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Chapter

Mobility of Trace Element Contaminants from Abandoned Gold Mine Dump to Stream Waters in an Agricultural Active Area

Godwin Okereafor, Elizabeth Makhatha, Lukhanyo Mekuto and Vuyo Mavumengwana

Abstract

In this study, the selected streams within the Blesbokspruit located in South Africa were characterised in this study. Because of prolonged mining activities coupled with ineffective management practices, several mine tailing (MT) dumps are widely distributed in this area. Metals and metalloid contamination from these tailing facilities have been reported to be major contributors to environmental hazards such as acid mine drainage (AMD). With increased agricultural activities in this area, an assessment of the general quality of water being utilised for irrigation purposes and feeding of farm animals becomes inevitable. A procedural method was implemented in a bid to identify relations between tailing and stream water contamination. Representative gold tailing sediments and water samples were collected, respectively. With the aid of X-ray fluorescence (XRF) and X-ray diffraction (XRD), the mineralogical characterisation of the tailing sediments was successfully carried out, while acid digestion using inductively coupled plasma-optical emission spectrometry (ICP-OES) was utilised in the determination of trace metal contents. Samples of different water sources were also characterised. There was a clear description of the link between tailings, water contamination and possible implications to animals and humans in the long run.

Keywords: contamination, livestock, acid mine drainage, water quality

1. Introduction

The mining of minerals such as gold, coal, titanium and other natural resources plays several roles in South Africa's emerging economy with many positive outcomes as well as negative consequences. Till date, the mining sector remains the largest employer of labour. Mining of various minerals is a common sight in the country but of late has become a public menace due to land degradation and contamination of major water bodies through the discharge of waste materials such as overburdens, waste rocks, tailings, slags, mine water and gaseous wastes.

The resource being mined, geology of an area and technology adopted are some of the factors that influence the nature, characteristic properties and level of mine waste generated at specific mines. Mining companies in South Africa, due to legislations and regulations pertaining to general waste management at mining sites, endeavour to manage waste generated during their operations in a bid to avoid the release of contaminants into the environment [1]. Unfortunately, some level of contaminants, which constitute crushed, sand-like materials, still finds their way into the ecosystem.

By definition, mine dumps, also known as residue stockpiles, refer to any debris, discard, tailing, slimes, screening, slurry, waste rock, foundry sand, beneficiation plant waste, ash or any other product derived from or incidental to a mining operation and which is stockpiled, stored or accumulated for potential reuse, or which is disposed of, by the holder of a mining right, mining permit, production right or an old order right [2, 3]. Generally, mine wastes are unwanted, currently uneconomic, solid and liquid materials found at or near mine sites that largely constitute one of the world's major waste streams due to their composition of high concentrations of elements and compounds that impact negatively on humans and animals, the surrounding environment and plants alike [4]. An alarming number of mine dumps often characterised by a complex mixture of metals and dust particles are located at several jurisdictions of the country. This implies that during windy conditions, exposure to dust could be high for close-by inhabitants. Other challenging issues associated with mine wastes include environmental impacts such as the loss of agricultural lands because of their conversion to waste storage facilities and the successive introduction of sediments and other impurities into adjoining surface and groundwater from water running over exposed chemically reactive wastes [5–8].

Most mine wastes have heavy metals (HMs) as a major component, and their continued circulation in soil and water puts the world in a nerve-wracking situation due to their toxic and deleterious effects [9]. HMs such as cadmium (Cd), thallium (Tl), zinc (Zn), lead (Pb), arsenic (As), mercury (Hg), chromium (Cr), copper (Cu), lead (Pb), iron (Fe) and nickel (Ni) are naturally occurring components of the earth's crust and are often referred to as metallic chemical elements with a relatively high density—at least five times the specific gravity of water [10]. At trace concentrations, HMs such as Cu, Cr + 3, Zn, Mn, Co and molybdenum (Mo) are of biological significance; however long-term exposures and high concentrations impact negatively on several biomolecules. It is noteworthy to mention that at very low concentrations, Hg, Cd, Cr + 6, As and Pb stand to be very toxic [11].

