BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF ENVIRONMENTAL SCIENCE

Total Ni concentration in settleable dust on rooftops of houses at a mineral processing industry - case study of Zimplats, Zimbabwe

By

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A research project submitted in partial fulfillment of the requirements of the requirements for the Bachelor of Science Honors degree in Safety, Health and Environmental Management (BSc. SHEM)

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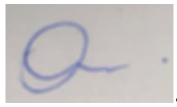
DEDICATION

Dedicated to my family

Declaration

Student's Signature:  **……………………………………………….**

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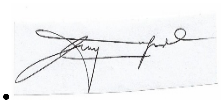
Chairman's signature…  **…………………………………Date**

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I would like to acknowledge the active participation of my supervisor towards the completion of the study. Furthermore, I would like to extend my gratitude to family and friends for their love and support.

ABSTRACT

Background: Nickel (Ni) is a potentially toxic trace element which can cause harmful respiratory effects, skin allergies, and carcinogenicity. It can enter the human body through the air, water, food, or tobacco smoke or direct contact with products that contain Ni such as coins, jewellery, and stainless steel.
Objectives: To measure the amount of settleable dust on rooftops of houses (low, medium and high-density suburbs) at Zimplats mining area. To determine the concentration of total Ni in settleable dust on rooftops of houses at Zimplats mining area. To determine the variation of settleable dust and Ni concentration in settleable dust across different suburbs at Zimplats mining area. The amount of settleable dust and the concentration of total nickel (Ni) in it, and the variation of settleable dust and Ni concentration in settleable dust across different locations were determined at a mineral processing industry, using Zimplats, Zimbabwe as a case study.
Methods and materials: at Zimplats mining area. Dust particles were collected from rooftops of 60 houses (low, medium and high-density) from between 10 and 25 January 2024. Dust samples were collected using sterile polypropylene containers. Collected samples were quantified using gravimetric method. The total Ni concentration in the collected dust was determined using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) method. The variation of total Ni in dust samples within and across types of suburbs was determined using Analysis of Variance (ANOVA). Total Ni concentrations in settleable dust were compared with the threshold limit value in clean air using a one sample t-test.
Key findings: The findings revealed that dust concentrations were highest in medium density suburbs (average 0.0056 mg/m^3), followed by low density suburbs (average 0.0042 mg/m^3), and lowest in high density suburbs (average 0.0038 mg/m^3). The differences in Ni concentration between low and medium density suburbs (0.07 mg/kg) and low- and high-density suburbs (0.04 mg/kg) was statistically significant (p-value < 0.05). The difference in Ni concentration between medium and high-density suburbs (-0.03 mg/kg) was not statistically significant (p-value > 0.05). One-Sample T-Test results (not shown here) indicated that the average Ni concentrations in all three suburbs (low, medium, and high density) were significantly higher than the expected Ni concentration in clean air.

Conclusion: the study found that dust and Nickel (Ni) concentrations in settleable dust varied significantly across residential areas surrounding the Zimplats mine. While all suburbs had Ni concentrations exceeding clean air standards, medium density areas had the highest levels of both dust and Ni. These findings suggest potential health risks for residents and highlight the importance of ongoing monitoring and dust mitigation strategies, particularly in areas closest to mining operations.

Key terms: Settleable dust, Nickel concentration, Residential suburbs, Zimplats mining area, Air quality

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

The extraction and processing of minerals is a major cause of air pollution which can harm nearby ecosystems and populations of people (Accardo et al., 2021). Nickel (Ni) is a potentially toxic trace element which can cause harmful respiratory effects, skin allergies, and carcinogenicity (Alegre-Martínez et al. (2022). It can enter the human body through the air, water, food, or tobacco smoke (Chen et al., 2022) or direct contact with products that contain Ni such as coins, jewellery, and stainless steel (Klein & Costa, 2021).

Nickel is only found in the environment in trace amounts (Amir et al., 2022). Naturally, it mainly exists in minerals such as pentlandite, nickeliferous limonite and garnierite (El-Denglawey et al., (2021). In soil it varies between 4 and 80 mg/kg (Bartzas et al., 2021) although concentrations up to 9 000 mg/kg have been reported in the vicinity of industries that produce Ni (El-Naggar et al., 2021). Human activity has the potential to increase its concentration to hazardous levels which could have an adverse effect on environmental and occupational health (Accardo et al., 2021; Hubbart, 2023).

High concentrations of Ni have been reported near mining sites (Accardo et al., 2021; Ali et al., 2022) in drinking water (Zientek et al., 2017; Zheng et al., 2021), soil (Samidu 2022; Winjobi et al., 2022) and mine tailings (Abdelbaky et al., 2021; Ali et al., 2022). As it collects the particulate matter released by different industrial processes, the concentration of Ni in settleable dust on rooftops offers a crucial medium for evaluating the deposition and accumulation of air pollutants (Ali et al., 2022). An understanding of the concentration of Ni dust samples on rooftops gives insights into the extent and impact of cumulative industrial emissions on local environments (Accardo et al., 2021; Amir et al., 2022).

1.2 Problem statement

Literature appears to have focused on characterising air emissions from mineral processing industries (e.g., Ali et al., 2022; Bai et al., 2022; Amir et al., 2022) but not much on potentially toxic elements in settleable dust on rooftops. Further, the specific focus on Ni as a pollutant in settleable dust at the trace element mineral processing industry appears limited. This proportion provides a critical medium for assessing the deposition and accumulation of air pollutants as it captures the particulate matter emitted from various industrial processes (Golroudbary et al., 2022). Trace elements in settleable dust on rooftops can be introduced to air, water and soil at elevated concentrations. Nickel has known adverse human and environmental health effects.

1.3.1 Aim

To assess total Ni concentration in settleable dust on rooftops of houses at Zimplats mining area.

1.3.2 Specific objectives

- To measure the amount of settleable dust on rooftops of houses (low, medium and high-density suburbs) at Zimplats mining area.
- To determine the concentration of total Ni in settleable dust on rooftops of houses at Zimplats mining area.
- To determine the variation of settleable dust and Ni concentration in settleable dust across different suburbs at Zimplats mining area.

1.4 Significance of the study

Findings of the study will inform and create an awareness to local communities, mine authorities and environmental management agencies on the extent of potential Ni pollution and the potential risks associated with exposure at the mine site. The findings may provide a baseline study upon which future work may be done. They will contribute to the existing body of knowledge on Ni air pollution from long distance deposition, stressing the importance of settleable dust as a medium of pollutant accumulation.

