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Occurrence of Heavy Metals in Mining Areas Case of Tete Province in Mozambique

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Abstract

Agricultural and mining activities are extremely important in terms of human needs, as they provide resources for survival and well-being, in addition to being a source of income in the world. In Mozambique, fossil fuels are the energy base of modern industrial society, with mineral coal being the non-renewable energy source with the greatest availability capable of sustaining 150 years of consumption in the absence of all energy sources. There are several coal deposits in Mozambique, the most outstanding and one of the largest in the world being the coal basin of Moatize, Tete province, with estimated reserves of just over 2.5 billion tons. The transport of heavy metals in mines and steel industries has caused contamination of the soil and mainly of the water. On the other hand, the irrigation of plants with contaminated water generates numerous waterborne diseases and the direct consumption of this water gives rise to serious health problems for man and even animals. Mining activities must be carried out taking into account the risk of contamination by heavy metals. There are some techniques for removing heavy metals in water and soil, and some of them have certain limitations. The risk assessment is done through models based on statistical tests and laboratory tests, according to the parameter to be evaluated. The most common heavy metals are copper, zinc and cadmium.

Keywords: Heavy metals • Water contamination • Remediation • Mineral coal • Deposits from Moatize

Introduction

It is often thought that contamination by heavy metals has become critical worldwide, in addition to the environmental impacts of contamination by heavy metals in public cemeteries in Brazil, the consumption of contaminated water has generated concern for human health [1]. A case in Mozambique reports the application of coal tailings to remove hexavalent chromium from contaminated water [2]. According to the results obtained, the coal waste frequently deposited, inappropriately and without treatment near the Moatize mining areas, can be used for the treatment of water contaminated with chromium IV. The inadequate deposit of these wastes can cause negative effects such as deterioration in the quality of surface and groundwater, contamination of soils and plants in the area, reduction of biodiversity, air pollution and health problems.

Heavy metals are the most dangerous and bioavailable elements in the aquatic ecosystem. The effect of cadmium on calcium levels in bones of freshwater fish results in the destruction of the human body, as these effects are manifested in humans through lung cancer, kidney abnormalities, fertility, liver functions and bone fractures the metals cadmium and copper, sodium and chlorine contaminate the groundwater of aquifers. Mining raises the levels of heavy metals in the soil and its effects go beyond the limits established in Brazil, therefore, there is a need to assess the impacts of mining and industrial activities and, therefore, the due remediation [3].

Literature Review

For the present work, a bibliographic research was carried out on contamination by heavy metals. For the search for works as a source of research, the descriptors were used: Heavy metals, water contaminated by metals, risk assessment to human health, toxicity and copper mining, in the online scientific electronic library (scielo) database in the period of 2013 to 2023.

In Scielo's health science and environment division, 149 articles were released, in Portuguese, English and other languages. Among this amount, 20 articles were selected and selected in addition to the 10 articles already available from other sources, articles that emphasized contamination by heavy metals, the latter being previously provided by the professor who teaches the subject of scientific research methodology, resulting in a final sample of 30 articles to be reviewed. The analysis of the information was carried

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out through exploratory reading of the material found, in a qualitative approach.

Occurrence of heavy metals in mining areas

Assessment of the risk of contamination in soils and total and soluble contents in water by heavy metals carried out a study on heavy metals, density and microbial activity in soil contaminated by zinc industry waste, in order to evaluate the total and water-soluble levels of heavy metals, the density and activity microbe, where he found that the metabolic quotient proved to be a promising indicator of soil multi-contamination by zinc, cadmium and copper.

Water is a renewable resource; however, population growth and the irrational use of the resource have contributed to the stress of the water system [4]. Then, the issue of the degradation of water resources and its effects on human health was addressed, where data on the availability of water resources and the reflection on their degradation in human health were analyzed, having found that the deterioration of water quality, caused by sewage and human excrements, has given rise to waterborne diseases which consequently, every 14 seconds a child dies. Water scarcity is a response to social unrest.

Siqueira also verified the implications of using the geometries of the vertical plane normal to the underground flow and the prism in estimating the risk to human health due to the ingestion of groundwater contaminated by benzene.

In Southern Brazil, the physical-chemical variability of surface sediments in an unchanneled section of the Corrego Diluvio and the influence of the channeled section on sedimentary pollution were evaluated. The results indicate that the sediments of the unchanneled section of Corrego Diluvio are predominantly sandy, with heavy metal contents below the quality reference values, with quartz and feldspar predominating throughout the area [5].

One of the surveys of the reviewed articles focuses on evaluating the damage caused to plant tissues, produced by water contaminated with arsenic. During the field study, a bioassay was carried out using the *Vicia fabia* to assess the genotoxic damage with the micronucleus induction test by exposure to Zimapan and Pachuca waters.

