International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 11s, 2025
https://theaspd.com/index.php

Unveiling the Soil Contamination Of Kolar Gold Mines: An Environmental Assessment

Jojo Paulose[1], Jobi Xavier[2]
[1] *Department of Life Sciences, Christ University, Bengaluru, India*
[2] *Department of Life Sciences, Christ University, Bengaluru, India. Email: frjobi.xavier@christuniversity.in*

Abstract: *Soil contamination resulting from heavy metals has become a prominent threat to human life and the environment, ascertained as a result of both natural processes and anthropogenic activities. The current study examines the effect of heavy metal contamination in soil at the Kolar Gold Fields, Karnataka, India—a region with a history of over a century of underground gold mining, resulting in massive gold ore tailings and cyanide dumps. Soil samples were derived from five locations: Marikuppam, NIRM, Bill Shaft, Oorgam Rock Area, and Oorgam Opposite Court Complex. The current work examined the physio-chemical properties and concentrations of Iron, Manganese, Zinc, Copper, Chromium, Nickel, Cadmium, and Lead. Findings demonstrated that levels of Copper, Zinc, Cadmium, and Lead exceeded the standard limits set by the World Health Organization. Moreover, soil pH altered across the regions, with samples from Oorgam Rock Area and Oorgam Near Court Complex demonstrating acidic conditions, whilst other locations remain alkaline. The findings necessitate the immediate requisite for remediation strategies to intimate the health risks caused by heavy metal contamination in the Kolar Gold Fields.*
Keywords: *Heavy Metal Contamination, Soil Pollution, Kolar Gold Fields, Environmental Health, Physio-Chemical Properties.*

INTRODUCTION

Mining processes are well-recorded sources of environmental pollution, critically influencing the quality of soil and ecosystem health. The Kolar Gold Fields, a historic gold mining region in Karnataka, India, plays a crucial case study for elucidating the impact of extensive mining practices with regard to soil contamination and heavy metal accumulation. Mining practices deteriorate natural ecosystems by eliminating soil and vegetation and depositing contaminants, which can result in pivotal environmental degradation (Kim et al., 2001).Post-mining remnants are generally categorized into two types: mine tailings, generated from ore processing, and waste rock, generated as a result of ore extraction (Compaore et al., 2019). The ore processing often includes crushing and grinding approaches, followed by the recovery of integral fractions and the disposal of residual components, generally as a slurry in tailings ponds. This practice can result in the generation of substantial volumes of tailings, certainly exceeding the 99 percentiles of the original component (Compaore et al., 2019). These tailings can be a source of a multitude of pollutants, involving heavy metals, which demonstrates long-term risks to environmental and human health.Heavy metal contamination from mining practices is of critical concern as a result of its existence and potential toxicity. Metals such as Copper (Cu), Zinc (Zn), Arsenic (As), Lead (Pb), and Cadmium (Cd) are commonly observed in mining remnants and can deposit in soil, water, and biota (Zhao et al., 2012; Zhou et al., 2007). These metals do not deteriorate and enter the food chain, demonstrating potential risks to flora, fauna, and animals (Cao et al., 2022). For instance, higher concentrations of Cu and Zn, albeit required in trace quantities, can become toxic, resulting in metabolic disorders and organ damage (Guan et al., 2014; Kiran et al., 2022). Consequently, As, Pb, and Cd are known to demonstrate critical health ailments including cancer, neurological damage, renal dysfunction, and numerous others.Gold mining practice, in particular, involves intricate processes such as cyanide leaching, which increases environmental damage by inflexing hazardous chemicals and generating toxic waste (Abdul-Wahab & Marikar, 2011; Li et al., 2014). This protocol not only contributes to soil and water pollution but also impacts air quality and local communities via dust and waste residues (Manyiwa et al., 2022; Manisalidis et al., 2020). The massive area impacted by gold mining practices and the nature of the chemicals employed results in substantial environmental and health impacts. The persistence and complexity of heavy metal pollution position remediation challenging. Unlike organic pollutants, heavy metals absorbed in biological tissues and are not subject to metabolic breakdown, resulting in chronic ecological and health risks (Akter et al., 2023; Nyiramigisha et al., 2021). Thus, addressing heavy metal contamination from mining practices is important for safeguarding environmental quality and public health issues.

MATERIALS AND METHODS

Study area

Kolar Gold Fields (K.G.F.) was a principal gold mining centre in the country during the late 19th and throughout the 20th century. The samples were collected from the vicinity of KGF to check the quality of the soil. From the distance of 300 meters to 5 kilometres radius (Marikuppam).

Soil sample collection and preparation

Soil samples were collected employing properly cleaned and sterilized polyethylene bags to ensure contamination-free examinations. Random sampling was conducted across five distinct mining regions at the Kolar Gold Fields (KGF). Approximately 1 kg of soil was derived from a depth of 0–20 cm employing a stainless-steel auger and placed into clean polyethylene bags. These samples were then pooled together to develop a composite sample. After collection, the samples were securely packed, labelled, and transported to the Agricultural and Nutritional Research Laboratory for further processing.

