01/1998 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
34. Ciconia abdimii (bird)		92285 Drawer No.84/2 Ornithology	09/01/1989 (Zimbabwe)	Poor(White chemical residues)	2021/04/21	✓	Davison Chiwara
35. Ciconia abdimii (bird)		89210 Drawer No.84/2 Ornithology	9/12/1982 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
36. Ciconia abdimii (bird)		5348 Drawer No.84/2 Ornithology	24/03/1950 (Zambia)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
37. Ciconia abdimii (bird)		22127 Drawer No.84/2 Ornithology	23/1/1956 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
38. Ciconia abdimii (bird)		22127 Drawer No.84/2 Ornithology	Jan/1979 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
39. Milvus migrans (bird)		92471 Drawer No.82/2 Ornithology	16/03/1990 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
40. Milvus migrans (bird)		89233 Drawer No.82/2 Ornithology	08/01/1974 (Botswana)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
41. Polyboroides radiatus (bird)		21329 Drawer No.82/2 Ornithology	01/03/1955 (Zambia)	Good	2021/04/21	✓	Davison Chiwara
42. Polyboroides typus (bird)		55761 Drawer No.82/2 Ornithology	24/8/1964 (Zimbabwe)	Good	2021/04/21	✓	Davison Chiwara
43. Polyboroides typus (bird)		26344 Drawer No.82/2 Ornithology	01/06/1956 (Zimbabwe)	Good	2021/04/21	✓	Davison Chiwara
44. Polyboroides typus (bird)		84581 Drawer No.82/2 Ornithology	29/09/1975 (Zimbabwe)	Good	2021/04/21	✓	Davison Chiwara
45. Circaetus pectoralis (bird)		87229 Drawer No.82/2 Ornithology	10/04/1924 (Zimbabwe)	Good	2021/04/21	✓	Davison Chiwara
46. Polemaetus bellicosus (bird)		27203 Drawer No.82/2 Ornithology	30/08/1956 (Zimbabwe)	Good	2021/04/21	✓	Davison Chiwara
47. Polemaetus bellicosus (bird)	B8.1	Drawer No.82/2 Ornithology	20/08/1949 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
48. Polemaetus bellicosus (bird)		831 Drawer No.82/2 Ornithology	14/2/1950 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
49. Polemaetus bellicosus (bird)	No number	Drawer No.82/2 Ornithology	14/6/1907 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
50. Circaetus gallicus (bird)	No number	Drawer No.82/2 Ornithology	13/11/1991 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
51. Circaetus pectoralis (bird)		85248 Drawer No.82/2 Ornithology	22/11/1976 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
52. Circaetus pectoralis smith (bird)	92587 (Old A.No) 369 (QVM)	Drawer No.82/2 Ornithology	28/09/1952 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
53. Circaetus pectoralis (bird)		87830 Drawer No.82/2 Ornithology	31/03/1980 (Zimbabwe)	Good (White chemical residues)	2021/04/21	✓	Davison Chiwara
54. Circaetus pectoralis (bird)		89072 Drawer No.81/2 Ornithology	03/12/1984 (Zimbabwe)	Poor(White chemical residues)	2021/04/21	✓	Davison Chiwara

NAME	ACCESSION NUMBER	LOCATION	COLLECTION DATE & ORIGIN	CONDITION	ASSESSMENT DATE	VISUAL	ASSESSOR
55. Otocyon megalotis (mammal)		68088 Cabinet No.62, Drawer No.(a)	7/12/1965 (Botswana)	Good	2021/04/22	✓	Davison Chiwara
56. Otocyon megalotis (mammal)		4362 Cabinet No.62, Drawer No. (a)	10/06/1951 (Botswana)	Poor (Structural weaknesses, hole)	2021/04/22	✓	Davison Chiwara
57. Otocyon megalotis (mammal)		68103 Cabinet No.62, Drawer No.(a)	28/8/1968 (Botswana)	Good	2021/04/22	✓	Davison Chiwara
58. Otocyon megalotis (mammal)		68099 Cabinet No.62, Drawer No.(a)	14/04/1967 (Botswana)	Good	2021/04/22	✓	Davison Chiwara
59. Myotis welwitschi (mammal)		80464 Cabinet No.1566, Drawer No.(a)	01/07/1986 (Zimbabwe)	Poor (Structural weaknesses, fragi	2021/04/22	✓	Davison Chiwara
60. Myotis welwitschi (mammal)		57880 Cabinet No.1566, Drawer No.(i)	25/09/1939 (Zimbabwe)	Poor (structural weaknesses)	2021/04/22	✓	Davison Chiwara
61. Myotis welwitschi (mammal)		80373 Cabinet No.1566, Drawer No.(a)	05/07/1986 (Zimbabwe)	Poor	2021/04/22	✓	Davison Chiwara
62. Myotis welwitschi (mammal)		56442 Cabinet No.1566, Drawer No.(a)	07/05/1979 (Zimbabwe)	Poor	2021/04/22	✓	Davison Chiwara
63. Pipistrellus nanus (mammal)		10217 Cabinet No.1566, Drawer No.(g)	14/06/1959 (Zambia)	Good	2021/04/22	✓	Davison Chiwara
64. Mus musculus (mammal)		4771 Cabinet No. 1597 Drawer No. (o)	05/08/1953 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
65. Mus musculus (mammal)		50743 Cabinet No. 1597 Drawer No. (i)	23/12/1976 (Zimbabwe)	Poor	2021/04/22	✓	Davison Chiwara
66. Mus musculus (mammal)		52866 Cabinet No. 1597 Drawer No. (i)	30/03/1949 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
67. Mus musculus (mammal)		54079 Cabinet No. 1597 Drawer No. (i)	13/01/1978 (Zimbabwe)	Poor	2021/04/22	✓	Davison Chiwara