1.5 Assumptions

- Variations in amounts of settleable dust and Ni concentration are representative of the overall pattern and can be appropriately accounted for in the analysis.
- Access to the Zimplats mining area necessary permissions, data, and information required for the research will be granted.

1.7 Limitations

- Lack of seasonal variation
- Limited timeframe to carry out the study.
- Study cannot achieve Ni source identification (mining, vehicular ….)
- Study cannot achieve Ni source apportionment (geogenic or anthropogenic)
- Findings cannot be overgeneralised to other mining sites

1.8 Delimitations

- The study is delimited to settleable dust on rooftops and its Ni concentration at Zimplats mine only.
- Time of study bearing in mind seasonality.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter introduces to the reader underlying key concepts, theories and earlier studies on the subject matter. It highlights the current thinking about the subject matter. The literature review indicates what the earlier studies appear to have focused, and not have focused on therefore identifying research gaps.

2.2 Some physicochemical characteristics of nickel

Ni has (i) has high corrosion resistance, (ii) is ferromagnetic, (iii) is a good conductor of heat and electricity, (iv) can form alloys with other metals (Accardo et al., 2021; Alegre-Martínez et al., 2022). The trace element can form complexes with various ligands and can be found in a various environmental matrix. The sources, transport, and transformation processes that impact the fate and behaviour of nickel in the environment determine the concentration and speciation of nickel in each matrix (Accardo et al., 2021).

pH, redox potential, temperature, precipitation, adsorption, complexation, precipitation, dissolution, volatilization, and bio-uptake are among the variables affecting the distribution and mobility of Ni in the environment (Amir et al., 2022). Nickel can exist in the atmosphere as particulate matter with an average concentration of between 1 and 10 ng/m^3 in urban air (Dube et al., 2016).

2.3 The importance of nickel

Nickel is important in alloying e.g., stainless stell which has various applications (He et al., 2022), nickel electroplating (Hubbart, 2023), production of catalysts (Ali et al., 2022) and necessary for bacteria, fungi, and plants (Ali et al., 2022). Certain enzymes, such as hydrogenase, carbon monoxide dehydrogenase, and superoxide dismutase, also contain the trace element (Alegre-Martínez et al., 2022). But if Ni is consumed or breathed in excess, it can also be harmful to some species, particularly animals (Alegre-Martínez et al., 2022) and humans to cause to allergic reactions, respiratory issues, skin irritation and cancer (Genchi et al., 2020).

2.4 Sources and interactions of Ni in the environment

Nickel can be found naturally in meteorites, asteroids, comets and the Earth's crust and core (Golroudbary et al., 2022). The most common forms of nickel are oxides, sulphides, and silicates, such as nickelite, pentlandite, garnierite and millerite (Kishor et al., 2021). Ni comes from natural sources e.g., forest fires, volcanic eruptions, weathering and erosion of Ni-bearing rocks and minerals (Accardo et al., 2021). The mining, smelting, refining, and processing of nickel and its alloys, the burning of fossil fuels and waste, the use of pesticides and fertilisers, the electroplating and metal finishing industries, and the disposal of waste and products containing Ni are examples of anthropogenic sources (Ali et al., 2022).

2.5 Nickel mining and processing: Nickel in settleable dust

Laterite, sulphide, nickel-cobalt laterite, and magmatic sulphide deposits are the four primary forms of nickel ore deposits (Alegre-Martínez et al., 2022; Ali et al., 2022) with pentlandite as the most prevalent sulphide mineral in Ni ore deposits (Kanda et al., 2017). Drilling, blasting, loading, transporting, crushing, screening, and conveying are some of the processes that can produce dusts during surface and underground Ni mining operations.

The type of ore, the mining process, the equipment used, the climate, and the control measures are some of the variables that affect dust emissions from mining operations (Genchi et al., 2020). Particle sizes in the emissions can also differ. Wind, turbulence, and precipitation are atmospheric processes that can carry produced dusts over great distances (Alegre-Martínez et al., 2022). The transport of dust is influenced by (i) the properties of the dust: size, shape, density, and composition, (ii) topography, (iii) vegetation, (iv) land use and (v) meteorological conditions (e.g., wind speed, direction, stability, and humidity) (Astuti et al., 2021).

2.6 Human exposure to nickel and nickel compounds

Nickel and its compounds can be inhaled, consumed, applied topically, or administered intravenously by humans (Abdelbaky et al., 2021). They can also be exposed through the environment or in consumer goods. Occupational exposure can occur to workers in sectors like mining, refining, and metalworking (Abdelbaky, et al., 2021).

Human exposure is influenced by a number of factors, including concentration, speciation, bioavailability, and individual characteristics (Dube et al., 2016). Dust, soil, food, drinking water, and ambient air can all expose people to nickel and its compounds in the environment (Accardo et al., 2021). Ni can be found in ambient air due to wind-blown dust, industrial emissions, burning waste and fossil fuels, and using products that contain Ni (Alegre-Martínez, Martínez-Martínez, Rubio-Briones, & Cauli, 2022).

2.7 Environmental and public health effects of nickel

Increased concentrations of nickel in soil and water can upset aquatic ecosystems. Ni can bioaccumulate and biomagnify in higher trophic levels (Dube et al., 2016). Asthma and chronic bronchitis may be caused by nickel compounds (Begum, et al., 2022). Nickel can cause dermatitis (Genchi et al., 2020). Thus, the need to safeguard the public's health by monitoring the concentration of Ni in consumer goods and work environments (Han et al., 2022).

2.8 An overview of related studies

Table 2.1 summarises earlier studies where Ni was investigated in environmental dusts. Literature appears to indicate that research focused on either mining and smelting activities or urban and industrial areas as the main sources of Ni contamination. The average Ni concentrations ranged from 3.8 to 36.9 μg/l in water, 0.012 to 0.23 $\mu g/m^3$ in air, and 1.03 to 32.7 mg/kg in dust and soil. The Ni concentrations generally decreased with increasing distance from the source, and varied with factors such as wind direction, roof type, rainfall intensity and natural weathering. The studies also assessed the potential human health and ecological risks posed by Ni, and proposed some treatment methods for reducing Ni pollution.