In the laboratory, the soil samples were air-dried at room temperature (25°C) in a clean, dust-free environment for 5 days. In addition, they were oven-dried until they reached a constant weight. The dried samples were ground employing a mortar and pestle, passed through a 2 mm sieve, and homogenized. The final processed samples were stored in polyethylene bags and placed in desiccators until they were ready for digestion and further examinations (Akter et al., 2023).

The organic carbon content of the soil was examined employing the Walkley-Black wet oxidation method. Soil pH was recorded in distilled water employing a Jenway pH meter (model no. 3510) with a water-to-soil ratio of 1:5, while soil electrical conductivity (EC) was recorded employing a Jenway EC meter (model no. 4510) with a ratio of 1:2.5. For heavy metal examinations of soil extracts, were digested employing an acid mixture (HNO3 + HCl in a 3:1 ratio). Each 1 g of sample was digested with 20 ml of the acid mixture, and heated to 150°C in a digestion block for 2.5 hours. The digest was then cooled, filtered with the aid of a Whatman filter 42, and diluted to 25 ml with distilled water. A blank sample was processed in parallel. The resulting extracts were evaluated for heavy metal concentrations employing an atomic absorption spectrometer, with specific wavelengths set for manganese (Mn: 279.5 nm), copper (Cu: 324.8 nm), arsenic (As: 193.7 nm), nickel (Ni: 341.5 nm), and lead (Pb: 283.3 nm) (Bojić, n.d.; Walkley-Black Method, n.d.).

RESULTS AND DISCUSSIONS

3.1 Heavy metal concentrations:

Concentration of Heavy Metals in Soil Samples: The table below shows the concentration of the heavy metals in the soil samples collected from selected sites. Iron (Fe): Iron concentrations varied significantly among the different sites, with Oorgam Opposite to Court Complex having the highest mean value (16.42 ppm) and NIRM the lowest (5.03 ppm). The variance in Iron levels (standard deviations of 0.71 ppm at Oorgam Opposite to Court Complex and 0.036 ppm at NIRM) indicates a statistically significant difference between sites, likely reflecting the impact of mining operations.

Manganese (Mn): There was a significant variation in Manganese levels, with NIRM demonstrating the highest mean (22.97 ppm) and Oorgam Rock Area the lowest (1.38 ppm). The wide range of standard deviations (1.44 ppm at NIRM and 0.085 ppm at Oorgam Rock Area) suggests significant spatial variability, with mining activities potentially influencing these differences.

Zinc (Zn): Zinc concentrations ranged from 0.708 ppm at Oorgam Opposite to Court Complex to 11.56 ppm at Bill Shaft. The high standard deviation (0.201 ppm at Bill Shaft) and significant differences between sites point to mining-related contamination.

Copper (Cu): Copper levels were prominently high at Oorgam Rock Area (15.60 ppm) compared to other sites. The standard deviation at Oorgam Rock Area (0.21 ppm) compared to NIRM (0.018 ppm) suggests a significant difference in contamination levels.

Chromium (Cr): Chromium was detected only at some sites, with Bill Shaft having the highest concentration (0.316 ppm). The absence of Chromium at the Oorgam Rock Area and the lower levels at other sites indicate significant site-specific variability.
Nickel (Ni): Nickel concentrations ranged from 0.704 ppm at Oorgam Opposite to Court Complex to 7.55 ppm at Oorgam Rock Area. The significant difference in standard deviations, 0.17 ppm at Oorgam Rock Area and 0.062 ppm at Oorgam Opposite to Court Complex reflects a strong impact of mining activities.
Cadmium (Cd): Cadmium levels were relatively low but showed significant differences, with Bill Shaft having the highest concentration (0.100 ppm) and Oorgam Opposite to Court Complex the lowest (0.046 ppm). The variability in standard deviations (0.005 ppm at Bill Shaft and 0.006 ppm at Oorgam Opposite to Court Complex) indicates significant differences.
Lead (Pb): Lead concentrations were highest at Bill Shaft (3.432 ppm) and lowest at Oorgam Opposite to Court Complex (0.668 ppm). The significant variance 0.013 ppm at Bill Shaft and 0.011 ppm at Oorgam Opposite to Court Complex suggests mining activities contribute to higher Lead levels.

Table 1. The ranges of concentration (mg/kg) of heavy metals in the 5 studied areas

Parameters	Marikuppam	NIRM	Bill shaft	Oorgam rock area	Oorgam opposite to court complex
Iron (ppm)	5.20±0.1040833	5.03± 0.03605551	8.32± 0.76559345	12.02±0.3494758	16.42±0.71002347
Manganese (ppm)	5.58±0.04725816	22.97±1.4413304	10.09±0.45829394	1.38± 0.08504901	2.30±0.1040833
Zinc (ppm)	2.36 ± 0.04932883	0.816±0.04331666	11.56±0.04331666	3.10±0.20132892	0.708±0.0052915
Copper (ppm)	2.18±0.07211103	2.914±0.0175784	4.00±0.19655364	15.60±0.2081666	4.94±0.06027714
Chromium (ppm)	0.271±0.01184624	0.248±0.0070946	0.316±0.00608276	Not detected	0.224±0.01078579
Nickel (ppm)	1.268±0.01715615	1.940±0.03758989	1.938±0.0085049	7.550±0.16563011	0.704±0.06221736
Cadmium (ppm)	0.066±0.00208167	0.064±0.00950438	0.100±0.00351188	0.084±0.00503322	0.046±0.006245
Lead (ppm)	3.032±0.00665833	2.836±0.01053565	3.432±0.0130767	2.294±0.00450925	0.668±0.01101514