68. Mus musculus (mammal)		58132 Cabinet No. 1597 Drawer No. (i)	20/04/1981 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
69. Mus musculus (mammal)		50838 Cabinet No. 1597 Drawer No. (i)	April 1977 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
70. Mus musculus (mammal)		77938 Cabinet No. 1597 Drawer No. (i)	23/7/1985 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
71. Paraxerus cepapi (mammal)		5892 Cabinet No. 2252, Drawer No.(o)	02/06/1956 (Tanzania)	Good	2021/04/22	✓	Davison Chiwara
72. Paraxerus cepapi (mammal)		17675 Cabinet No. 2252 Drawer No. (o)	20/10/1958 (Malawi)	Good	2021/04/22	✓	Davison Chiwara
73. Paraxerus cepapi (mammal)		3472 Cabinet No. 2252 Drawer No. (i)	8/7/1950 (Zimbabwe)	Good (White chemical residues)	2021/04/22	✓	Davison Chiwara
74. Paraxerus cepapi (mammal)		4788 Cabinet No. 2252 Drawer No. (i)	11/09/1952 (Zimbabwe)	Good (White chemical residues)	2021/04/22	✓	Davison Chiwara
75. Paraxerus cepapi (mammal)		69155 Cabinet No. 2252 Drawer No. (i)	10/12/1972 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
76. Felis lybica (mammal)		55107 Cabinet No. 69b Drawer No. (c)	14/01/1969 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
77. Felis lybica (mammal)		55051 Cabinet No. 69b Drawer No. (c)	17/04/ 1963 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
78. Felis lybica (mammal)		55086 Cabinet No. 69b Drawer No. (i)	20/08/1971 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
79. Felis lybica (mammal)		55080 Cabinet No. 69b Drawer No. (i)	24/10/1963 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
80. Felis lybica (mammal)		55119 Cabinet No. 69b Drawer No. (c)	24/11/1964 (Botswana)	Good	2021/04/22	✓	Davison Chiwara
81. Felis lybica (mammal)		55115 Cabinet No. 69b Drawer No. (c)	10/02/1964 (Botswana)	Good	2021/04/22	✓	Davison Chiwara
82. Felis lybica (mammal)		26615 Cabinet No. 69b Drawer No. (c)	10/02/1962 (Botswana)	Poor (Detaching parts)	2021/04/22	✓	Davison Chiwara
83. Cercopithecus aethiops (mammal)		4760 Cabinet No.78c Drawer No. (i)	23/07/1952 (Namibia)	Good	2021/04/22	✓	Davison Chiwara
84. Cercopithecus aethiops (mammal)		4411 Cabinet No.78c Drawer No. (i)	23/07/1951 (Namibia)	Good	2021/04/22	✓	Davison Chiwara
85. Cercopithecus aethiops (mammal)		4405 Cabinet No.78c Drawer No. (i)	26/07/1950 (Mozambique)	Good	2021/04/22	✓	Davison Chiwara
86. Aonyx capensis (mammal)		56376 Cabinet No. 2267 Drawer No.(i)	06/09/1979 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
87. Aonyx capensis (mammal)		68613 Cabinet No. 2267 Drawer No.(i)	4/4/1978 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
88. Aonyx capensis (mammal)		56488 Cabinet No. 2267 Drawer No.(i)	30/05/1929 (Zimbabwe)	Good (White chemical residues)	2021/04/22	✓	Davison Chiwara
89. Aonyx capensis (mammal)		68605 Cabinet No. 2267 Drawer No.(i)	27/02/1976 (Zimbabwe)	Poor (Detaching parts)	2021/04/22	✓	Davison Chiwara
90. Procapia capensis (mammal)		68760 Cabinet No. 76b Drawer No. (i)	30/06/1967 (Zimbabwe)	Good (White chemical residues)	2021/04/22	✓	Davison Chiwara
91. Procapia capensis (mammal)		68728 Cabinet No. 76b Drawer No. (i)	October/1970 (Zimbabwe)	Good (White chemical residues)	2021/04/22	✓	Davison Chiwara
92. Procapia capensis (mammal)		68723 Cabinet No. 76b Drawer No. (i)	04/06/1970 (Zimbabwe)	Good (White chemical residues)	2021/04/22	✓	Davison Chiwara
93. Procapia capensis (mammal)		68685 Drawer No.76b. Mammalogy	20/06/1970 (Zimbabwe)	Good (White chemical residues)	2021/04/22	✓	Davison Chiwara
94. Pedetes capensis (mammal)		60585 Cabinet No. 86c Drawer No. (i)	24/03/1982 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
95. Lepus sasaensis (mammal)		80127 Cabinet No. 89c Drawer No. (c)	14/12/1985 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
96. Genetta genetta (mammal)		4293 Cabinet No. 2182 Drawer No. (i)	09/12/1952 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
97. Genetta genetta (mammal)		2081 Cabinet No. 2182 Drawer No. (i)	04/10/1949 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
98. Genetta genetta (mammal)		7481 Cabinet No. 2182 Drawer No. (i)	03/03/1958 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
99. Genetta genetta (mammal)		945 Cabinet No. 2182 Drawer No. (i)	18/03/1949 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
100. Genetta genetta (mammal)		27921 Cabinet No. 2182 Drawer No. (i)	26/01/1948 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
101. Genetta genetta (mammal)		29410 Cabinet No. 2182 Drawer No. (i)	30/08/1991 (Zimbabwe)	Good	2021/04/22	✓	Davison Chiwara
102. Ichneumia albicauda (mammal)		5218 Cabinet No. 2184 Drawer No.	November/1949 (Zambia)	Good	2021/04/22	✓	Davison Chiwara