Sediments are vital components of aquatic habitat as they can retain contaminants that are not bioavailable to humans [12]. Pollutants are released into water bodies via processes such as sediment resuspension, desorption and redox reactions of sorptive substances. This further explains why sediments despite being reservoirs could at the same time act as likely source of pollutants in the aquatic system [12, 13]. Mine tailings (MT) having the possibilities of containing some HMs are seen in different areas of Blesbokspruit in Ekurhuleni Municipality, South Africa. Over the years, these mine tailings solidify, leaving mountainous structures made of very fine sand particles. Several agents of erosion such as wind and surface run-off after heavy rainfall transport sediments to surrounding water bodies (rivers). These rivers are major sources of water supply to agricultural lands and may constitute diverse environmental problems to humans, animals and plants [14].

A comprehensive understanding of the physicochemical features of soil and water pollutants provides a platform for careful soil management aimed at reducing the adverse effect of the pollutants on the ecosystem. Heavy metals from mine tailings in ionic solutions sometimes contaminate groundwater via leaching and are absorbed by plants; thus it is introduced to the food chain [15]. In another instance,

animals drink from stream waters containing these HMs. The final consumption of these plants and animals is of great concern due to danger of HM toxicity.

South Africa's agricultural sector had suffered immense setbacks in the recent past, owing to issues of water shortages and the problem of acid mine drainage (AMD), amongst others. These issues over the years have impacted adversely on the quality and quantity of farm produce. Due to irregular municipal water supply, farmers suffer economically in the quest for portable water; thus, they end up relying on surrounding stream water for their animals and crops. Following the growing numbers of small-scale farming in the Blesbokspruit area of Ekurhuleni, this study seeks to investigate the physicochemical features of selected stream waters and sediments from an abandoned gold mine tailing site with the goal of assessing the distribution of HMs in stream water and sediments from surrounding mining sites and the ecological risks of such HMs.

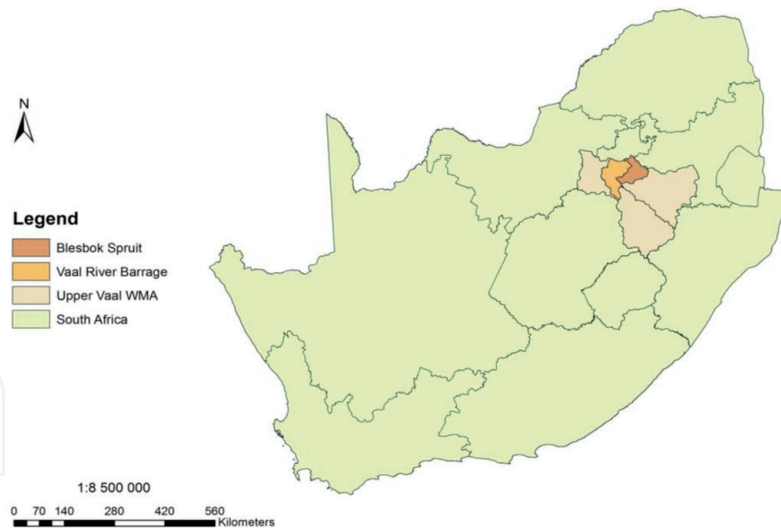
2. Sampling and samples

2.1 Description of the sampling site

Due to outraging scarcity of water resources, South Africa is referred as a semi-arid nation. Study materials were obtained from a mine tailing dump facility located within the Blesbokspruit catchment (26°10'12"S 28°27'52"E), Heidelberg (34°01'59"S 18°52'28"E) and Suikerbosrand (26°29'46"S 28°21'00"E) rivers, respectively, all of which constitute part of the Vaal River Barrage secondary catchment, located in the eastern region of the Gauteng Province. The Blesbokspruit catchment has in it an important and international wetland covering an area of about 1858 km² with a Ramsar recognition dated as far back as 1986. This wetland has a gold mine tailing dump located very close to it and provides support and habitat to several species of birds and plants [16]. Extended part of the study area is used for agricultural activities such as cultivation of crops and rearing of animals. The sampling sites (**Figure 1a**) were selected due to what seems to be the ironic presence of an abandoned gold mine tailing dump that has located next to it an artificial wetland. The wetland was supposed to aid in remediation of the discharge from the mines. In addition, an informal settlement characterised with mostly rural–urban dwellers that engage in farming activities was also in proximity. The rivers being considered in this study are to the best of our knowledge the major water sources for farming activities such as irrigation and feeding of local cows. The subsistence farmers within this area created artificial channels in a bid to redirect water from the streams to special reservoirs that service mostly the animals (**Figure 1b**). During rainfall and often windstorms, sediments from the tailing dumps get eroded into the wetland and subsequently into the surrounding rivers as a result of overflow and surface run-offs (**Figure 1c**).