The waters to be tested have similar characteristics, with the water from Pachuca having indices below the detention limits. By the micronucleus induction test, Pachuca water has high concentrations of arsenic. Starting from the hypothesis that the variations in the environment cause the washing of high amounts of toxic species that, in turn, through the food chain, reach living beings, it was proposed the accumulation of heavy metals in natural association, as a way to minimize the transport and propagation of metals [6].

The state management of the national water commission of Hidalgo is aware of the high concentrations of arsenic in the water supplied by the wells to the population of Zimapan, so it was decided to close some wells.

One way to assess cytogenetic damage is through the merismatic cell system, as this system is easy to monitor. In short, two water samples were taken, where it was found that the waters of Zimapan, Zimapan, in the treated samples, compared to samples of waters from Pachuva, show a statistically positive reduction in relation to toxic damage.

Reis, et al. studied heavy metals in soils and forage grasses irrigated with water from the Vieira River, Montes Claros, Brazil, contaminated with sanitary sewage with the aim of evaluating the areas irrigated with water from the Vieira River for contamination by metals heavy. It concludes that irrigation with polluted water from the Vieira River increased the concentration of nitrogen in the water, that of chromium, copper, nitrogen, zinc and lead in the soil and the concentration of zinc in forage grasses which resulted in soil pollution and contamination.

Barros, et al. used the models (Langmuir and Freundlich) to evaluate the mobility of copper and cadmium metals in an alluvial soil of the Capibaribe River, in Northeastern Brazil, through kinetic tests. Compared to the pseudoyfirst-order model, the pseudoysecond-order model better describes the copper and cadmium sorption kinetics. The Freundlich model, in relation to the Langmuir model, better describes the sorption isotherms for Cd and Cu.

Franco, et al. enrichment and bioavailability of toxic elements in intensive vegetable production areas, aims to identify the main factors responsible for changes in the pseudototal and bioavailable contents of Cd, Cu, Ni, Cr, Mn and Zn in soils under intensive cultivation of vegetables. The soils showed low contamination by these metals, with the exception of Cd which showed the highest contamination.

Magalhaes, et al. talks about zinc and copper fractions in oxisols of different textures fertilized with swine manure. By the Kruskalywallis test, higher concentrations of zinc in exchangeable form were observed in areas with greater use of swine manure and copper in residual form in areas with and without use of swine manure.

In studies of mobility of contaminants in sandy soils after the application of treated wastewater produced in the steel industry, According to Carvalho, after carrying out a modeling study of the dispersion of contaminants in the soil with wastewater produced and treated in a steel industry, it is observed that wastewater applications in sandy soils with clay content of up to 54 g/kg and organic matter content of up to 1.03 g/kg present an environmental risk in terms of groundwater contamination. A study evaluating soil contamination by heavy metals in public cemeteries in the municipality of Lages, Southern Brazil, with a view to identifying the adequacy of funerary activities in two public cemeteries in the municipality of Lages, shows that the soils of the areas under study, they have adequate physical characteristics for funerary activity, however, they do not have adequate chemical characteristics [7]. According to Khan 2022, with regard to phytoremediation of toxic heavy metals in polluted soils and waters in Dargai Malakand Kyber Pakhtunkhwa district, Pakistan, based on calculated Bio Concentration Factor (BCF) and Translocation Factor (FT), the maximum BCF for zinc was recorded for the roots of Peris travela (3.93), while the minimum was recorded for the leaves of verbas cum tipus (0.306).

The root of *Pteris vittata*, the highest BCF value for chromium was recorded for *Populus nigra* roots (0.717) while the lowest was for *Persicaria maculosa* leaves (0.031). The highest TF values for iron, zinc and chromium were observed for *Pteris vittata* (0.988), *Verbascum thpsus* (0.944) and *Xanthium strumairum* (0.968), respectively. In conclusion, all selected plants have the potential for bioaccumulation of heavy metals and are recommended for planting in the contaminated area. In 2020, several studies were carried out on contamination by heavy metals. As for the potential of phytosorption of metals from hydrocotyle ranunculoides to mitigate water pollution in high Andean wetlands of Peru, the use of aquatic plants in the treatment of polluted water shows efficiency in the removal of heavy metals [8].

In the recovery of aquatic environments through the absorption of trace elements by the root, the disadvantage of this technique of removal of heavy metals is that some Hipe plants accumulate only a few trace elements. The advantage is that it has a low maintenance cost and is considered ecologically correct and easy to accept by the general public [9]. A study was also carried out on the growth and chromium content of castor bean grown in soil that received tannery and carboniferous residues in order to evaluate the residual effect of successive additions of tannery and coal mining residues on the chemical properties of the soil. And the accumulation of chromium in castor bean. Among the treatments applied, it was possible to verify that the treatment with the addition of chrome sawdust showed a higher yield of dry mass and there was no harmful effect from the applications of this residue, but rather greater vegetative growth of plants in the soil subjected to this treatment [10].