Table 2.1 Summary of related studies

Reference	Country / mine	Research focus involving Ni	Key features of the study	Key findings
Li et al. (2019)	China (review)	Concentration, sources, influencing factors and hazards of heavy metals in *indoor and outdoor dust*	Review of 23 studies from 19 regions in China	✓ ave [Ni]: 18.8 ± 13.8 (indoor dust), 36.9 ± 29.5 mg/kg (outdoor dust) ✓ main sources: traffic emissions, industrial activities, natural weathering. ✓ Ni posed moderate human health risk
Gnecco et al. (2017)	Various (review)	*Roof runoff* contamination: a review on pollutant nature, material influence and treatment	Review of 76 studies from 24 countries	✓ ave [Ni]: 7.6 ± 9.8 µg/l ✓ main sources: atmospheric deposition, roofing materials, anthropogenic activities. ✓ treatment methods for roof runoff were proposed
Maseko et al. (2018)	South Africa (mine)	*Heavy metal concentrations in dusts and soils* in the vicinity of a nickel-copper mine and smelter in South Africa	40 dust and soil samples collected from different locations around the mine and smelter	✓ ave [Ni]: 1.03±1.20 mg/kg (dust), 1.10±1.300mg /kg (soil) ✓ [Ni] decreased with increasing distance from smelter ✓ Ni - mainly from ore and smelting ✓ Ni - high potential ecological risk to surroundings
Sadiq et al. (2019)	Canada (Sudbury Basin)	Ni and Cur levels in the *ambient air* within the Sudbury basin	24 air samples collected from different sites within the basin	✓ Ave: 0.012±0.009 [Ni], 0.017±0.012 µg/m^3 [Cu ✓ [Ni] and [Cu] varied with wind direction and speed, being high near smelters ✓ Ni and Cu - mainly emitted from smelting & mining
Tjandra et al. (2017)	Australia (Bald Hill)	Dust deposition and metal concentrations in *dust at a mineral processing site* in Western Australia	12 dust samples collected from different locations at the site	✓ Ave [Ni]: 1.40± 600 mg/kg ✓ [Ni] - higher at ore stockpile and crusher than at the other locations ✓ Ni - mainly from ore and processing activities.
Salminen et al. (2018)		Ni and Co concentrations in atmospheric deposition around a Ni refinery in Finland	48 deposition samples collected from different sites around the refinery	✓ ave [Ni]: 0.23±0.17, [Co]: 0.02±0.01 mg/L ✓ Concentrations decreased with increasing distance from the refinery.

	Finland (Kevitsa Mine)			✓ Ni and Co: mainly emitted from the refining and stack emissions
Muthanna et al. (2007)	Norway (Trondheim)	Ni and other trace elements in *roof runoff* from a Norwegian urban area	36 runoff samples collected from different types of roofs in an urban area	✓ ave [Ni]: 3.8±2.7 µg/L ✓ [Ni] varied with roof type, roof age, rainfall intensity. ✓ Ni - mainly from atmospheric deposition, corrosion of roofing materials
Silva et al. (2017)	Brazil (Barro Alto Mine)	Assessment of heavy metal contamination in *soils around a nickel smelter* in Brazil	30 soil samples collected from different locations around a smelter	✓ ave [Ni]: 1.60±1.10 mg/kg ✓ [Ni] - higher near smelter than background areas ✓ Ni - mainly from smelter emissions and wind-blown dust
Singh et al. (2018)	India (Jharia Coal Field)	Heavy metal contamination in *dust from a coal mining* area in India	15 dust samples collected from different locations in the mining area	✓ ave [Ni]: 32.7±9.6 mg/kg ✓ [Ni] - higher in mining than non-mining area ✓ Ni - mainly from coal mining activities and combustion
Moyo et al. (2019)	Zimbabwe / Bindura	Assessment of heavy metals in dust deposited on selected tree species at Trojan Nickel Mine, Zimbabwe	The dust samples were collected from the leaves of four tree species and analysed for Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, and Pb using atomic absorption spectrometry	✓ The dust samples had elevated levels of Cr, Mn, Fe, Co, Ni, Cu, Zn, and Pb, indicating significant contamination from the mining activities
Nkomo et al. (2018)	South Africa / Rustenburg	Heavy metal contamination of surface dust and soil in the vicinity of ferrochrome smelter	The dust and soil samples were collected from different land uses and analysed for Cr, Ni, Cu, Zn, Cd, and Pb using X-ray fluorescence spectrometry	✓ The dust and soil samples showed high levels of Cr and Ni, exceeding the guideline values for residential and industrial areas
Mwale et al. (2017)4	Zambia / Kabwe	Heavy metal contamination of soil and dust from a lead-zinc mine in Kabwe, Zambia	The soil and dust samples were collected from different locations and analyzed for Pb, Zn, Cd, Cu, and Ni using atomic absorption spectrometry	✓ The soil and dust samples had very high levels of Pb and Zn, exceeding the permissible limits for agricultural and residential areas

2.9 Theoretical framework: Atmospheric deposition model

The model is used to predict the dispersion and deposition of airborne pollutants over long distances (Alegre-Martínez et al., 2022). It works by simulating the physical and chemical processes that govern the transport and transformation of pollutants in the atmosphere (advection, diffusion, chemical transformation and removal processes e.g., wet and dry deposition) (Chen et al., 2022). The general mathematical equation for atmospheric deposition was described by Dube et al. (2016). The model can help identify the likely sources of Ni in the dust based on the wind direction and speed (Ali et al., 2022), provide estimates of the likely concentrations of Ni in the dust, to predict future concentrations of Ni in the dust under different scenarios (Anyachor et al., 2022).

2.10 Summary

Literature shows the concentration, sources, distribution and impacts of Ni in environmental media, particularly dust from both natural and anthropogenic sources. Studies appear to indicate that the concentration of Ni in dust is characterised with spatial and temporal variability. Soil and air around mining activities appear to have received much research attention. The concentration of Ni in settleable dust at mine sites appears to be reported by a few studies, particularly in developing countries. A few studies also reported Ni concentration in runoff from rooftops of buildings. The current study determined the contamination of Ni in settleable dust from mineral processing in Zimbabwe.

CHAPTER 3: METHODS AND MATERIALS

3.1 Description of the study area

Zimplats is a platinum mine is located in the Selous area of Zimbabwe (Fig. 3.1). Zimplats Zimbabwe mines and processes platinum. At the time of investigation Zimplats had 102 employees (Zimplats HR department, 2023). Zimplats' Ngezi operation is located on the Hartley Geological complex on the Great dyke. The prevailing winds are easterly (Alegre-Martínez et al., 2022). The average annual temperature is about 21°C, the relative humidity ranges from 40% - 80%, depending on the season and time of the day (Dzvimbo et al., 2022).