2.2 Collection of samples and pretreatment

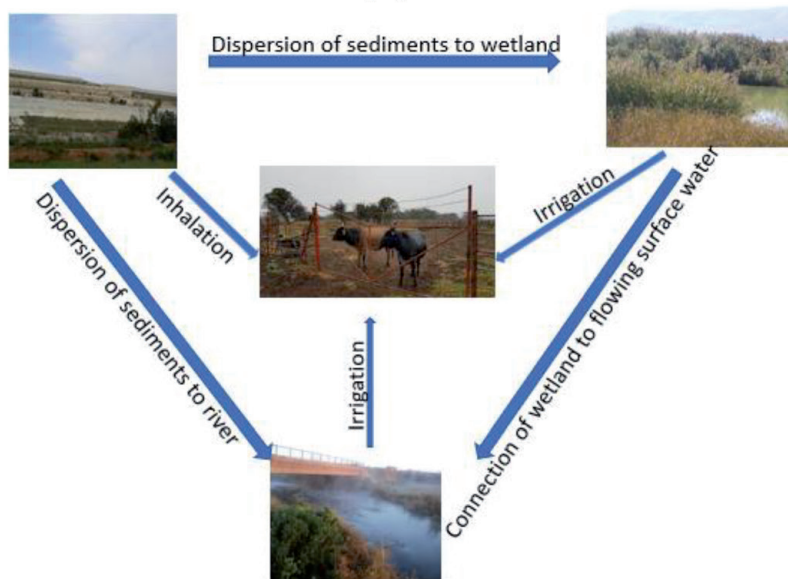
Using sterile bottles, water samples were randomly obtained from four sampling sites located at various directions and distances within the Blesbokspruit catchment. The water samples were assigned names: wetland (WL), Blesbokspruit (BS), Heidelberg (HB) and Suikerbosrand (SB). Soil samples (mine tailing sediments) were collected using a Teflon-coated soil auger and put in labelled polyethylene bags with clear designation MT1–MT4, respectively. The collected water samples from identified streams were stored in an insulated icebox and transported to the laboratory for storage at 4°C prior to further analysis. Collected soil samples were oven



(a)



(b)



(c)

Figure 1. (a) Map of South Africa showing the Blesbokspruit water catchment [17]; (b) study area showing tailing dump site, wetland and river; (c) transfer mechanism of trace metals/elements.

dried at 100°C and then stored in polyethylene bags for mineralogical and heavy metal analyses.

3. Analysis

3.1 Experimental analysis

Soil samples (tailing sediments) were oven dried at 100°C for 24 hours and mechanically pass through a sieve for particle distribution [18]. Approximately 2 g aliquots of the various soil samples were weighed into a Teflon crucible and then moistened with 100 mL of 1 M HCl acid in a microwave digestion system for the determination of the HCl-soluble fraction of heavy metals. The mixtures were covered and placed on a shaker for 12 hours at 130 rpm. The solutions were filtered using a Whatman filter paper and the filtrates stored in sterile bottles prior to being analysed for heavy metals using inductively coupled plasma-optical emission spectrometry (ICP-OES, GBC Quantima Sequential).

At very high pressure using a mould, 10 g of each of the representative soil samples were pelletised and then inserted in the sample compartment of an X-ray fluorescence (XRF; Rigaku ZSX PrismusII), to help in analysing the elemental compositions of the various minerals that make up the soil samples.

Morphological and mineralogical phase analyses of the tailing material were carried out using a scanning electron microscope (SEM, Tescan Vega 3 XMU) operated with an Oxford software and X-ray diffractometer (XRD; Rigaku Ultima IV), respectively.

In a soil-to-water suspension (1:2.5, w/w), the pH of representative soil samples was determined, while electrical conductivity (EC) was measured in a 1:5 soil-to-water suspension using a Crison multimeter model MM 41. Also carried out was an assessment of the total dissolved solids (TDS) in guidelines as stipulated by standard protocols of APHA [19].