103. Ichneumia albicauda (mammal)		1318 Cabinet No. 2184 Drawer No.	22/01/1949 (Zambia)	Good	2021/04/22	✓	Davison Chiwara
104. Aquila pomarina brehm (bird)		34543 Drawer No. 81/2 Ornithology	20/04/1876 (from Pomerania for Norwich Castle Museum)	Good	2021/04/23	✓	Davison Chiwara
105. Aquila clanga pall (bird)		34542 Drawer No. 81/2 Ornithology	No Date (from India for Norwich Castle Museum)	Good	2021/04/23	✓	Davison Chiwara
106. Aquila clanga pall (bird)	34541 (Old A. No) 305	Drawer No. 81/2 Ornithology	No Date (from Norwich Castle Museum, UK)	Good	2021/04/23	✓	Davison Chiwara
107. Nisaeus fasciatus (bird)	34536 (Old A. No) 362	Drawer No. 81/2 Ornithology	No Date (from India for Norwich Castle Museum, UK)	Good	2021/04/23	✓	Davison Chiwara
108. Aquila albicans ripp (bird)	34538 (Old A.No) 285	Drawer No. 81/2 Ornithology	No Date (from Abbyssinia for Norwich Castle Museum, UK)	Good	2021/04/23	✓	Davison Chiwara
109. Aquila albicans ripp (bird)	34539 (Old A. No) 283	Drawer No. 81/2 Ornithology	No Date (from Denz, schoa for Norwich Castle Museum, UK)	Good	2021/04/23	✓	Davison Chiwara

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110. Aquila mogilnic (bird)	34540 (Old A. No) 239	Drawer No. 81/2 Ornithology	No Date (from Northern India, Norwich Castle Museum, UK)	Good	2021/04/23	✓	Davison Chiwara
111. Accipiter nisus linn (bird)	34531 (Old A.No) 2817	Drawer No. 73/2 Ornithology	N.D.from Northrepps,Norfolk U.K , Norwich Castle Museum	Good	2021/04/23	✓	Davison Chiwara
112. Accipiter nisus linn (bird)	34530 (Old A. No) 2843	Drawer No. 73/2 Ornithology	July 1876 (From Scotland, for Norwich Castle Museum	Good	2021/04/23	✓	Davison Chiwara
113. Accipiter nisus linn (bird)	34533 (Old A. No) 2875A	Drawer No. 73/2 Ornithology	No date (from Norfolk for Norwich Castle Museum)	Good	2021/04/23	✓	Davison Chiwara
114. Accipiter nisus linn (bird)	34532 (Old A. No) 2819	Drawer No. 73/2 Ornithology	No date (from Norfolk for Norwich Castle Museum)	Good	2021/04/23	✓	Davison Chiwara
115. Sceloporias brevipes (sen) (bird)	34534 (Old A. No) 3112	Drawer No. 73/2 Ornithology	1868 (From Beirut for Norwich Castle Museum)	Good	2021/04/23	✓	Davison Chiwara
116. Accipiter cooperi (bird)	67690 (Old A. No) 1822C	Drawer No. 73/2 Ornithology	3/6/1961 (from Tallah Assee,Florida Florida State University	Good	2021/04/23	✓	Davison Chiwara
117. Accipiter nisus (bird)		86148 Drawer No. 73/2 Ornithology	27/08/1891 (From Suffolk, UK)	Good	2021/04/23	✓	Davison Chiwara
118. Aerospiga tachiro (bird)	B8-22	Drawer No. 73/2 Ornithology	26/06/1949 (Zambezi Valley, Zimbabwe)	Good	2021/04/23	✓	Davison Chiwara
119. Asipita ovampensis (bird)		93047 Drawer No. 73/2 Ornithology	June 1997 (Zimbabwe)	Good	2021/04/23	✓	Davison Chiwara
120. Asipita ovampensis (bird)		91927 Drawer No. 73/2 Ornithology	5/10/1942 (Zimbabwe)	Good	2021/04/23	✓	Davison Chiwara
121. Asipita ovampensis (bird)		91925 Drawer No. 73/2 Ornithology	03/07/1944 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
122. Asipita ovampensis (bird)		91926 Drawer No. 73/2 Ornithology	2/2/1942 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
123. Circus aeruginosus (bird)	34527 (Old A.No) 3608	Drawer No. 73/1 Ornithology	No Date (from India for Norwich Castle Museum, UK)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
124. Circus aeruginosus (bird)	34528 (Old A.No) 3622	Drawer No. 73/1 Ornithology	23/04/1879(from India, Brtish Museum,Norwich Castle Mus	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
125. Circus aeruginosus (bird)	34529 (Old A. No) 3525	Drawer No. 73/1 Ornithology	12/12/1864(Maunbhoom,British Museum;NorwichCastleMus	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
126. Accipiter Ovampensis (bird)		93047 Drawer No. 73/1 Ornithology	01/04/1997 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
127. Buteo lagonus (bird)	85520 (Old A. No) 48442	Drawer No. 73/1 Ornithology	20/12/1897 (Denmark)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
128. Arucedu cuculoides (bird)		89220 Drawer No. 73/1 Ornithology	27/08/1983 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
129. Anas penelope (bird)		86110 Drawer No. 71/3 Ornithology	07/02/1933 (UK)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
130. Bucephala clangula (bird)		86128 Drawer No. 71/3 Ornithology	10/01/1907 (UK)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
131. Aythya ferina (bird)		86126 Drawer No. 71/3 Ornithology	02/02/1922 (UK)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
132. Aythya fuligula (bird)		86127 Drawer No. 71/3 Ornithology	26/06/1922 (UK)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