For the removal of copper in aqueous media, the Langmuir and Freundlich models were applied in the study of banana peel as a copper (II) bioadsorbent in aqueous media. Although synthetic materials are more efficient in removing heavy metals in aqueous solution, however, they add high costs compared to bioadsorbents. Biosorbents stand out for being abundant, renewable and inexpensive for remediating effluents with heavy metals in ionized form, which are favorable for removing copper in aqueous media [11]. As for the phytotoxicity associated with microcystins, it was proposed to monitor food in order to avoid exposure to contaminated water, since the phytotoxicity of microcystins causes a reduction in protein phosphatase 1 and 2A, oxidative stress and a decrease in photosynthetic activity [12]. In the observation of density effects in the oxidizing solution of sodium persulfate in intergranular aquifer and fractured aquifer contaminated by chlorinated ethenes, the contaminated area was remediated by chemical oxidation through sodium persulfate. During the remediation, considerable oscillations were observed in the concentrations of sulfate dissolved in groundwater. Highlighting the removal of metals from the water of the Yarinacocha lagoon with activated carbon from cocoa husks, shows that the removal of metals from water with activated carbon from cocoa husks is feasible through thermal activation, carbonization and modification time.

To analyze the lead and cadmium content in water and sediment and the physical and chemical parameters in water, determine the enrichment factor and the rate of accumulation of lead and cadmium in sediments and identify the water quality based on the pollution index, statistical techniques were applied, principal component analysis and pearson dynamics. The lead and cadmium contents observed were 3.09 and 1.88 mg/L respectively, thus exceeding the quality standard and the sediment did not meet the quality standard. The enrichment factor and the lead and cadmium content index, 0.36 and 0.07 shows that the downstream waters were not contaminated, however, considered unfit for human consumption. The pollution index shows it has been polluted. The river waters can only be used for Tjahjono irrigation [13].

Assessment of contamination risk in mining activities in Moatize, Mozambique

According to Barbosa 2017, coal mining activity increases the production of tailings that return to the mining pits in Moatize, causing acid mine drainage. In response to this problem and as an alternative for the use of these wastes, they are applied in the treatment of liquid effluents as solid solvents for the removal of chromium IV from water contaminated. Due to its carcinogenic and mutagenic effects, toxicity, abundance and tendency to persist and accumulate, widely used in various industries, chromium IV is the most prominent heavy metal and is highly harmful to living organisms. The solid was used in two different particle sizes, between 0.7 and 1.5 mm and smaller than 0.074 mm. Another way of removing chromium from contaminated water is sorption, due to its flexibility in dimensioning and operation and because it is recognized as an efficient and economical technique for the treatment of water contaminated with heavy metals.

According to Nascimento and Cunha, the soils of scheelite mines are sources of contamination by heavy metals. A study was carried out in order to evaluate the effect of the exposure time of overburden and waste piles that do not comply with environmental protection measures on the stage of soil contamination by heavy metals in the Scheelita mines. it was found that regardless of the exposure time of sterile piles, protection and recovery measures are important for the supply and availability of heavy metals, this because the increments in the levels of heavy metals resulting from the exploitation of Scheelite present contamination scenarios environmental impact at similar stages in active and decommissioned mines. Evaluated the sorption of lead, chromium, cadmium and arsenic by two soils, with doses of 1.2 and 4% of Portland cement. The mixture of the two soils under study with cement shows a high retention capacity for heavy metals, taking into account that the addition of cement to the soil contributes to raising the PH in the medium. Mining activity has devastated the world with regard to contamination by heavy metals, such that studied the increase in environmental risk due to contamination by heavy metals caused by a copper mining activity in Southern Brazil.

Brazil. The objective was to evaluate contamination by heavy metals resulting from mining, for this purpose, samples were taken at two points in the Joao Dias stream: Station 1 y bottom area and station 2 y contaminated area. Due to the potential risks that heavy metals and toxicity pose to human and ecosystem health, special attention is required to sulphide mining facilities and to the manifestations of operation in the watercourses drained from Corrego Joao Dias.

To assess the risk associated with contamination by heavy metals, it was suggested to separate the levels of natural and anthropogenic heavy metals, identify and quantify possible changes due to mining activities in the availability of metals in solid phases, sediments and suspended solids, quantifying the increment of risk potential that can be attributed to mining activities relative to naturally occurring risk potential [14].

Results and Discussion

Results show that the mining activity in the copper mines of Camaqua increases the total concentrations of heavy metals in the waters where the basin is drained, in this case, the Corrego Joao Dias. For a more conclusive answer, after the risk assessment for the daily intake of heavy metals, it is concluded that, unlike the contaminated area, there is a danger index lower than the unit for the background area, indicating the absence of any probable threat public health. In the contaminated area, the effects of daily ingestion of heavy metals are worrying.