3.2 Quality assurance and quality control

For precision analysis, all reagents used were of analytical standards, while apparatus and glassware inclusive were acid-washed with a 5% nitric acid. Multiple levels of calibration standard solutions are prepared from a Certipur ICP multi-element standard (Merck KGaA) by diluting the stock multi-elemental standard solution (1000 mg L⁻¹) in 0.5% (v/v) nitric acid. The calibration curves for all the studied elements were in the range of 0.01–1.0 mg L⁻¹. The conditions of the ICP were the same as described in a similar study as reported by Okereafor et al. [20].

4. Results and discussion

4.1 Particle size distribution of tailing sediments

Table 1 highlights the textural characteristics of the tailing sediments as gotten from mechanical sieve analysis. The main fractions of all tailing sediments were fine sand (0.150–0.075 mm) and clay (0.075–0.053 mm) with average composition of 66.03% for fine sand, 23.08% clay and 10.89% silt, respectively. With fine sand constituting a major part of the soil within the tailing dump site which are loose with little or no vegetation cover, wind and soil erosion particularly during continued rainfall are likely to occur with no restriction. The steep and inclined nature of

Sieve size (ASTM) % materials, retains (gms)	
No. 100	5.68
No. 140	45.51
No. 200	15.84
No. 270	10.25
PAN	22.72
Total	100
% Sand	67.03
% Silt	10.25
% Clay	22.72

Table 1.
Sieve analysis of the soil from the gold mine tailing.

the dump will support surface run-off of sediments which end up as discharge into the wetland.

4.2 Physicochemical analysis

Various indices such as electrical conductivity, pH, moisture, soil organic matter, texture, temperature, etc. contribute to the quality of soil and as such have great influence on its basic functions such as water retention, promotion of biodiversity, flood resistance, landslides, erosion and agricultural support [21]. However, the physicochemical properties of water to a large extent affect water usage. **Table 2** gives a summary of the observed physicochemical properties of water analysed in this study.

4.2.1 pH of stream water and soil samples

As a physical parameter, pH is a measure of the hydrogen ion concentration in the water/soil samples as ranked on a scale of 1.0–14.0. The lower the pH value of a material (soil/water), the more acidic it is, and the higher the pH value, the basic, or alkaline, it is. Generally, many chemical and biological processes are affected by pH as different organisms flourish better at different ranges of pH. A pH metre (Jenway model 3510) was used to determine the pH levels of the different water samples and sediments obtained from an abandoned gold mine dump. The observed pH values were within the limit of standard irrigation water (6.5–8.4), ranging from 6.31 to 6.35, thus validating the mobility and availability of heavy metals for plant uptake due to the presence of fewer H^+ ions [22]. A low pH of 4.21 was recorded for the tailing sediments which supports the heterogeneous deposits of sulphidic residues from mining activities. The ability of plants to take up nutrients could be affected by the acidity of tailings, hence the sparse distribution of vegetation at the mine tailing site. The identified heavy metals (Zn^{2+} , Ni^{2+} , Pb^{2+} , As^{2+} , Cu^{2+}) together with the observed pH of the tailings and wetland could result in acid mine drainage (AMD).

In the long run, the continuous erosion of the tailing sediments to surrounding water bodies could result in damage to metal pipes, tanks and fittings used for irrigation purposes by farmers. Consequently, the alkalinity (acid absorbing potential) of the various water samples based on the reported pH (6.31–6.35) is an indication that most of the available dissolved carbon dioxide have been converted into bicarbonate ion.

Sample names	pH	EC $\mu\text{S}/\text{cm}$	TDS mg/L
Wetland (WL)	6.31	948.00	606.72
Blesbokspruit (BS)	6.33	1040.00	665.60
Heidelberg (HB)	6.34	1235.00	790.40
Suikerbosrang (SB)	6.35	488.00	312.32
Mine tailing	4.21	132.00	84.48

Table 2.
Physicochemical analysis of sediments and water samples.

4.2.2 Electrical conductivity

The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC_w). EC measures salinity from all identified ions dissolved in a sample including negatively charged ions (e.g., Cl^- , NO_3^-) and positively charged ions (e.g., Ca^{++} , Na^+).

The values of electrical conductivity were determined by the concentration of ionic species contained in water. Using a standard of $84\mu\text{S}$ and a Crison multimeter (MM 41), water samples from Heidelberg (HB) recorded the highest electrical conductivity value of $1235\mu\text{S}$ followed by (BS) $1040\mu\text{S}$, (WL) $948\mu\text{S}$ and (SB) $488\mu\text{S}$.