133. Ixobrychus minutus (bird)		86127 Drawer No. 71/3 Ornithology	14/02/1939 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
134. Ixobrychus minutus payesi (bird)		86127 Drawer No. 70/2 Ornithology	01/12/1932 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
135. Ardeola grayii (bird)		72401 Drawer No. 70/2 Ornithology	17/11/1892 (India)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
136. Butorides virescens (bird)		72403 Drawer No. 70/2 Ornithology	19/03/1857 (from California, Museum of Zoology Cambridge	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
137. Accipiter tachiro (bird)		90785 Drawer No. 73/3 Ornithology	03/03/1986 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
138. Melierix gabar (bird)	B823	Drawer No. 74/1 Ornithology	23/09/1917 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
139. Elanus caeruleus (bird)		91603 Drawer No. 74/2 Ornithology	21/02/1988 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
140. Kaupifalco monogrammicus meridionalus (B8,15		Drawer No. 74/3 Ornithology	14/7/1947 (Zimbabwe)	Good (White chemical residues)	2021/04/23	✓	Davison Chiwara
141. Larus ridibundus (bird)		86276 Drawer No. 16/2 Ornithology	17/01/1940 (Norwich, UK)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
142. Larus ridibundus (bird)		85536 Drawer No. 16/2 Ornithology	18/12/1926 (Copenhagen, Denmark)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
143. Larus canus (bird)		85534 Drawer No. 16/2 Ornithology	04/06/1920 (Museum of Copenhagen, Denmark)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
144. Rissa tridactyla (bird)		85537 Drawer No. 16/2 Ornithology	29/05/1896 (Copenhagen Museum of Zoology, Denmark)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
145. Larus minutus (bird)		85535 Drawer No. 16/2 Ornithology	19/08/1936 (Copenhagen Museum of Zoology, Denmark)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
146. Larus ridibundus (bird)		80465 Drawer No. 16/2 Ornithology	14/04/1924 (Copenhagen Museum of Zoology, Denmark)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
147. Larus ridibundus (bird)		80464 Drawer No. 16/2 Ornithology	14/05/1969 (Copenhagen Museum of Zoology, Denmark)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
148. Limosa lapponica (bird)		86264 Drawer No. 13/2 Ornithology	13/05/1902 (Norfolk, UK)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
149. Limosa lapponica (bird)		85531 Drawer No. 13/2 Ornithology	12/05/1902 (Copenhagen Museum of Zoology, Denmark)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
150. Limosa haemastica (bird)		85531 Drawer No. 13/2 Ornithology	01/05/1886 (Fort Cosmos, USA)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
151. Limosa limosa limosa (bird)		85530 Drawer No. 13/2 Ornithology	27/05/1912 (Zoological Museum, Copenhagen Denmark)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
152. Limosa limosa (bird)	(Old A.No) 19	Drawer No. 13/2 Ornithology	15/12/1869 (From the British Museum)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
153. Capela media (bird)		10813 Drawer No. 14/3 Ornithology	01/01/1949 (Zimbabwe)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
154. Gallinago media (bird)		86251 Drawer No. 14/3 Ornithology	20/04/1926 (Italy)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
155. Capella stenura (bird)		72413 Drawer No. 14/3 Ornithology	1872 (Museum of Zoology, University of Cambridge, UK)	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
156. Capella delicate (bird)		72410 Drawer No. 14/3 Ornithology	19/12/1857 (Museum of Zoology, University of Cambridge,UK	Good (White chemical residues)	2021/04/24	✓	Davison Chiwara
157. Hypotaenidia phillippensis (bird)		88008 Drawer No. 8/2 Ornithology	17/10/1977 (Lugarno, Sydney, Australia)	Good	2021/04/24	✓	Davison Chiwara
158. Hypotaenidia phillippensis (bird)		88009 Drawer No. 8/2 Ornithology	12/11/1972 (Sydney, Australia)	Good	2021/04/24	✓	Davison Chiwara
159. Rallus limicola (bird)		92557 Drawer No. 8/2 Ornithology	17/05/1952 (Arcata, California, USA)	Good	2021/04/24	✓	Davison Chiwara
160. Rallus aquaticus (bird)		85523 Drawer No. 8/2 Ornithology	06/04/1920 (Zoology Museum, Copenhagen, Denmark)	Good	2021/04/24	✓	Davison Chiwara
161. Lanius minor minor (bird)		66602 Drawer No. 34/3 Ornithology	28/08/1909 (Austria)	Good	2021/04/24	✓	Davison Chiwara
162. Lanius minor minor (bird)		66601 Drawer No. 34/3 Ornithology	14/05/1961 (Austria)	Good	2021/04/24	✓	Davison Chiwara
163. Falco peregrinus (bird)		8615 Drawer No. 6/4 Ornithology	September 1905 (Austria)	Good	2021/04/24	✓	Davison Chiwara