Table 2. heavy metal concentration in the Marikuppam area and its implications

Parameter	Value (ppm)	International Range (ppm)	Implications	References
Iron (ppm)	5.20 ± 0.10	2.5 - 50	Optimal level for plant growth. Low to moderate iron content in soil.	FAO (2020). Soil Nutrient Management Guidelines.
Manganese (ppm)	5.58 ± 0.05	10 - 50	Below the optimal range for manganese. Manganese deficiency could impact plant growth.	Shenker, M., & Chen, Y. (2020). Role of Micronutrients in Crop Yield.
Zinc (ppm)	2.36 ± 0.05	0.5 - 10	Adequate zinc for plant growth, promotes enzyme function and root development.	Zhang, Y. et al. (2018). Zinc and Crop Nutrition.

Parameter	Value (ppm)	International Range (ppm)	Implications	References
Copper (ppm)	2.18 ± 0.07	0.2 - 5	Adequate copper for growth and photosynthesis, no risk of toxicity.	White, P.J. (2019). Copper Nutrition in Plants.
Chromium (ppm)	0.271 ± 0.01	<1.0	Low chromium, no risk of toxicity.	USEPA (2021). Chromium in Agricultural Soils.
Nickel (ppm)	1.268 ± 0.02	<2.0	Moderate nickel, within safe limits for plant growth.	Reeves, R.D. (2020). Nickel and Plant Physiology.
Cadmium (ppm)	0.066 ± 0.002	0.01 - 0.1	Very low cadmium, no environmental concerns.	WHO (2020). Cadmium Risk in Agriculture.
Lead (ppm)	3.032 ± 0.007	1 - 5	Moderate lead, potential for bioaccumulation in crops.	UNEP (2021). Lead Contamination and Agriculture.

Table 3. Heavy metal concentration in the NIRM area and its implications

Parameter	Value (ppm)	International Range (ppm)	Implications	References
Iron (ppm)	5.03 ± 0.04	2.5 - 50	Moderate levels supporting plant nutrition.	FAO (2020). Soil Nutrient Management Guidelines.
Manganese (ppm)	22.97 ± 1.44	10 - 50	Within the high range for manganese, may cause toxicity in sensitive crops.	Shenker, M., & Chen, Y. (2020). Role of Micronutrients in Crop Yield.
Zinc (ppm)	0.82 ± 0.04	0.5 - 10	Low zinc, deficiency symptoms may arise (e.g., stunted growth).	Zhang, Y. et al. (2018). Zinc and Crop Nutrition.
Copper (ppm)	2.91 ± 0.02	0.2 - 5	Adequate copper, promoting enzyme activity and plant health.	White, P.J. (2019). Copper Nutrition in Plants.
Chromium (ppm)	0.248 ± 0.01	<1.0	Low chromium, unlikely to cause any issues in plant growth.	USEPA (2021). Chromium in Agricultural Soils.
Nickel (ppm)	1.940 ± 0.04	<2.0	Slightly elevated nickel, may cause stress in sensitive plants.	Reeves, R.D. (2020). Nickel and Plant Physiology.
Cadmium (ppm)	0.064 ± 0.01	0.01 - 0.1	Low cadmium, not a risk for plants or human health.	WHO (2020). Cadmium Risk in Agriculture.
Lead (ppm)	2.836 ± 0.011	1 - 5	Potential for lead uptake in plants, moderate risk of contamination.	UNEP (2021). Lead Contamination and Agriculture.

Table 4. Heavy metal concentration in the Bill shaft area and its implications

Parameter	Value (ppm)	International Range (ppm)	Implications	References
Iron (ppm)	8.32 ± 0.77	2.5 - 50	Elevated iron levels, can impact microbial activity at higher concentrations.	FAO (2020). Soil Nutrient Management Guidelines.

Manganese (ppm)	10.09 ± 0.46	10 - 50	Within the acceptable range for manganese, may enhance plant growth.	Shenker, M., & Chen, Y. (2020). Role of Micronutrients in Crop Yield.
Zinc (ppm)	11.56 ± 0.04	0.5 - 10	Excessive zinc, can lead to nutrient imbalances and zinc toxicity in plants.	Zhang, Y. et al. (2018). Zinc and Crop Nutrition.
Copper (ppm)	4.00 ± 0.20	0.2 - 5	Moderately high copper, near toxic levels in some sensitive crops.	(Wyszkowska, n.d.)
Chromium (ppm)	0.316 ± 0.01	<1.0	Slightly elevated chromium, no risk to crops at these levels.	USEPA (2021). Chromium in Agricultural Soils.
Nickel (ppm)	1.938 ± 0.01	<2.0	Slightly elevated nickel, but not harmful for most plants.	Reeves, R.D. (2020). Nickel and Plant Physiology.
Cadmium (ppm)	0.100 ± 0.004	0.01 - 0.1	At the upper threshold for cadmium, requires careful monitoring.	WHO (2020). Cadmium Risk in Agriculture.
Lead (ppm)	3.432 ± 0.013	1 - 5	Highest lead concentration, may lead to contamination if not monitored.	UNEP (2021). Lead Contamination and Agriculture.