A value of $132\mu\text{S}$ was recorded for the tailing sediments. The higher electrical conductivity recorded could imply the presence of higher dissolved salt or ion concentration which suggests that the samples have higher conductivity.

The observed high EC_w water on crop productivity will result in plants' inability to compete with ions in the soil solution for water (physiological drought). The higher EC implies less water is available to plants, despite the soil appearing wet, thus a reduced yield potential. This is because plants can only transpire "pure" water as usable plant water in soil solution decreases as EC increases.

4.2.3 Total dissolved solids

Using the expression $0.64 \times \text{EC}$, a measure of the total dissolved amount of substance was obtained. The lowest value was observed in the MT (84.48 mg/L) with HB recording the highest (790.40 mg/L). WL and BS both had 606.72 mg/L and 665.60 mg/L , respectively, while 312.32 mg/L was recorded in (SB). Crop yield can be adversely affected by the higher concentration of salt in water, thereby leading to soil degradation and pollution of groundwater. This parameter however did not deviate from the international standards, but the high concentrations of dissolved solids could result in some technical effects. Dissolved solids can produce hard water, which leaves deposits and films on fixtures and on the insides of irrigation pipes.

4.3 Chemical composition of tailing sediments

The energy-dispersive X-ray (EDX) microanalysis is a technique of elemental analysis associated to electron microscopy based on the generation of characteristic X-rays that reveal the presence of elements present in specimens. EDX technique is useful in the study of environmental pollution as it carries a huge vantage in the detection of heavy metals because they are nonbiodegradable and they can accumulate in ecological systems, thus resulting in pollution.

The scanning electron microscope (SEM) and EDX analyses (**Figure 2**) indicate homogenous distribution of granules throughout mining tailing samples with EDX analysis, further confirming elements such as Si (33.58%), Fe (19.12%), O (54.25%), Al (5.33%), K (1.76%) and Mg (0.44%) which could be compared to elemental composition revealed from X-ray fluorescence (XRF).

A typical mineralogical composition of the tailing sediments is shown in **Figure 3** as determined by XRD. The XRD results confirm the presence of silicate minerals which are quartz (SiO_2), marcasite FeS_2 , dialuminium silicate $\text{Al}(\text{SiO}_4)\text{O}$, pyrite (FeS_2) and gupeite (Fe_3Si). These could be linked with the elements identified from both XRF and ICP-OES.

Table 3 reports the partial compositional analysis of the tailing sediments collected from the abandoned gold mine dump. SiO_2 (81.82%) was shown to be the most abundant compound found in the tailing sediments. The oxides of Al, Fe and S were 6.93, 3.59 and 3.41%, respectively. Oxides of K were 1.98%, while those of Na, Mg, Ca, Mn, Zn, Pb and Cu were less than 1%.

ICP-OES analysis as illustrated in **Table 4** shows heavy metal concentrations in the sediments, wetland and surround streams. Filtrate from the tailing sediments showed very high concentration of various heavy metals with Cr recording the highest value of 43.13 mg/L, followed by Al 16.42 mg/L, As 10.17 mg/L, Pb 6.29 mg/L and Ni 1.34 mg/L, respectively. Considering the proximity and the fact that the artificial wetland and studied streams all get fed from the run-off water from the dump site during rainfall, it is not a coincidence that higher metal concentrations were observed. Many metal elements are essential nutrients for animals and crops but, in excess, may result in chronic or toxic effects.

Toxic substances are often in solution or as suspended solids in water which may affect the nutritional availability of toxic elements or substance in animals. Although short-term intake of toxic substance by animals has little or no noticeable effects, long-term exposure to those substances may result in serious damage. The extent of damage inflicted on animals by toxic elements may be determined by health status, age, and rate of consumption of toxic elements by the animals. However, the intake of toxic substances may not cause any measurable effect on growth, production, or reproduction yet may cause subcellular damage in farm animals which could be expressed as increased susceptibility to disease or to parasitic invasion.