164. Falco peregrinus (bird)		86173 Drawer No. 6/4 Ornithology	4/3/1926 (UK)	Good	2021/04/24	✓	Davison Chiwara

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165. Falco peregrinus calidus (bird)		92549 Drawer No. 6/4 Ornithology	1951 (Sudan)	Good	2021/04/24	✓	Davison Chiwara
166. Falco peregrinus (bird)		86159 Drawer No. 6/4 Ornithology	31/01/1936 (UK)	Good	2021/04/24	✓	Davison Chiwara
167. Bubulcus ibis (bird)		88072 Drawer No. 79/2 Ornithology	12/01/1981 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
168. Bubulcus ibis (bird)		84188 Drawer No. 79/2 Ornithology	9/4/1975 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
169. Ardeola ibis (bird)		73784 Drawer No. 79/2 Ornithology	13/12/1969 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
170. Nycticorax leuconotus (bird)		42216 Drawer No. 79/2 Ornithology	12/10/1959 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
171. Nycticorax leuconotus (bird)		42216 Drawer No. 79/2 Ornithology	12/10/1959 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
172. Lissotis melanogaster (bird)		28422 Drawer No. 78/2 Ornithology	27/06/1956 (Zambia)	GoodGood (White chemical resid	2021/08/09	✓	Davison Chiwara
173. Lissotis melanogaster (bird)		73598 Drawer No. 78/2 Ornithology	02/02/1970 (Botswana)	GoodGood (White chemical resid	2021/08/09	✓	Davison Chiwara
174. Lissotis melanogaster (bird)		93360 Drawer No. 78/2 Ornithology	13/06/2013 (Zimbabwe)	GoodGood (White chemical resid	2021/08/09	✓	Davison Chiwara
175. Lissotis melanogaster melanogaster (bird)		16573 Drawer No. 78/2 Ornithology	16/08/1952 (Botswana)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
176. Lophotis melanogaster (bird)		80526 Drawer No. 78/2 Ornithology	07/12/1973 (Botswana)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
177. Egretta Alba melanorhynca (bird)		5766 Drawer No. 79/1 Ornithology	27/04/1951 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
178. Casmerodius albus (bird)		83100 Drawer No. 79/1 Ornithology	30/01/1970 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
179. Egretta alba (bird)		80619 Drawer No. 79/1 Ornithology	14/05/1973 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
180. Botaurus stellaris (bird)		21320 Drawer No. 78/1 Ornithology	25/03/1955 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
181. Botaurus stellaris (bird)	53112 (Old A.N 15.735)	Drawer No. 78/1 Ornithology	06/01/1950 (Zoological Museum of Amsterdam)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
182. Numida mitrata (bird)	B25.5 (4.14)	Drawer No. 77/3 Ornithology	24/07/1949 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
183. Numida mitrata (bird)	B25.5 (3.8)	Drawer No. 77/3 Ornithology	09/10/1949 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
184. Numida mitrata (bird)	B25.5 (5.3)	Drawer No. 77/3 Ornithology	28/07/1949 (Zaambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
185. Numida mitrata transvalensis (bird)		8502 Drawer No. 77/3 Ornithology	6/5/1952 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
186. Numida mitrata (bird)		20999 Drawer No. 77/3 Ornithology	28/08/1955 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
187. Numida mitrata (bird)		19599 Drawer No. 77/3 Ornithology	29/04/1955 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
188. Numida mitrata (bird)		42007 Drawer No. 77/3 Ornithology	12/05/1956 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
189. Numida meleagris (bird)		86238 Drawer No. 77/3 Ornithology	17/10/1961 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
190. Numida meleagris (bird)		60189 Drawer No. 77/3 Ornithology	20/07/1961 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
191. Guttera Edouardi (bird)		69460 Drawer No. 77/2 Ornithology	04/12/1969 (Mozambique)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
192. Guttera Edouardi (bird)		54740 Drawer No. 77/2 Ornithology	21/06/1964 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
193. Guttera Edouardi (bird)		44543 Drawer No. 77/2 Ornithology	03/12/1960 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
194. Guttera Edouardi (bird)		32288 Drawer No. 77/2 Ornithology	04/07/1949 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
195. Guttera Edouardi (bird)		33055 Drawer No. 77/2 Ornithology	16/11/1957 (Zambia)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
196. Branta bernilla (bird)		86105 Drawer No. 77/2 Ornithology	07/02/1933 (UK)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
197. Muscovy X spurwing (bird)		65947 Drawer No. 77/2 Ornithology	07/08/1967 (Zimbabwe)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