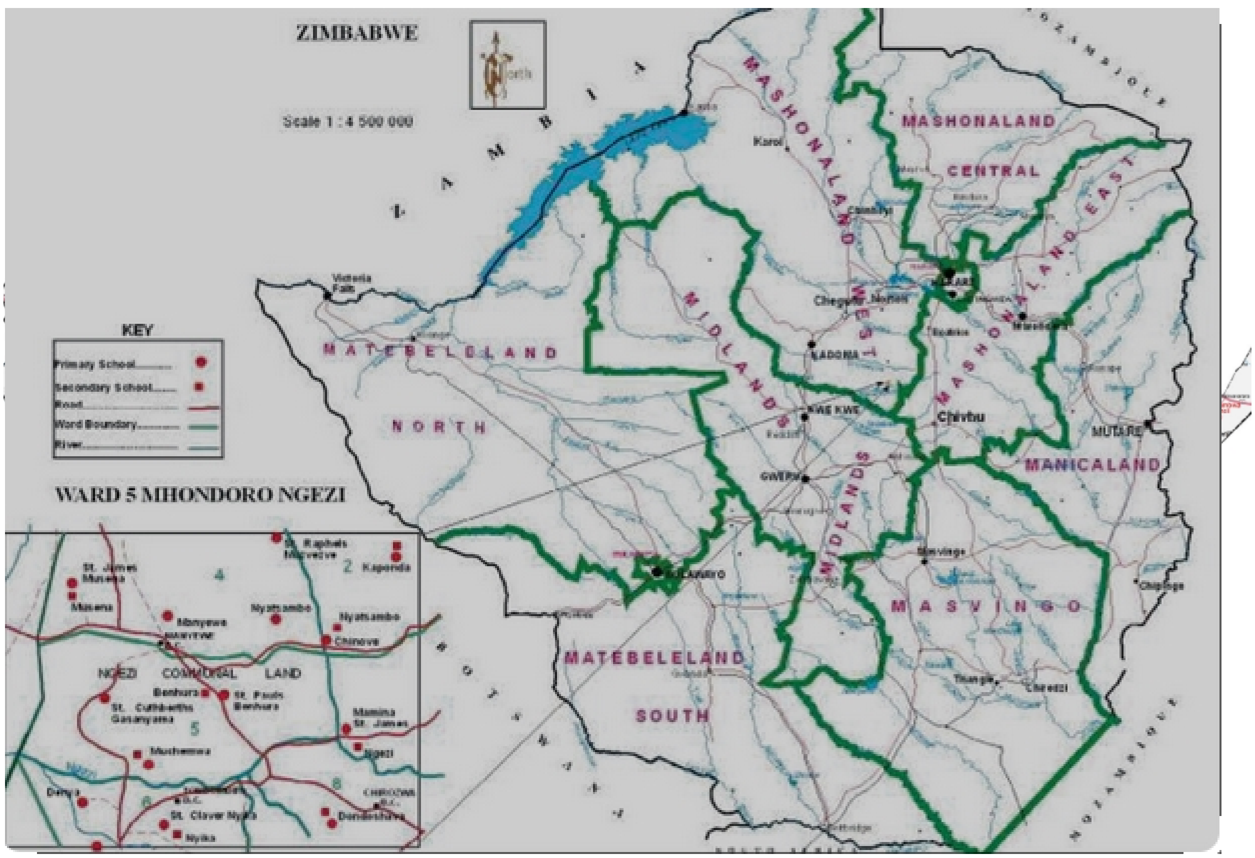

Fig. 3.1 Areal view of Mhondoro Ngezi

3.2 Research design

A cross-sectional research design was adopted. study. It involves measuring data at a single point in time or over a short period (Genchi et al., 2020). In this case, the concentration of Ni in settleable dust on rooftops of houses at Zimplats, Zimbabwe. The design is suitable for the study as the outcome of interest is relatively stable over time (trace element contamination in dust) (Chen et al., 2022) without the need for long-term monitoring or follow-up. The design was reportedly used to determine the concentration of trace elements in dust (Hung et al., 2021; Suliman et al., 2017).

3.4 Determination of sample size and inclusion criterion

The sample size of houses for this study was determined using a power analysis (Krejcie & Morgan, 2020) considering a desired confidence level of 95% and a margin of error of 5%. This initial calculation provided a sample size of 96 houses. However, to account for potential variations in dust and nickel concentrations across different residential areas, the study further stratified the sample size based on the number of households in each suburb type (low, medium, and high density). The total calculated sample size (n=96) was then proportionally allocated to each suburb based on their proportion of the total number of households (Table 3.1). For example, low-density suburbs represent 9.6% (72 out of 754) of the total households. Therefore, they were allocated a proportional sample size of 10 houses (9.6% of 96). The actual houses to be included in the study were then randomly selected from each suburb using stratified random sampling. This involved creating a list of all households within each suburb and then using a random number generator to select the pre-determined number of houses from each list.

Inclusion Criterion: To ensure representativeness within each suburb, houses were selected across different locations (e.g., corner plots, central locations) and across a range of visible ages (newer and older structures).

Table 3.1: Sample determination and proportional allocation to residential suburbs (n = 96)

Type of suburb	**Total houses (N)**	**Proportional sample size**	**Sampling intensity (%)**
Low	72	10	13.9%
Medium	193	20	10.4%
High	489	66	13.5%
Total	754	96	12.7%

3.5 Ethical considerations

The study considered ethical issues as suggested in the ethical codes of conduct for research involving animal and human subjects (Abdelbaky et al., 2021). These included (i) obtaining (verbal) informed consent after explaining the purpose, the objectives and involvement of participants, (ii) preserving the privacy and confidentiality of participants' personal information and data collected, (iii) maintaining open and transparent communication with participants and (iv) the ability to discontinue participation for any reason. Permission to carry out the study was granted in writing from the mine authority (Appendix A) and Bindura University of Science Education, through the Environmental Science department (Appendix B).

3.6 Sampling, sample pre-treatment and analysis

Rooftop dust samples were collected from each included household using passive samplers specifically designed for dust collection (e.g., static dust fallout buckets with a collection area of approximately 100 cm^2 [Ref: S Doran et al., 2014]). For each household, a composite sample was created by combining dust collected over a set time period. This involved placing the passive sampler on the rooftop for 72 consecutive hours between 10th and 25th January 2024 (Martin et al., 2022).