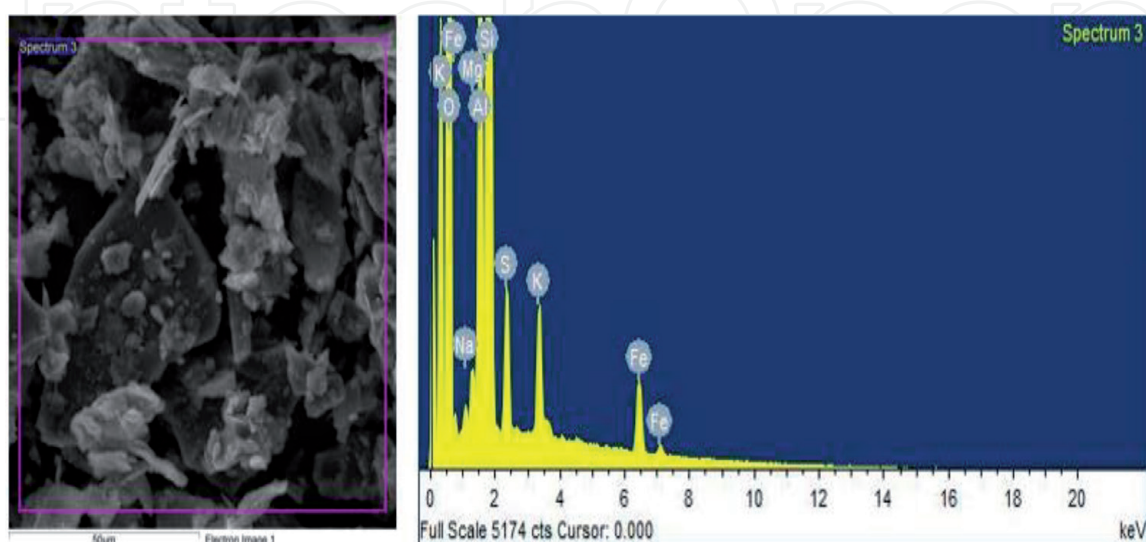


Figure 2.
SEM micrograph of tailing sediments.

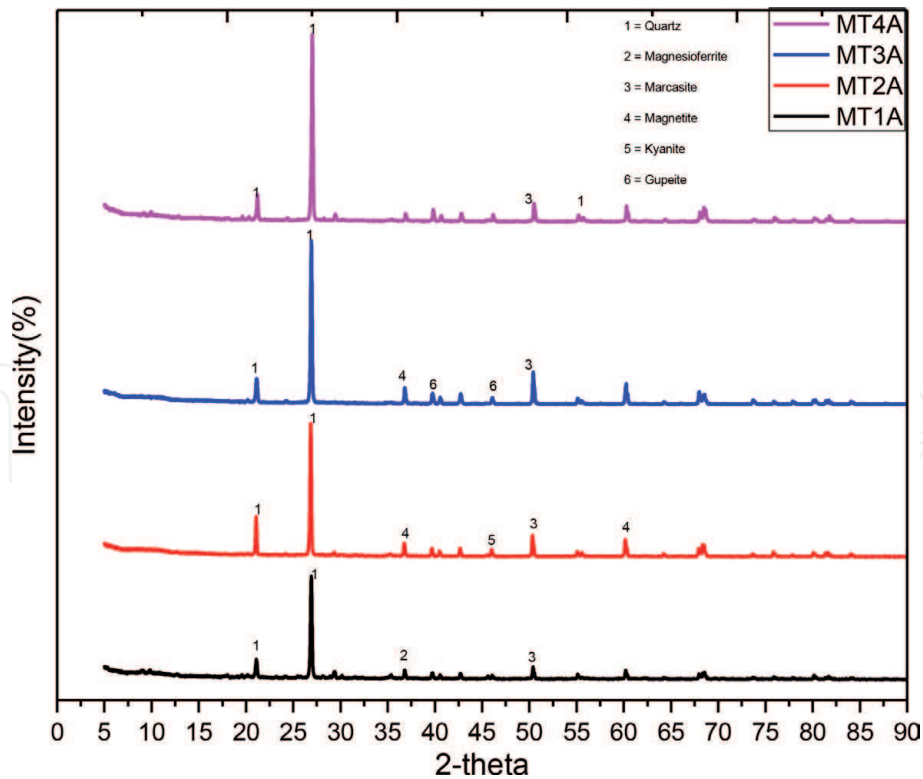


Figure 3.
 XRD patterns of the filtered sediments.