Table 5. Heavy metal concentration in the Oorgam area and its implications

Parameter	Value (ppm)	International Range (ppm)	Implications	References
Iron (ppm)	12.02 ± 0.35	2.5 - 50	High iron levels, could lead to nutrient imbalances and reduced plant nutrient uptake.	FAO (2020). Soil Nutrient Management Guidelines.
Manganese (ppm)	1.38 ± 0.09	10 - 50	Below the acceptable range for manganese, deficiency likely to impact plant performance.	Shenker, M., & Chen, Y. (2020). Role of Micronutrients in Crop Yield.
Zinc (ppm)	3.10 ± 0.20	0.5 - 10	Moderate zinc, beneficial for plant growth, no toxicity risk.	(Saboor et al., 2021)
Copper (ppm)	15.60 ± 0.21	0.2 - 5	Excessively high copper, very high risk of toxicity in sensitive plants.	(Wyszkowska, n.d.)
Chromium (ppm)	Not detected	<1.0	No chromium detected, safe for plant growth.	USEPA (2021). Chromium in Agricultural Soils.
Nickel (ppm)	7.550 ± 0.17	<2.0	Extremely high nickel, very high risk of toxicity for crops, especially sensitive species.	(Rabinovich et al., 2024)
Lead (ppm)	2.294 ± 0.005	1 - 5	Moderate lead concentration, within safe limits, but continuous monitoring recommended.	UNEP (2021). Lead Contamination and Agriculture.

Table 6. Heavy metal concentration in the Oorgam opposite to court complex area and its implications

Parameter	Value (ppm)	International Range (ppm)	Implications	References
Iron (ppm)	16.42 ± 0.71	2.5 - 50	High iron levels, potentially toxic to sensitive crops and could cause nutrient imbalances.	FAO (2020). Soil Nutrient Management Guidelines.
Manganese (ppm)	2.30 ± 0.10	10 - 50	Low manganese, may affect plant metabolism and performance.	(Assunção et al., 2022)
Zinc (ppm)	0.71 ± 0.01	0.5 - 10	Deficient zinc, could negatively affect enzyme function and plant growth.	(Saboor et al., 2021)
Copper (ppm)	4.94 ± 0.06	0.2 - 5	Moderate copper, within the safe range for most plants, supports enzymatic activity.	White, P.J. (2019). Copper Nutrition in Plants.
Chromium (ppm)	0.224 ± 0.01	<1.0	Low chromium, unlikely to cause toxicity, safe for plant growth.	USEPA (2021). Chromium in Agricultural Soils.
Nickel (ppm)	0.704 ± 0.06	<2.0	Low nickel, no risk of toxicity, within safe limits for plant growth.	(Genchi et al., 2020)
Cadmium (ppm)	0.046 ± 0.006	0.01 - 0.1	Very low cadmium, no significant environmental or health concerns.	WHO (2020). Cadmium Risk in Agriculture.
Lead (ppm)	0.668 ± 0.011	1 - 5	Very low lead, minimal risk of contamination, safe for plant and human health.	UNEP (2021). Lead Contamination and Agriculture.

The data reveals significant variation in metal concentrations across the five locations. Bill Shaft shows the highest levels of lead (3.43 ppm), chromium (0.316 ppm), and nickel (1.938 ppm), indicating potential contamination. Oorgam rock area exhibits elevated copper (15.60 ppm) and nickel (7.55 ppm), suggesting environmental or industrial influence. NIRM stands out with the highest manganese concentration (22.97 ppm). Meanwhile, Oorgam opposite the court complex has the highest iron concentration (16.42 ppm) but shows the lowest levels of lead (0.668 ppm), pointing to variability in metal deposition across regions. The analysis of soil samples from five different sites of Kolar Gold Fields—Marikuppam, NIRM, Bill Shaft, Oorgam Rock Area, and Oorgam Opposite to Court Complex explains remarkable variations in both heavy metal concentrations and soil attributes.