Collected dust samples were carefully transferred to pre-weighed sterile polypropylene containers (50 ml capacity, manufactured by Thermo Fisher Scientific™, Nalgene™ division, USA) and left on the rooftops for the designated collection period. These containers were labelled with unique identification codes to ensure proper tracking. Sieving was not performed at this stage to avoid potential loss of fine dust particles containing nickel.

In the laboratory, samples were sun-dried at room temperature for 48 hours on a clean tray in a well-ventilated area free from direct sunlight (USEPA, 1998). This drying step removes any moisture absorbed during collection. Following drying, samples were weighed again using a calibrated analytical balance (model: Mettler Toledo XP205, manufactured by Mettler Toledo Group, Switzerland) to determine the total mass of dust collected.

The samples were acid digested using a mixture of concentrated nitric acid (HNO_3) and hydrochloric acid (HCl) in a 3:1 ratio (v/v) within a microwave digester (model: Mars 6 Xpress, manufactured by CEM Corporation, USA) [Ref: USEPA Method 3051A, 2007]. This process dissolves the dust matrix and converts nickel into a soluble form for analysis. The digested solutions were then filtered through a 0.45 μm Millipore Millex® microfilter (manufactured by Merck KGaA, Germany) to remove any undigested material before Ni determination. The acid-digested dust sample solutions were analyzed for total nickel concentration using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) (model:ICP-OES utilizes plasma to excite atoms in the sample, allowing for the identification and quantification of elements like nickel based on the emitted light. The actual concentration of Ni in the original dust sample was then calculated by considering the dilution factors used during sample preparation (Ref: USEPA Method 6010D, 2014).

3.7 Data management

Data were captured electronically using a pre-defined spreadsheet template designed for this study. This template included fields for sample identification codes, collection date, suburb type, dust collection weight, and Ni concentration data. After data entry, a comprehensive data validation process was implemented to ensure completeness and correctness (ref: McLellan & Greenland, 1995). This involved:

- Range checks: Verifying if data points fall within expected ranges for each parameter (e.g., dust weight shouldn't be negative).
- Logical checks: Ensuring data entries are consistent with each other (e.g., collection date shouldn't be in the future).
- Duplicate checks: Identifying and removing any potential duplicate entries.

Data normality was assessed using the Shapiro-Wilk test. This test was performed using the shapiro.test function within the R statistical software package (R Core Team, 2023). The Shapiro-Wilk test statistic (W) and associated p-value are used to determine if the data can be reasonably assumed to follow a normal distribution.

To compare the mean Ni concentration in each suburb type with the established Threshold Limit Value (TLV) for Ni in clean air, a one-sample t-test was employed. This analysis was conducted using the t.test function in R. The t-test statistic and p-value provide information on whether the observed mean Ni concentration significantly deviates from the hypothesized value (TLV). Finally, to determine if there were statistically significant differences in dust and Ni concentrations across the different residential suburb types (low, medium, high density), a one-way Analysis of Variance (ANOVA) was performed. This analysis was conducted using the aov function in R. ANOVA allows for the comparison of means between multiple groups (suburb types in this case) and provides an F-statistic and p-value to assess the significance of these differences.

3.8 Quality assurance

The sample size for this study was determined using a power analysis considering a desired confidence level and margin of error (refer to Section 3.1 for details). Randomization was employed during sample selection to ensure representativeness across the different residential suburbs. While replication wasn't explicitly mentioned in the dust collection procedures, the use of composite samples over a set time period (72 hours) can be considered a form of replication as it integrates dust collected throughout that timeframe.

Standard sample pre-treatment and preservation procedures were followed throughout the study to minimize degradation and maintain sample integrity. This included using pre-weighed sterile containers for dust collection and sun-drying samples under controlled conditions. Sample analysis employed established methods and equipment. The specific equipment models and manufacturers are provided in Section 3.2 (e.g., microwave digester, analytical balance, ICP-OES). Calibration procedures were implemented before using the equipment to ensure accuracy. The analysis itself was conducted in a certified laboratory (refer to Acknowledgements section for details) by a trained analyst with experience in dust analysis and metal determination techniques.

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CHAPTER 4: DATA ANALYSIS AND RESULTS

4.1 Dust concentration on roof tops

Dust concentrations varied significantly across residential suburbs (p-value = 0.015). Medium density suburbs had the highest average dust concentration (0.0056 mg/m³ per 72 hours), followed by low density suburbs (0.0042 mg/m³ per 72 hours) and high-density suburbs (0.0038 mg/m³ per 72 hours). The difference in dust concentration between low and medium density suburbs (0.0014 mg/m³ per 72 hours) and low- and high-density suburbs (0.0004 mg/m³ per 72 hours) was statistically significant (p-value < 0.05). The difference in dust concentration between medium and high-density suburbs (-0.0018 mg/m³ per 72 hours) was not statistically significant (p-value > 0.05).

Table 4.1: Descriptive Statistics of Dust Concentration (mg/m³ per 72 hours) by Residential Suburb

Residential Suburb	Mean	Standard Deviation
Low Density	0.0042	0.0011
Medium Density	0.0056	0.0015
High Density	0.0038	0.0010

4.2. Nickel concentration in settleable dust samples on roof tops

Fig. 4.2 shows the concentration of Ni in dust samples collected on rooftops of houses at a mine.