Oxides	MT1 conc. (%)	MT2 conc. (%)	MT3 conc. (%)	MT4 conc. (%)	MT _{Ave.} conc. (%)
SiO ₂	69.42	86.87	86.35	84.63	81.82
Al ₂ O ₃	9.09	6.03	5.18	7.42	6.93
Fe ₂ O ₃	5.87	2.37	2.60	3.53	3.59
SO ₃	8.94	1.44	2.32	0.92	3.41
K ₂ O	2.71	1.61	1.64	1.96	1.98
MgO	1.49	0.38	0.30	0.33	0.63
TiO ₂	0.58	0.49	0.51	0.49	0.52
CaO	0.90	0.23	0.55	0.13	0.45
Na ₂ O	0.27	0.14	0.14	0.16	0.18
Cr ₂ O ₃	0.15	0.17	0.15	0.14	0.52
PbO	0.04	0.03	0.04	0.04	0.04
NiO	0.11	0.01	0.02	0.01	0.04

Table 3.
 Results of XRF analysis detailing composition of tailing sediments.

With agricultural activities taking place around the vicinity of the tailing dump, farmers employ water from the streams in irrigation and feeding of animals despite the high heavy metal concentrations that apparently exceed the maximum permissible level of the US Environmental Protection Agency water composition [23, 24]. Al, As, Zn, Cd, Ni, Cu, Pb and Cr were all above the required standard. There is a strong likelihood of the run-off water from the tailing dumps and fine particles being blown during severe windstorm introducing heavy metals such as Al, As,

Metal	MT (mg/L)	WL (mg/L)	SB (mg/L)	HB (mg/L)	BS (mg/L)	DWAF (1990) livestock	WHO (2011) domestic
Al	16.42	2.98	1.76	1.77	0.33	5.00	0.90
As	10.17	7.78	4.27	2.65	9.70	0.50	0.01
Cd	0.46	0.35	0.35	0.58	1.10	0.50	0.01
Pb	6.29	2.83	2.70	2.76	2.53	0.05	0.01
Ni	1.34	0.03	0.15	0.09	0.70	1.00	0.07
Zn	0.28	0.68	0.50	0.19	0.34	25.00	3.00
Cr	43.13	46.75	36.48	59.59	32.13	<0.05	<0.05
Cu	0.03	0.38	0.43	0.29	0.29	0.50	2.00

Table 4.

Results of ICP-OES analysis on stream water samples and filtrate from tailing sediments showing heavy metal concentration.

Cd, Pb, Ni, Zn, Cr and Cu into nearby rivers. Direct consumption of such waters by humans and animals such as cattle gets into the gastrointestinal system, leaving some adverse effects by increasing the gastrointestinal pH, resulting in surficial coating on the stomach [25]. In addition, some of the trace metals get leached into the water table through percolation and are absorbed by plants which the animals feed from.

In humans, several forms of cancer have been linked to arsenic, and chronic exposure to arsenic through drinking water has been associated to health effects such as nervous disorders, high blood pressure, diabetes and hyperkeratosis [26]. However, there are little or no reports on the effect of arsenic in drinking water on the health and/or effect of farm animals. Arsenic availability in soil can disturb normal functioning of plant metabolism, consequently leading to stunted growth and low crop productivity [27]. Previous studies indicated arsenic to be responsible for reduction in gas exchange attributes (photosynthetic rate, transpiration rate, stomatal conductance) and chlorophyll concentrations [28].

The total aluminium concentration in a human body is approximately 9 ppm (dry mass) with an approximately daily intake of 5 mg, of which only a small fraction is absorbed. The high aluminium content of the various water sources observed may have negative impacts on plants, humans and animals. Various ailments of the nervous system, such as Parkinson's disease, amyotrophic lateral sclerosis (Lou Gehrig's disease) and Alzheimer's disease as well as functional lung disorder, may be experienced in humans [29]. There are currently no reports on aluminium toxicity to ruminants. However, there are indications about the risks of inducing either a phosphorus deficiency or a condition known as grass tetany when ruminants consume large amounts of aluminium from soil, aluminium-rich forages or water high in aluminium content [30]. In general, more soluble forms of aluminium in plants may pose some risk such as the inhibition of root elongation [31].