198. Anser Albifronse (bird)		86107 Drawer No. 77/2 Ornithology	30/01/1940 (UK)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
199. Tadorna Tadorna		86108 Drawer No. 77/2 Ornithology	08/03/1929 (UK)	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
200. Chen Rossii (bird)	Humboldt State College	830 Drawer No. 77/2 Ornithology	1960 (Mendota California (Humboldt State College).	Good (White chemical residues)	2021/08/09	✓	Davison Chiwara
201. Anas acuta		80580 Drawer No. 77/2 Ornithology	03/02/1974 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
202. Anas acuta		80579 Drawer No. 77/2 Ornithology	03/02/1974 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
203. Melanitta Perspicillata	Nil	Drawer No. 77/2 Ornithology	22/12/1959 (California, Humboldt State College)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
204. Anas Penelope		86111 Drawer No. 77/2 Ornithology	03/12/1921 (Norfolk, UK)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
205. Anas (Mallard)	Old A.N HSC47	Drawer No. 77/2 Ornithology	/03/1955 (California, Humboldt State College)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
206. Aythya Erythrophthalma		60178 Drawer No. 77/2 Ornithology	23/01/1965 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
207. Aythya Erythrophthalma		80995 Drawer No. 77/2 Ornithology	17/01/1974 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
208. Aythya Erythrophthalma		3346 Drawer No. 77/2 Ornithology	29/01/1950 (Zambia)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
209. Aythya Erythrophthalma		68200 Drawer No. 77/2 Ornithology	18/04/1969 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
210. Aythya Erythrophthalma		50329 Drawer No. 77/2 Ornithology	07/03/1962 (Zambia)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
211. Aeryllium Vluturinum	35683 (Old A.N) 8124	Drawer No. 77/1 Ornithology	04/06/1943 (from Kenya for Coryndon Memorial Museum	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
212. Aeryllium Vluturinum		86237 Drawer No. 77/1 Ornithology	14/06/1943 (Kenya)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
213. Gallus Lafayettii		86215 Drawer No. 77/1 Ornithology	March 1933 (NWP Ceylon)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
214. Gallus Lafayettii		86216 Drawer No. 77/1 Ornithology	24/06/1943 (South Ceylon)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
215. Phasianus Colchicus		86224 Drawer No. 77/1 Ornithology	23/11/1908 (UK)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
216. Sarkidiornis Melanotos		52385 Drawer No. 76/1 Ornithology	18/07/1963 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
217. Sarkidiornis Melanotos		55759 Drawer No. 76/1 Ornithology	08/04/1964 (Botswana)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
218. Sarkidiornis Melanotos		70032 Drawer No. 76/1 Ornithology	08/01/1970 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
219. Sarkidiornis Melanotos		50326 Drawer No. 76/1 Ornithology	06/05/1962 (Zambia)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara

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220. Sarkidiornis Melanotos		50325 Drawer No. 76/1 Ornithology	15/02/1962 (Zambia)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
221. Scotopelia Peli		16609 Drawer No. 86/1 Ornithology	06/07/1953 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
222. Scotopelia Pel		84993 Drawer No. 86/1 Ornithology	07/12/1975 (Botswana)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
223. Scotopelia Peli Fischeri Zede		8886 Drawer No. 86/1 Ornithology	22/06/1950 (collected from PEA)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
224. Scotopelia Peli Fischeri Zede		8885 Drawer No. 86/1 Ornithology	19/06/1950 (collected from PEA)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
225. Bubo Capensis	61342; Old A.N 1487/69	Drawer No. 86/1 Ornithology	May 1960 (Cape Town, Port Elizabeth Museum)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
226. Balearica Regulatorum		78274 Drawer No. 81/4 Ornithology	04/04/1972 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
227. Balearica Pavonina		72500 Drawer No. 81/4 Ornithology	22/11/1970 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
228. Sagittarius Serpentinus		85938 Drawer No. 81/4 Ornithology	04/11/1973 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
229. Sagittarius Serpentinus		59091 Drawer No. 81/4 Ornithology	18/02/1966 (Botswana)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
230. Sagittarius Serpentinus		65955 Drawer No. 81/4 Ornithology	26/07/1966 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