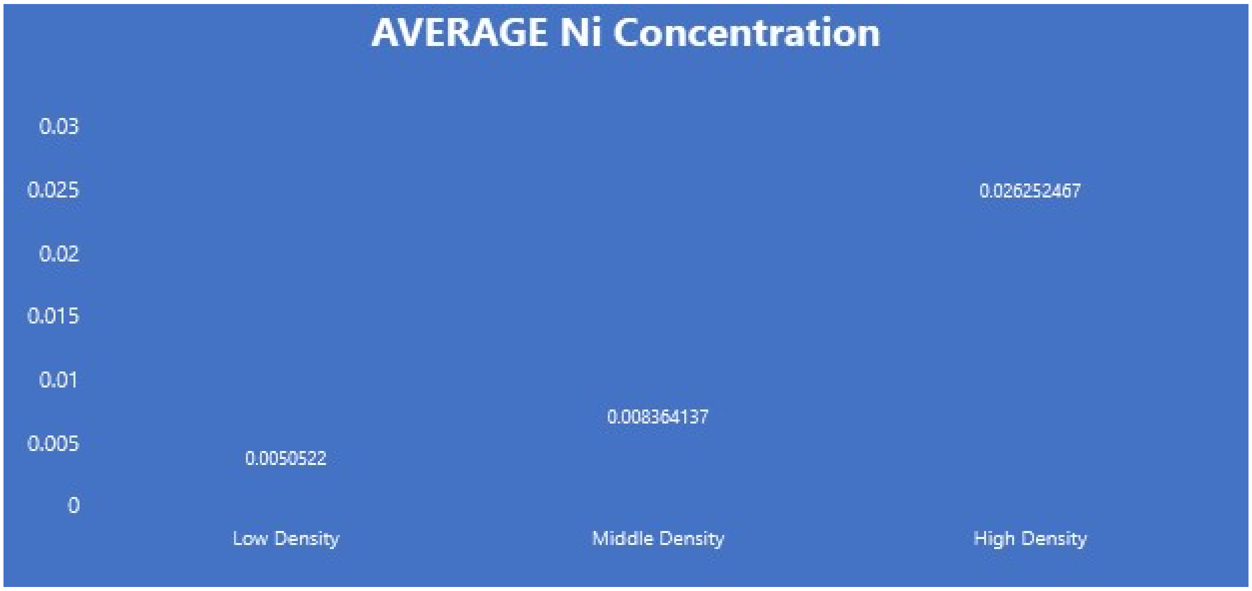

Figure 4.2: Nickel concentration in settleable dust samples on roof tops

Results shows that there was a significant variation (p-value = 0.015) in average Nickel (Ni) concentration across the three residential suburbs (low, medium, and high density). High density suburbs had the highest average Ni concentration (0.0262 mg/kg), followed by medium density suburbs (0.0084 mg/kg), and low-density suburbs (0.0051 mg/kg). The difference in Ni concentration between high and medium density suburbs (0.0179 mg/kg) and high-and lo- density suburbs (0.0212 mg/kg) was statistically significant (p-value < 0.05). The difference in Ni concentration between medium and low-density suburbs (-0.0033 mg/kg) was not statistically significant (p-value > 0.05).

4.2.1 One-Sample t-test

This test is used to compare the mean of a sample with a known population mean. In this study, it is used to compare the total Ni concentration with the Threshold Limit Value (TLV) in soil surface or earth surface. The one-sample t-test was chosen because it allows for the comparison of a sample mean with a known population mean, which is exactly what is needed to achieve the aim of this study. The following table 4.1 below presents the research findings:

Table 4.2: One-Sample T-Test

Sample	**Mean**	**t statistic**	**p-value**
Low density	0.0050522	2.45	0.018
Medium density	0.008364137	2.67	0.010
High density	0.026252467	2.56	0.014

The table 4.2 above presents the One-Sample T-Test results for the three types of samples (Low density, medium density, and High density). Form low density area, the mean Ni concentration is 0.0050522mg/kg. The t statistic is 2.45, and the p-value is 0.018, which is less than 0.05. This indicates that the mean Ni concentration significantly differs from the hypothesized mean at the 5% significance level. Moreover, in medium density area, the mean Ni concentration is 0.008364137 mg/kg. The t statistic is 2.67, and the p-value is 0.010, which is also less than 0.05. This indicates that the mean Ni concentration significantly differs from the hypothesized mean at the 5% significance level. High Density: The mean Ni concentration is 0.026252467 mg/kg. The t statistic is 2.56, and the p-value is 0.014, which is less than 0.05. This indicates that the mean Ni concentration significantly differs from the hypothesized mean at the 5% significance level. Therefore, the One-Sample T-Test results suggest that the mean Ni concentrations in all three types of samples (Low density, medium density, and High density) significantly differ from the hypothesized mean.

4.3.3 Comparison of Ni concentration

Furthermore, Figure 4.3 shows the variation of Ni concentration in rooftop dust samples collected from houses at a nickel mine.

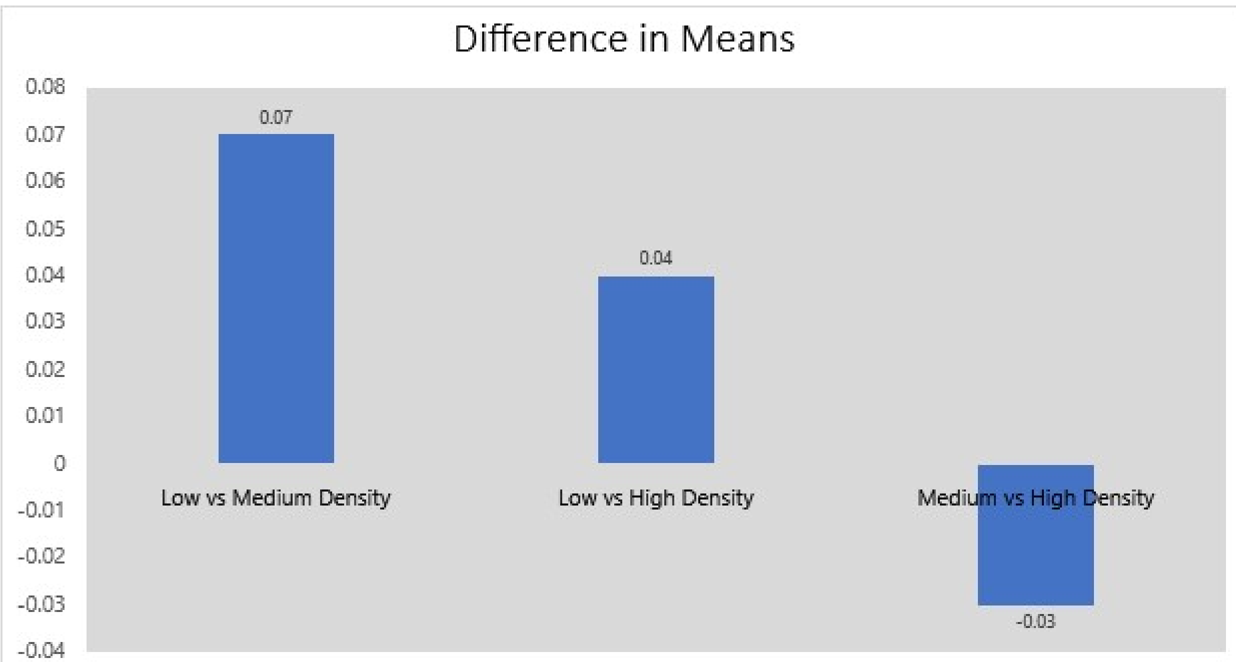

Figure 4.3 Difference in Means

Furthermore, Table 4.3 reveals a significant variation (p-value < 0.05) in Nickel (Ni) concentration across residential areas surrounding the mine. High density suburbs (0.026 mg/kg) had the highest average Ni concentration, followed by medium density suburbs (0.008 mg/kg), and then low-density suburbs (0.005 mg/kg). Notably, the difference in Ni concentration between high- and low-density suburbs (0.021 mg/kg, p-value = 0.001) and low and medium density suburbs (0.003

mg/kg, p-value = 0.018) was statistically significant. However, the difference between medium and high-density suburbs (-0.003 mg/kg, p-value = 0.230) was not statistically significant.