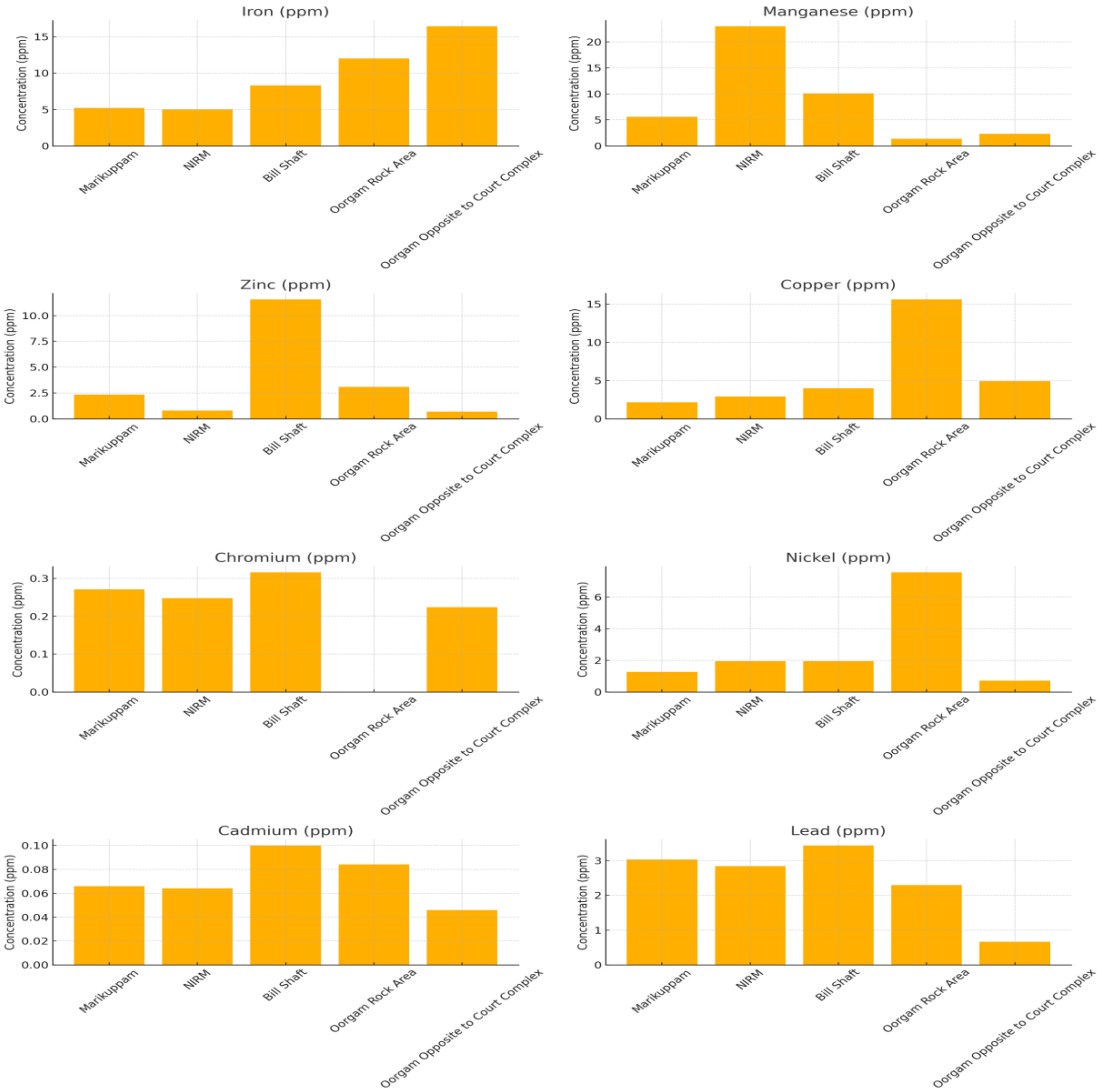

Fig 1. Compiled data of metal content

Soil Properties

pH: The pH values ranged from 4.10 at Oorgam Opposite to Court Complex (highly acidic) to 7.47 at NIRM (basic). The standard deviation in pH values ranged from 0.10 to 1.00, indicating significant differences across sites. This variance reflects the impact of mining on soil acidity.

Electrical Conductivity (EC): EC values varied from 0.10 dS/m at Oorgam Rock Area to 1.10 dS/m at Oorgam Opposite to Court Complex. The wide range in standard deviations (0.10 at Oorgam Rock Area and 1.10 at Oorgam Opposite to Court Complex) suggests significant differences in soil salinity.

Organic Carbon: Organic carbon content was highest at Marikuppam 1.98% and lowest at Oorgam Opposite to Court Complex 0.34%. The variability in standard deviations 0.065% at Marikuppam and 0.105% at Oorgam Opposite to Court Complex indicates significant differences in soil fertility.

Nitrogen, Phosphorus, Potassium (NPK): Nitrogen and phosphorus levels were highest at Bill Shaft 740.80 kg ha^{-1} and 179.36 kg ha^{-1}, respectively, while potassium was highest at Marikuppam 818.60 kg ha^{-1}. The differences in standard deviations, 13.98 kg ha^{-1} at Marikuppam for nitrogen and 3.03 kg ha^{-1} at NIRM for potassium highlight significant spatial variability in soil nutrient levels.