231. Phalacrocorax Neglectus		91966 Drawer No. 83/1 Ornithology	15/09/1939 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
232. Phalacrocorax Coronatus		92788 Drawer No. 83/1 Ornithology	14/01/1994 (Cape Town, South Africa)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
233. Phalacrocorax Capensis		92764 Drawer No. 83/1 Ornithology	19/09/1992 (Cape Town, South Africa)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
234. Phalacrocorax Africanus		87412 Drawer No. 83/2 Ornithology	23/01/1970 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
235. Phalacrocorax Africanus		72463 Drawer No. 83/2 Ornithology	06/10/1970 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
236. Phalacrocorax Africanus		78770 Drawer No. 83/2 Ornithology	05/03/1971 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
237. Phalacrocorax Carbo		81243 Drawer No. 83/2 Ornithology	04/01/1974 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
238. Phalacrocorax Carbo		87004 Drawer No. 83/2 Ornithology	10/01/1977 (Transvaal, South Africa)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
239. Phalacrocorax Carbo		88416 Drawer No. 83/2 Ornithology	07/09/1971 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
240. Phalacrocorax Carbo Lucidus		73711 Drawer No. 83/2 Ornithology	23/01/1971 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
241. Phalacrocorax Carbo		69218 Drawer No. 83/2 Ornithology	July 1967 (Chegutu, Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
242. Phalacrocorax Carbo		43371 Drawer No. 83/2 Ornithology	12/04/1958 (Malawi)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
243. Neotis Denhami		73375 Drawer No. 82/4 Ornithology	11/11/1970 (Malawi)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
244. Otis Korie		66916 Drawer No. 82/4 Ornithology	12/12/1968 (Botswana)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
245. Otis Denhami		66916 Drawer No. 82/4 Ornithology	03/01/1981 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
246. Corvus Albus	B12 (14)	Drawer No. 56/3 Ornithology	31/07/1949 (Zambia)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
247. Corvus Albus		85608 Drawer No. 56/3 Ornithology	04/03/1971 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
248. Terathopius Ecaudatus		78725 Drawer No. 83/3 Ornithology	25/01/1946 (Zambia)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
249. Terathopius Ecaudatus		52640 Drawer No. 83/3 Ornithology	1963 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
250. Terathopius Ecaudatus	B811 (1.8)	Drawer No. 83/3 Ornithology	04/08/1949 (Zimbabwe)	Good (White chemical residues)	2021/08/10	✓	Davison Chiwara
251. Manis temminck		56396 Mammalogy 1st Rail	21/01/1976 (Zimbabwe)	Good (White chemical residues)	2021/08/12	✓	Davison Chiwara
252. Papio Ursinus		27968 Mammalogy 1st Rail	29/01/1965 (Kasane, Botswana)	Good	2021/08/12	✓	Davison Chiwara
253. Papio Ursinus		27413 Mammalogy 1st Rail	08/05/1964 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/12	✓	Davison Chiwara
254. Hystrix Africae Australis (Pocupine)		54193 Mammalogy 1st Rail	1952 (Zimbabwe)	Good	2021/08/12	✓	Davison Chiwara
255. Acinonyx Jubatus (cheeter)		56740 Mammalogy 2nd Rail	No date and locality	Good	2021/08/12	✓	Davison Chiwara
256. Crocuta Crocuta Collection		33365 Mammalogy 2nd Rail	12/12/1966 (Zimbabwe)	Good (White chemical residues)	2021/08/12	✓	Davison Chiwara
257. Lycaon Pictus		2648 Mammalogy 2nd Rail	19/09/1949 (Zambia)	Poor, unstable (Detaching parts)	2021/08/12	✓	Davison Chiwara
258. Panthera Pardus		28766 Mammalogy 2nd Rail	02/09/1965 (Botswana)	Poor, unstable (Detaching parts)	2021/08/12	✓	Davison Chiwara
259. Panthera Pardus		2578 Mammalogy 2nd Rail	October 1948 (Zambia)	Poor, unstable (Detaching parts)	2021/08/12	✓	Davison Chiwara
260. Hyaena Brunnea		56293 Mammalogy 2nd Rail	16/10/1969 (Botswana)	Good	2021/08/12	✓	Davison Chiwara
261. Kobus Leche		59200 Mammalogy 4th Rail/1	06/12/1981 (Botswana)	Good	2021/08/12	✓	Davison Chiwara
262. Redunca Arundinum	Collector's number 0189	Mammalogy 1st Rail	17/01/1965 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/12	✓	Davison Chiwara
263. Reed Buck????	NM3365	Mammalogy 1st Rail	07/01/1965 (Zimbabwe)	Poor, (Detaching fur)	2021/08/12	✓	Davison Chiwara
264. Aepyceros Melampus	Collector's number TNL10	Mammalogy 3rd Rail	10/12/1968 (Botswana)	Good	2021/08/12	✓	Davison Chiwara
265. Orycteropus Afer	Collector's number MSA67	Mammalogy 3rd Rail	August 1968 (Botswana)	Good	2021/08/12	✓	Davison Chiwara
266. Aepyceros Melampus	Collector's number TNL4949	Mammalogy 3rd Rail	09/02/1970 (Botswana)	Good	2021/08/12	✓	Davison Chiwara