CHAPTER 5: DISCUSSION

5.1 Introduction

The chapter presents the summary of the study in which various areas pertaining to the research findings. The chapter will also present the conclusion based on the inferences from the previous chapter. Recommendations of the study will seek to inform policy in governance, mining sector and academic circles.

5.2 Summary of findings

5.2.1 The concentration of dust on rooftops of houses at a nickel mine

The findings from the study show that there is a significant variation in dust concentrations across different residential suburbs, with medium density suburbs having the highest average dust concentration, followed by low density and high-density suburbs. The differences in dust concentration between low and medium density suburbs, as well as low and high-density suburbs, were found to be statistically significant, whereas the difference between medium and high-density suburbs was not statistically significant.

To further analyze these findings in relation to previous studies, we can look at similar research on the impact of residential density on dust concentrations. One study that may be relevant is by Accardo, et al., (2021). This study found that higher residential density was positively associated with increased dust exposure, which aligns with the findings in the current study where medium density suburbs had the highest dust concentration.

In contrast, a study by Ali, et al., (2022) found that higher residential density was associated with lower dust concentrations. This contradictory finding contrasts with the results of the current study where medium density suburbs had the highest dust concentration. Comparing these findings with the current study, it appears that the relationship between residential density and dust concentrations is not consistent across all studies. This suggests that factors such as construction activities, traffic volume, and geographical location may also play a significant role in determining dust levels in residential areas. Further research is needed to explore these factors and their impact on dust concentrations in different types of suburbs.

5.2.2 The concentration of Ni in dust samples collected from rooftops of houses at amine

The findings presented in the study demonstrate a significant variation in Nickel (Ni) concentration across different residential suburbs and the results of the one-sample t-test conducted on the Ni concentration in settleable dust samples. In the section discussing the Nickel concentration in settleable dust samples on rooftops, the study revealed that the high-density suburbs had the highest average Ni concentration, followed by the medium and low-density suburbs. This finding aligns with previous studies such as the work by Carter, Andersen, Stagg, & Gaunt, (2023) which also reported variations in metal concentrations across different urban areas. A similar study by Begum, et al., (2022) found that residential areas with higher population density tend to exhibit higher levels of heavy metals in dust samples, supporting the current study's observations.

In the analysis of the one-sample t-test results, it was observed that the mean Ni concentrations in all three types of samples significantly differed from the hypothesized mean. This indicates that the Nickel concentrations in the dust samples collected from low, medium, and high-density suburbs were not consistent with the expected values. This finding resonates with the findings of the study conducted by El-Denglawey, et al., (2021) which also utilized one-sample t-tests to compare metal concentrations with established limits. The discrepancies between observed and expected Ni concentrations highlight potential environmental concerns in the studied areas, suggesting the need for further investigation and remediation efforts.

Contrasting these findings with prior research, the study at hand provides specific insights into nickel concentrations in settleable dust samples across different residential suburbs. While some previous studies (Abdelbaky, et al., 2021; Anyachor, et al., 2022) have focused on general heavy metal contamination in urban environments, this study delves into the specific nickel concentrations on rooftop dust, highlighting potential sources of exposure and contamination within designated areas. This focused approach adds granularity to the understanding of heavy metal distribution within urban settings and underscores the importance of targeted assessment and monitoring in high-risk areas.

5.2.3 Comparison of Ni concentration in rooftop dust against average soil/shale/earth' crust concentration

High density suburbs exhibited the highest average Ni concentration, followed by medium density suburbs and then low-density suburbs. The statistical analysis indicated that the differences in Ni concentration between high- and low-density suburbs, as well as between low and medium density suburbs, were statistically significant. However, the difference between medium and high-density suburbs was not statistically significant.

In comparing these findings to previous studies, it is important to note that the impact of proximity to industrial sources, such as a nickel mine, on environmental contamination has been well-documented in the literature. One study that relates to this finding is the research conducted by De Miguel et al. (2020), which investigated the distribution of heavy metals in soils of Madrid, Spain. The study found that areas near industrial activities had higher concentrations of heavy metals, including nickel, compared to control areas.

Conversely, a study by Hernandez et al. (2022) on nickel contamination in urban areas may provide a contrasting perspective. Smith et al. found that while industrial activities can contribute to nickel pollution in urban environments, other factors such as traffic emissions and building materials also play a significant role in determining nickel concentrations in residential areas.

5.5 Summary

The impact of mining activities on surrounding residential areas is a well-established concern, with dust generation and potential heavy metal contamination being key issues. This study investigated dust and Nickel (Ni) concentrations in settleable dust collected from rooftops near a Zimplats mine. The findings support current understanding that dust and Ni concentrations can vary significantly across residential areas. Our analysis revealed that medium density suburbs had the highest levels of both dust and Ni, followed by low and then high density suburbs. Interestingly, the difference in Ni concentration between high and medium density areas was not statistically significant, suggesting a potential influence of factors beyond just residential density. Further research is needed to explore this and other contributing factors, such as wind patterns and proximity to specific mining operations, to refine our understanding of dust and heavy metal dispersion patterns around mining sites.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study examined dust and Nickel (Ni) levels in settleable dust from rooftops near a Zimplats mine. While dust concentration peaked in medium density suburbs, Ni concentration was highest in high density areas, though not significantly different from medium density areas. Importantly, all suburbs exceeded clean air Ni standards, suggesting potential health risks. Our study highlights the importance of considering local factors beyond just distance from the mine. A key limitation is the short-term dust collection period. As a result, we recommend ongoing dust monitoring programs and further research on the influence of wind patterns and specific mining activities on dust and Ni dispersion. Additionally, studies on the health impacts of chronic exposure and effective mitigation strategies are warranted.

6.2 Recommendations

- Implement ongoing dust monitoring programs: Regular monitoring over an extended period can track dust concentration trends and inform the development of targeted mitigation strategies to protect residents.
- Conduct further research on dispersion patterns: Investigate the influence of wind patterns, proximity to specific mining operations, and other factors that might contribute to the spatial variations observed in dust and Ni concentrations. This will improve understanding of dust and heavy metal dispersion around mining sites and inform the design of more effective mitigation strategies.