Plant growth and development is often affected adversely by cadmium, a non-essential element due to its high toxicity and large solubility in water [32]. The uptake of minerals by plants has been reported to be altered by cadmium which impacts on the availability of minerals from the soil as well as a reduction in the population of soil microbes [33]. Stomatal opening, transpiration and photosynthesis have been reported to be affected by cadmium in nutrient solutions, but the metal is taken up into plants more readily from nutrient solutions than from soil [34]. The accumulation of cadmium in humans could lead to renal failure,

decreased vitamin D synthesis and consequently osteoporosis. The high concentration of cadmium may adversely interfere with the metabolism of essential trace elements which in farm animals such as cattle could result in an unthrifty appearance; rough coat hair; dry scaly skin; dehydration; loss of hair from the legs, thighs, ventral chest, and brisket; mouth lesions; oedematous, shrunken scaly scrotum; sore and enlarged joints; impaired sight; extreme emaciation; and some atrophy of hindlimb muscles [35].

Despite plants being able to take up high levels of lead of up to 500 ppm from soils, as toxic pollutants, lead and some of its compounds can limit the synthesis of plant chlorophyll [36]. The growth of plants is often retarded by higher concentrations of lead. Crops cultivated in the study area stand a risk of suffering damage and reduced growth.

Besides gaining access into the food chain via plant uptake, humans, through water intake, consume more lead. With the alarming concentrations of lead shown in **Table 4**, inhabitants are likely to have excess lead intake which could, over time, result in paralysis, skin pigmentation and colic. Females may experience menstrual disorder, infertility and spontaneous abortion, while children may suffer lower IQs, behavioural changes and concentration disorder. Lead is the most common cause of cattle poisoning. Animals die or perform poorly after inadvertently ingesting lead either through feed or water. Gradual poisoning of the areas cannot be ruled out as evidenced from the tailing sediments. Lead when consumed by ruminants end up in the reticulum (fore stomach) which provides a reservoir from which it is absorbed into the bodies of cattle, sheep and goats. In older cattle and sheep, subacute lead poisoning is characterised by anorexia, rumen stasis, colic, dullness and transient constipation, frequently followed by diarrhoea, blindness, head pressing, bruxism, hyperesthesia and incoordination [37].

Chromium (Cr) occurs in the environment primarily in two valence states, trivalent chromium (Cr III) and hexavalent chromium (Cr VI), with the latter being more toxic.

The high concentration levels of Cr as contained in **Table 4** are worrisome as it is known from previous studies to be a toxic metal that can cause severe harm to plants depending on its oxidation state. Some of the toxic effects of Cr on plant growth and development include alterations in the process of germination and growth of roots, stem, and leaves, which may affect total dry matter production and yield [38]. Excessive Cr also impacts adversely on plant's physiological processes such as photosynthesis, water relations, mineral nutrition, oxidative imbalance and inhibition of enzymatic activities. Chromium can affect antioxidant metabolism in plant. The corrosive nature of some chromium (VI) compounds, when in excess, results in ulcerations, dermatitis and allergic skin reactions in humans. When inhaled on the other hand, it could lead to ulceration and perforation of the mucous membranes of the nasal septum, irritation of the pharynx and larynx, asthmatic bronchitis, bronchospasms and oedema [39]. In mammals, chromium (III) is an essential trace element involved in lipid and glucose metabolism [40]. Chromium (VI) as reported from previous studies adversely affected the developing embryo, causing retarded foetal development in cattle during gestation, resulting in reductions in the number of foetuses and foetal weight and a higher incidence of stillbirth and post-implantation loss [41].

5. Conclusion

This study revealed that the tailing sediments were largely comprised of fine sands that are loosely packed and prone to erosion, thus supporting the migration

of trace metal contaminants. The ability of plants to survive in the area based on the recorded physicochemical data such as acidity and electrical conductivity of the tailing sediments and water from wetland is daisy. A continuous erosion and surface run-off of sediments from the tailing dump site increases the migration of Al, As, Pb and Cr, which were observed to be in elevated concentrations, into the wetland and streams, thus endangering sustainable agricultural activities within the surrounding farmlands as water sources to farm facilities are highly prone to contamination from heavy metals trapped in tailing sediments especially given their high concentrations. The dispersion of such tailing sediments not only affects the agricultural activities within the studied area but may also have a health-related effect on the human population that reside in proximity to this mine dump. There should be metal speciation studies carried out to ascertain the extent of metal toxicity exposures within these areas.

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Conflict of interest

The authors declare no conflict of interest.

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