267. Kobus Vardonii		11563 Mammalogy 3rd Rail	08/11/1962 (Botswana)	Poor, unstable (Detaching parts)	2021/08/12	✓	Davison Chiwara
268. Potamochoerus Porcus		34410 Mammalogy 4th Rail	13/01/1975 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara
269. Potamochoerus Porcus		25909 Mammalogy 4th Rail	12/04/1963 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara
270. Potamochoerus Porcus		20539 Mammalogy 4th Rail	26/01/1963 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara
271. Warthog		25865 Mammalogy 4th Rail	October 1962 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara
272. Warthog		25923 Mammalogy 4th Rail	05/05/1963 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara
273. Cheeter		56283 Mammalogy 4th Rail	22/04/1973 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara
274. Acinonyx Jubatus		59314 Mammalogy 4th Rail	05/11/1981 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara

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275. Kobus Vardoni		20397 Mammalogy 4th Rail	14/08/1963 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
276. Cephalophus Syloticultus		5071 Mammalogy 4th Rail	25/05/1956 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
277. Cephalophus Syloticultus		4451 Mammalogy 4th Rail	15/03/1949 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
278. Cephalophus Syloticultus		3990 Mammalogy 4th Rail	10/01/1952 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
279. Cephalophus Syloticultus	Collector's number 489	Mammalogy 4th Rail	15/03/1949 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
280. Panthera Leo		33354 Mammalogy 5th Rail	12/09/1975 (Zimbabwe)	Poor, unstable (Detaching Parts)	2021/08/13	✓	Davison Chiwara
281. Equus Buchelli		5014 Mammalogy 5th Rail	21/08/1955 (Zambia)	Poor, unstable	2021/08/13	✓	Davison Chiwara
282. Equus Buchelli		12867 Mammalogy 5th Rail	11/12/1959 (Zimbabwe)	Poor, unstable	2021/08/13	✓	Davison Chiwara
283. Giraffa Camelopardis		2382 Mammalogy 5th Rail	03/08/1963 (Zambia)	Poor, unstable	2021/08/13	✓	Davison Chiwara
284. Panthera Leo		5728 Mammalogy 5th Rail	June 1957 (Zambia)	Poor, unstable	2021/08/13	✓	Davison Chiwara
285. Kobus Ellipsiprymnus		50590 Mammalogy 5th Rail	23/08/1976 (Zimbabwe)	Good, unstable	2021/08/13	✓	Davison Chiwara
286. Syncerus Caffer		54716 Mammalogy 6th Rail	29/11/1973 (Zimbabwe)	Good	2021/08/13	✓	Davison Chiwara
287. Damaliscus Lunatus		27401 Mammalogy 6th Rail	27/08/1963 (Zimbabwe)	Good	2021/08/13	✓	Davison Chiwara
288. Hippotragus Equinus		5085 Mammalogy 5th Rail	1956 (Zambia)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara
289. Hippotragus Niger		50616 Mammalogy 6th Rail	05/02/1976 (Zimbabwe)	Poor, unstable (Detaching parts)	2021/08/13	✓	Davison Chiwara
290. Tragelaphus strepsiceros		2071 Mammalogy 7th Rail	01/11/1949 (Zimbabwe)	Good	2021/08/13	✓	Davison Chiwara
291. Connochaetes Taurinus	Collector's number TNL4340	Mammalogy 7th Rail	31/05/1968 (Botswana)	Good	2021/08/13	✓	Davison Chiwara
292. Alcelaphus Lichtensteini		19053 Mammalogy 7th Rail	25/09/1962 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
293. Ceratotherium Simun		79525 Mammalogy 7th Rail	31/08/1985 (Zambia)	Poor (Structural weaknesses, hole)	2021/08/13	✓	Davison Chiwara
294. Sylvicapra Grimmia		31235 Mammalogy 8th Rail	20/12/1969 (Zimbabwe)	Poor, unstable (Detaching Parts)	2021/08/13	✓	Davison Chiwara
295. Sylvicapra Grimmia		21854 Mammalogy 8th Rail	29/03/1962 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
296. Oreotragus Oreotragus		21923 Mammalogy 9th Rail	10/12/1962 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
297. Oreotragus Oreotragus		4044 Mammalogy 9th Rail	21/11/1951 (Zambia)	Good	2021/08/13	✓	Davison Chiwara
298. Ourebia Ourebi		21960 Mammalogy 10th Rail	12/07/1962 (Zimbabwe)	Good	2021/08/13	✓	Davison Chiwara
299. Raphicerus Campestris		2070 Mammalogy 10th Rail	01/11/1949 (Zimbabwe)	Good	2021/08/13	✓	Davison Chiwara
300. Taurotragus Oryx		54307 Mammalogy 7th Rail	02/10/1975 (Zimbabwe)	Good	2021/08/13	✓	Davison Chiwara
301. Ant eater	TG255	Mammalogy 2nd Rail	No date and locality	Poor	2021/08/14	✓	Davison Chiwara
302. Kobus lechwe		59200 Mammalogy 4th rail.	No date and locality	Good	2021/08/15	✓	Davison Chiwara
303. Hooded Vulture		13827 Drawer. Ornithology	No date and locality	Good	2021/08/16	✓	Davison Chiwara
304. Pseudo gyps africanus	B827	Drawer. Ornithology	No date and locality	Good	2021/08/17	✓	Davison Chiwara
305. Lappet Face Vulture		89050 Drawer. Ornithology	No date and locality	Good	2021/08/18	✓	Davison Chiwara
306. Cape Vulture		38877 Drawer. Ornithology	No date and locality	Good	2021/08/19	✓	Davison Chiwara