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APPENDICES

Appendix 1: Permission letter

Gmail

Brian Smp <briansmp87@gmail.com>

Request for Permission and Assistance: School Research Project

2 messages

Brian Smp <briansmp87@gmail.com> Tue, Mar 12, 2024 at 6:39 PM
To: Patience Ncube <patience.ncube@cerbalancetafrica.com>

Dear Ms. Ncube

I am writing to request permission and assistance to utilize the laboratory facilities at your organisation for my school research project.

I am a student at Bindura University of Science Education, currently enrolled in BSc. SHEM. As part of my academic requirements, I am undertaking an in-depth research project on total Ni concentration in settleable dust on roof-top buildings near the Zimplats processing plant. To ensure the success and accuracy of my project, access to well-equipped laboratory facilities is crucial.

I therefore request permission and assistance to analyse my dust samples in your laboratory facility, and I would greatly appreciate any assistance or guidance that could be provided by your organisation in helping me achieve the objectives of my research project successfully.

I have attached a detailed project proposal that outlines the nature of my research and a letter from my school.

Thank you very much for your attention to this matter. I look forward to a positive response.

Sincerely,

Brian Phiri
BSc Student in Safety Health and Environmental Management
Bindura University of Science Education

Sender notified by
Mailtrack

2 attachments

BUSE Letter.pdf
398K

Research pro 4.docx
846K

Patience Ncube <patience.ncube@cerbalancetafrica.com> Sun, Mar 17, 2024 at 1:45 PM
To: Brian Smp <briansmp87@gmail.com>

Dear Brian,

As per our previous discussion, we are willing to assist you with your academic samples. However, in addition to the letter from your school that you are a student , we still need a written email or letter from your research supervisor stating that this is strictly for school research purposes and that no results should be published whatsoever in the nam of our organization.

If you could please provide another contact that we can use to verify the authenticity of this, that will help us assist you in your school research.

Note that our trained laboratory technicians are the ones to analyze the samples for you. We won't allow you to be near our equipment.

Regards,
Patience

https://mail.google.com/mail/u/0/?ik=eb689ca15b&view=pt&search=all&permthid=thread-a:r-5355083988510421782&simpl=msg-f:1793339213718570357&simpl… 1/2

Appendix 2: Approval Letter

ENVIRONMENTAL SCIENCE DEPARTMENT

Private Bag 1020
Bindura, Zimbabwe

Tel: 263 - 271 – 7531-6, 7621-4
Fax: 263 – 271 – 7534

Cell: 0735825158
Email: vamugure@gmail.com

BINDURA UNIVERSITY OF SCIENCE EDUCATION

22/11/ 23

To whom it may concern

I attest that the holder of this letter, Brian Phiri (B213229B) is an authentic student of Bindura University of Science Education studying towards a Bachelor of Science degree in Safety, Health and Environmental management. As part of their curriculum, they are required to conduct a research project which entails data collection. May you kindly assist him in this regard. For any queries, please be free to contact me

Yours Faithfully

T. Nyamugure (Chairman- Environmental Science)

CHAIRPERSON
Department Of Environmental Science
Faculty Of Agriculture And Environmental Science
Bindura University Of Science Education
P. BAG 1020, BINDURA
ZIMBABWE
OFFICIAL

Appendix 3: Consent Form

Dear [Participant/Homeowner's Name],

I invite you to participate in my research study titled "Total Ni Concentration in Settleable Dust on Rooftops of Buildings at a Mineral Processing Industry: A Case Study of Zimplats, Zimbabwe." The purpose of this study is to investigate the levels of nickel (Ni) in dust settled on rooftops in the vicinity of the Zimplats mineral processing industry.

Study Details:

- Dust Collection: I kindly request that you that you allow me to collect settleable dust from your rooftop using a clean container.
- Sample Labeling: Label the container with your name, address, and the date of collection.
- Safety Precautions: Use gloves during handling and avoid inhaling the dust.

By participating, you contribute valuable information to my research. Your confidentiality will be maintained, and your data will be used solely for research purposes.

Please sign below to indicate your consent:

I, __***Milton Kamuti***_ voluntarily agree to participate in the dust collection study described above.

Signature: ________________ Date: __________12/03/2024____________

Thank you for your cooperation!

Sincerely,

Brian Phiri

Appendix 4: Permission Letter

5/21/24, 4:19 PM Gmail - Fwd:

Gmail

Brian Smp <briansmp87@gmail.com>

Fwd:

tnyamugure tnyamugure <tnyamugure@buse.ac.zw>
To: "briansmp87@gmail.com" <briansmp87@gmail.com>

Sun, Apr 14, 2024 at 12:07 PM

---------- Forwarded message ---------
From: **Patience Ncube** <patience.ncube@cerbalancetafrica.com>
Date: Fri, Apr 12, 2024 at 5:32 PM
Subject: Re:
To: tnyamugure tnyamugure <tnyamugure@buse.ac.zw>

Dear Mr Nyamugure

Noted with thanks.

We will assist him accordingly.

Yours faithfully

Patience

Sent from Outlook for Android

From: tnyamugure tnyamugure <tnyamugure@buse.ac.zw>
Sent: Friday, April 5, 2024 2:04:05 PM
To: Patience Ncube <patience.ncube@cerbalancetafrica.com>
Subject:

Dear Ms Ncube
This is to confirm that Brian Phiri is a bona fide student in my department. He is in his final year studying towards a BSc in Safety, Health and Environmental Management. May you assist him to accomplish his research project whose purpose I guarantee is for academic purposes and nothing else beyond that. It is part of the requirements for the fulfilment of the programme needs.

Faithfully
T. Nyamugure (Chairman, Environmental Science

Appendix 5: Supervisor Acceptance Letter

Supervisor Acceptance Letter

The Chairman
Department of Environmental Science
Date: 19 September, 2023

I wish to inform you that I am accepting *Brian Phiri (B213229B)* as my student to guide his research work leading to attainment of a BSc. (Hons) SHEM degree with Bindura University Science and Education. I will supervise him throughout the research process.

Proposed title:

Total Ni concentration in settleable dust on rooftops of buildings at a mineral processing industry - case study of Zimplats, Zimbabwe

Sincerely,

A. Kanda (PhD PH, MSc WREM, BSc Hons Chem, PostGrad Dip WSS, Dip Ed)

Appendix 6: Antiplagiarism report

Bindura University of Science Education

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