Calcium and Magnesium: Calcium and magnesium concentrations were notably lower at Oorgam Rock Area compared to other sites. The standard deviations 0.33 meq/100 g for calcium at Oorgam Rock Area indicate significant differences in soil mineral content.
Sulphur: Sulphur content ranged from 2.88 ppm at Oorgam Rock Area to 110.95 ppm at Oorgam Opposite to Court Complex. The substantial variance in sulphur levels and standard deviations 1.47 ppm at Oorgam Opposite to Court Complex suggests significant contamination.

Table 7. The soil properties

Parameters	Marikuppam	NIRM	Bill shaft	Oorgam rock area	Oorgam opposite to court complex
pH (1:2.5)	7.24	7.47	7.24	6.42	4.10
Electrical conductivity (dS/m) (1: 2.5)	0.31	0.29	0.32	0.10	1.10
Organic carbon (%)	1.98 ±0.06429101	1.26±0.04358899	2.380±0.20223748	0.58±0.1569501	0.34±0.10503968
Nitrogen (kg ha-1)	426.84±13.984582	527.30±6.51499808	740.80±5.1119957	351.23±3.41037144	188.66±1.73793939
Phosphorus (kg ha-1)	34.78±0.53125637	67.85±0.31942657	179.36±3.82419055	28.64±1.3286961	14.66±2.46041324
Potassium (kg ha-1)	818.60±0.36170891	697.4±3.03534732	469.40±4.37530951	190.32±1.9409362	315.00±2.55797446
Calcium (meq/100 g)	17.50±0.49244289	18.00±0.35930488	31.20±1.33192843	4.80±0.33060551	10.00±0.50083264
Magnesium (meq/100g)	4.00±0.1761628	6.80±0.11357817	12.60±0.55644706	1.20±0.36473735	2.00±0.52728866
Sulphur (ppm)	17.3±0.55075705	25.96±0.5870548	24.99±0.89276723	2.88±0.22501852	110.95±1.47091808

Table 8. The soil properties at Marikuppam area with its implications

Parameter	Observed Value	Standard Range	Implications	Reference
pH	7.24	6.0 - 7.5	Optimal pH for most crops, no adjustment needed.	(Varvel et al., 2007)
EC (dS/m)	0.31	< 0.8	Non-saline soil, good for most crops.	Maas, E.V., & Hoffman, G.J. (1977). Crop salt tolerance. Journal of Irrigation and Drainage.
Organic Carbon (%)	1.98	1 - 2%	Adequate organic carbon level for good soil structure and fertility.	Lal, R. (2004). Soil carbon sequestration. Science.
Nitrogen (kg/ha)	426.84	200 - 600 kg/ha	Adequate nitrogen content, supporting healthy plant growth.	Raun, W.R., & Johnson, G.V. (1999). Improving nitrogen use efficiency. Agronomy Journal.
Phosphorus (kg/ha)	34.78	30 - 80 kg/ha	Sufficient phosphorus level for crop growth.	Vance, C.P. (2003). Phosphorus acquisition and use. New Phytologist.

Parameter	Observed Value	Standard Range	Implications	Reference
Potassium (kg/ha)	818.6	150 - 250 kg/ha	Excessive potassium, could lead to nutrient imbalances, especially for calcium and magnesium uptake.	Mengel, K., & Kirkby, E.A. (2001). Principles of plant nutrition. Springer Science.
Calcium (meq/100g)	17.5	10 - 20 meq/100g	Adequate calcium content, good for plant health and pH stability.	White, P.J., & Broadley, M.R. (2003). Calcium in plants. Annals of Botany.
Magnesium (meq/100g)	4	2 - 6 meq/100g	Optimal magnesium level, supporting healthy photosynthesis and nutrient absorption.	Cakmak, I. (2010). Magnesium: A forgotten element in crop production. Better Crops.
Sulphur (ppm)	17.3	20 - 30 ppm	Slightly low sulphur, could benefit from sulphur supplementation.	Havlin, J.L., Tisdale, S.L. (2013). Soil fertility and fertilizers. Pearson Education.

Table 9. The soil properties at NIRM area with its implications

Parameter	Observed Value	Standard Range	Implications	Reference
pH	7.47	6.0 - 7.5	Slightly alkaline, but within acceptable range	Brady & Weil (2002)
EC (dS/m)	0.29	< 0.8	Non-saline soil, no issues	Maas & Hoffman (1977)
Organic Carbon (%)	1.26	1 - 2%	Slightly lower than optimal, but adequate	Lal (2004)
Nitrogen (kg/ha)	527.3	200 - 600 kg/ha	High nitrogen content, promoting strong plant growth	Raun & Johnson (1999)
Phosphorus (kg/ha)	67.85	30 - 80 kg/ha	Adequate phosphorus for plant growth	Vance (2003)
Potassium (kg/ha)	697.4	150 - 250 kg/ha	Excessive potassium, possible imbalances with Mg and Ca	Mengel & Kirkby (2001)
Calcium (meq/100g)	18	10 - 20 meq/100g	Adequate calcium content	White & Broadley (2003)
Magnesium (meq/100g)	6.8	2 - 6 meq/100g	Slightly above optimal range, but not likely to cause issues	Cakmak (2010)
Sulphur (ppm)	25.96	20 - 30 ppm	Adequate sulphur content	Havlin & Tisdale (2013)