Plant tolerance to heavy metals

Santos, et al. cites the physiological behavior of *Latuca sativa* and tolerance to heavy metals lead nitrate and silver nitrate. It is known that high concentrations of heavy metals generate numerous carcinogenic diseases, in addition to causing damage to the central nervous system and the liver, kidney, hematopoietic and skeletal systems, which is why limits and laws governing the concentrations of heavy metals in agricultural soils have been established. By the national council for the environment. Due to research, the maximum acceptable dose of silver is lower compared to the maximum acceptable dose of lead. *Latuca sativa* has a high ability to germinate under silver and lead stress. During research, an assessment was made of the cadmium tolerance and bio-sorption potential of *Bacillus cereus* GCFSD01 isolated from soil contaminated with cadmium, in order to reduce toxic metals from the environment through the application of bacterial isolates resistant to heavy metals. Studies carried out indicate that the native bacterial strain GCFSD01 *B. cereus* isolated from the soil of Faisalabad Pakistan had cadmium tolerance capacity and bio-sorption potential [15].

Assessment of the risk of contamination in fish and animals

Research on the influence of cadmium on calcium levels in the skeleton of freshwater fish indicates that cadmium was bio-accumulated in the bones of the fish and caused toxicity in the skeleton of the fish [16]. In 2023 Khan conducts a potential ecological risk assessment of toxic metal (lead) in contaminated grasslands in the vicinity of the suburban town: Soil VS Forage VS Livestock to analyze lead contamination in the food chain under three different irrigation sources: Soil, canal and wastewater. After collecting samples of soil, plants and animals, it was concluded that domestic animals had lead poisoning because the soil and forage plants constantly accumulated metallic lead. In the assessment of mercury contamination in the Amazon, high concentrations of mercury were detected, not being able to state any negative consequences and more data are needed to understand the relevance of these concentrations for cats in the Amazon region [17].

Environmental pediatrics

In 2011, Valenzuela, highlighted in environmental pediatrics, with the aim of raising awareness among parents and guardians about the numerous conditions and dangerous domestic situations to which children are exposed [18]. According to Siqueira 2017, taking into account the potential, effects on health and advances in prevention in environmental pediatrics, there are implications for using the geometries of the vertical plane normal to the underground flow and the prism in estimating the risk to human health due to water intake. Underground contaminated by benzene. The most used transport model is the Domenico model, which applies to a normal plane or underground flow, and cannot be applied to wells or trenches. According to the WHO, more than 3 million children under 5 years of age die every year due to exposure to environmental factors that have threatened human health. 30 to 40% of the diseases to which children are vulnerable are associated with environmental factors such as contaminated water, lack of adequate sanitary facilities, air pollution, disease vectors, chemical risks, injuries and accidents. This vulnerability makes environmental pediatrics a fundamental issue to prevent or minimize some of the risk facts [19].

Source age estimation in areas contaminated by gasoline with ethanol

Muller, Rosario, and Corseuil, 2013 carried out a study on forensic investigations and estimation of source age in areas contaminated by gasoline with ethanol. The objective is to conduct a forensic investigation based on the SCBR software for estimating the age of the source in areas contaminated by gasoline with ethanol in order to test the potential of the featured software.

According to studies carried out in the field, it can be stated that, due to the increasing use of fuel worldwide, there has been an increase in the risk of environmental accidents with compounds such as ethanol [20].

Conclusion

Generally, several methods are applied for remediation, although they are still not sufficient to reach the level of maximum concentrations of acceptable contaminants. Therefore, the scientific

community saw the need to expose human beings to a risk assessment and associated this hypothesis with remediation plans. From a scientific point of view, applications that deal with risk assessment do not have a high capacity to represent the most diverse forms of release and transport of contaminants between physical media, in addition to the limitation of not being applicable to all possible types from sources of contamination and therefore the results of the assessment are unreliable. The most used transport model is the Domenico model, which applies to a normal plane or underground flow, and cannot be applied to wells or trenches. Due to the limitations that the different models present, solutions were also proposed for risk assessment, such as a fountain with a vertical plane geometry normal to the underground flow and a prismatic fountain. In view of the objective of this research, according to the observed results, it is concluded that the prismatic source offers better results regarding the risk assessment to public health, not diminishing the importance of the geometry of the vertical plane for the simulation of the transport of contaminants in the most cases.

In assessing the risk of mercury contamination in animals, the implications of high mercury concentrations in felines were not indicated, thus requiring a thorough study of the highlighted content.

Recommendations

Since there is no conclusive answer on the assessment of the risk of mercury contamination, an investigation is recommended so that this metal can be removed in case there are negative consequences for cats due to mercury ingestion.

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