学位論文内容の要旨
Abstract of the dissertation

博士の専攻分野の名称：博士（獣医学）　　氏名：Banda Nelly

学位論文題名
Environmental Distribution and Biological Impact of Lead and Metalloids in Protected Areas: Intergenerational Exposure and Nutritional Mitigation Strategies
(生態系保護地域における鉛および金属類の環境汚染と生物影響 : 世代間曝露と栄養学的緩和戦略)

Environmental contamination by non-essential metals and metalloids increasingly threatens public health, wildlife, and ecosystem stability, particularly in regions experiencing expanding mining activity. As extractive industries intensify, chronic exposure to toxic metals such as lead (Pb) becomes more likely across trophic levels. This dissertation investigates these challenges by examining the biochemical, reproductive, neurological, and ecological consequences of heavy metal exposure, with a central focus on Pb. It also evaluates potential mitigation strategies using sentinel species, molecular profiling, and nutritional interventions. By integrating field studies in Zambia with controlled laboratory experiments in mouse models, the research provides a multiscale understanding of metal toxicity and its intergenerational effects.

Fieldwork was conducted in Zambia's Lower Zambezi National Park, a protected area recently opened to mining exploration. Soil and *Acacia spp.* bark samples were analysed for ten metals and metalloids using inductively coupled plasma mass spectrometry. Although most concentrations remained within established human safety thresholds, elevated levels were detected in areas with

increased vehicular movement and exploratory mining activity. These spatial patterns raise concerns about long-term ecological disruption, particularly given the park's biodiversity and the added pressures of climate change. The findings underscore the need for proactive monitoring to safeguard wildlife populations whose adaptive capacity may be compromised by cumulative environmental stressors.

Complementing the field component, laboratory studies using mouse models examined the intergenerational effects of Pb exposure through contaminated soil. Breeding experiments were structured across four parental exposure groups to evaluate reproductive performance and neurological development in F1 offspring: (1) exposed dams with unexposed sires, (2) exposed sires with unexposed dams, (3) both parents exposed, and (4) unexposed controls. In the F0 generation, Pb exposure reduced conception rates, with the most pronounced deficits observed when both parents were exposed. Testicular gene expression analyses implicated oxidative stress pathways in reduced fertility. Behavioural assessments using the Morris water maze and rotarod tests revealed impaired spatial learning and motor coordination in F1 offspring, with paternal exposure exerting particularly strong effects on female progeny.

Transcriptomic profiling of F1 gonadal tissues demonstrated sex-dependent gene expression changes. Female offspring of exposed sires exhibited significant alterations associated with protein-arginine deiminase activity and citrullination. Group 1 F1 males showed the highest differentially expressed testis-specific genes and an elevated immune response, patterns not observed in Group 3 males despite their prenatal exposure. Similar Y-chromosome alterations in

Groups 2 and 3 highlighted the critical role of paternal Pb exposure in the inheritance of infertility-related traits.

A complementary study in Kabwe, one of the world's most Pb-contaminated towns, evaluated dogs as sentinel organisms to test the therapeutic potential of L-ascorbic acid (L-AA). After 14 days of supplementation, dogs exhibited reduced oxidative stress markers and improved biochemical profiles. Age- and sex-specific responses suggested nuanced physiological interactions between L-AA and metal burden.

Together, these studies illuminate the multifaceted impacts of metal exposure, from ecosystem-level disturbances to molecular and reproductive dysfunction. They demonstrate the value of sentinel species, transcriptomic tools, and nutritional interventions in environmental toxicology, while providing essential baseline data for conservation and public health strategies in mining-affected regions.