Table 10. The soil properties at Bill shaft area with its implications

Parameter	Observed Value	Standard Range	Implications	Reference
pH	7.24	6.0 - 7.5	Optimal pH for most crops, no major adjustments needed	Fageria (2002)
EC (dS/m)	0.32	< 0.8	Non-saline soil, no salinity issues	Maas & Hoffman (1977)
Organic Carbon (%)	2.38	1 - 2%	High organic carbon level, excellent for soil fertility and water retention	Lal (2004)

Parameter	Observed Value	Standard Range	Implications	Reference
Nitrogen (kg/ha)	740.8	200 - 600 kg/ha	Excessive nitrogen, could lead to overgrowth and environmental issues due to runoff	Raun & Johnson (1999)
Phosphorus (kg/ha)	179.36	30 - 80 kg/ha	Extremely high phosphorus, risks of environmental pollution through runoff	Vance (2003)
Potassium (kg/ha)	469.4	150 - 250 kg/ha	Very high potassium, could lead to nutrient imbalances, especially with magnesium and calcium	Mengel & Kirkby (2001)
Calcium (meq/100g)	31.2	10 - 20 meq/100g	Excessively high calcium, could interfere with magnesium uptake	White & Broadley (2003)
Magnesium (meq/100g)	12.6	2 - 6 meq/100g	Very high magnesium, causing imbalances in calcium and potassium absorption	Cakmak (2010)
Sulphur (ppm)	24.99	20 - 30 ppm	Adequate sulphur content	Havlin & Tisdale (2013)

Table 11. The soil properties at Oorgam rock area area with its implications

Parameter	Observed Value	Standard Range	Implications	Reference
pH	6.42	6.0 - 7.5	Slightly acidic but within an acceptable range for most crops	Brady, N.C., & Weil, R.R. (2002). Nature and Properties of Soils. Prentice Hall.
EC (dS/m)	0.1	< 0.8	Non-saline, no salinity issues	Maas, E.V., & Hoffman, G.J. (1977). Crop salt tolerance. Journal of Irrigation and Drainage.
Organic Carbon (%)	0.58	1 - 2%	Low organic carbon, requires organic matter addition to improve soil structure and fertility	Lal, R. (2004). Soil carbon sequestration. Science.
Nitrogen (kg/ha)	351.23	200 - 600 kg/ha	Adequate nitrogen content, supporting plant growth	Raun, W.R., & Johnson, G.V. (1999). Improving nitrogen use efficiency. Agronomy Journal.
Phosphorus (kg/ha)	28.64	30 - 80 kg/ha	Slightly low phosphorus, needs supplementation for optimal plant development	Vance, C.P. (2003). Phosphorus acquisition and use. New Phytologist.
Potassium (kg/ha)	190.32	150 - 250 kg/ha	Adequate potassium level for plant growth	Mengel, K., & Kirkby, E.A. (2001). Principles of plant nutrition. Springer Science.
Calcium (meq/100g)	4.8	10 - 20 meq/100g	Low calcium, requires lime or gypsum to increase calcium availability	White, P.J., & Broadley, M.R. (2003). Calcium in plants. Annals of Botany.
Magnesium (meq/100g)	1.2	2 - 6 meq/100g	Low magnesium, needs magnesium fertilizers like	Cakmak, I. (2010). Magnesium: A forgotten element in crop production. Better Crops.

Parameter	Observed Value	Standard Range	Implications	Reference
			Epsom salts to correct deficiency	
Sulphur (ppm)	2.88	20 - 30 ppm	Very low sulphur, supplementation with sulphur-containing fertilizers is necessary	Havlin, J.L., Tisdale, S.L. (2013). Soil fertility and fertilizers. Pearson Education.

Table 12. The soil properties at Oorgam Opposite to Court Complex area with its implications

Parameter	Observed Value	Standard Range	Implications	Reference
pH	4.1	6.0 - 7.5	Highly acidic, requires liming to raise pH and reduce aluminium toxicity	Fageria, N.K. (2002). Nutrient management for tropical soils. Communications in Soil Science.
EC (dS/m)	1.1	< 0.8	Slightly saline, which can restrict plant water uptake	Maas, E.V., & Hoffman, G.J. (1977). Crop salt tolerance. Journal of Irrigation and Drainage.
Organic Carbon (%)	0.34	1 - 2%	Very low organic carbon, needs immediate organic matter addition to improve soil health	Lal, R. (2004). Soil carbon sequestration. Science.
Nitrogen (kg/ha)	188.66	200 - 600 kg/ha	Nitrogen-deficient, requires nitrogen fertilization for adequate plant growth	Raun, W.R., & Johnson, G.V. (1999). Improving nitrogen use efficiency. Agronomy Journal.
Phosphorus (kg/ha)	14.66	30 - 80 kg/ha	Low phosphorus, requires supplementation to support crop development	Vance, C.P. (2003). Phosphorus acquisition and use. New Phytologist.
Potassium (kg/ha)	315	150 - 250 kg/ha	Slightly high potassium, which may cause nutrient imbalances if not managed	Mengel, K., & Kirkby, E.A. (2001). Principles of plant nutrition. Springer Science.
Calcium (meq/100g)	10	10 - 20 meq/100g	Adequate calcium content, no immediate need for calcium adjustments	White, P.J., & Broadley, M.R. (2003). Calcium in plants. Annals of Botany.
Magnesium (meq/100g)	2	2 - 6 meq/100g	Magnesium at the lower bound, needs magnesium supplementation for optimal growth	Cakmak, I. (2010). Magnesium: A forgotten element in crop production. Better Crops.
Sulphur (ppm)	110.95	20-30 ppm	Excessively high sulphur, likely contributing to soil acidification. Improved drainage and leaching are required	Havlin, J.L., Tisdale, S.L. (2013). Soil fertility and fertilizers. Pearson Education.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 11s, 2025
https://theaspd.com/index.php

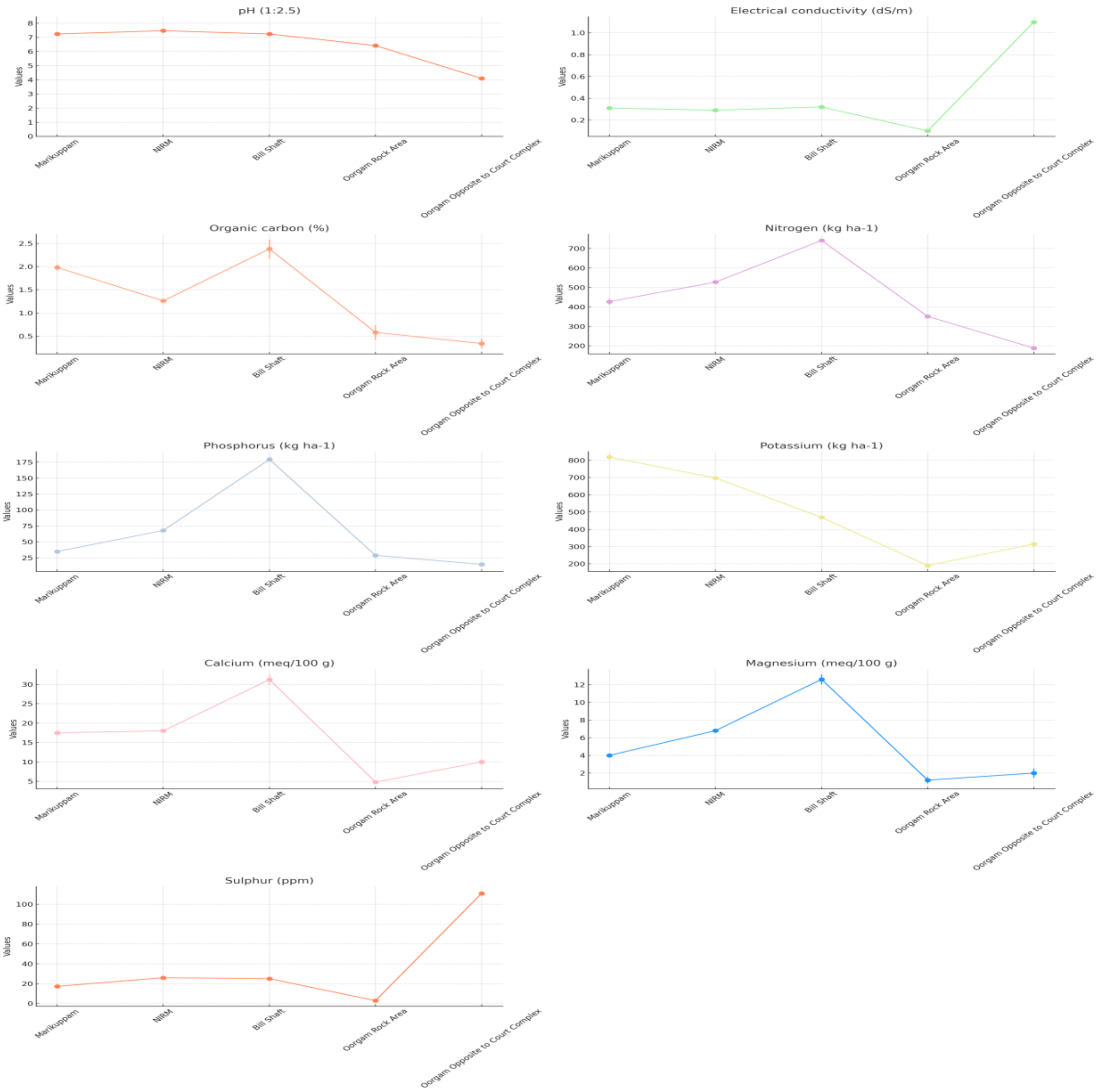

Fig 2. Compiled data of soil properties

Soil fertility varies considerably, with Bill Shaft exhibiting the most favourable conditions, including high nitrogen (740.8 kg/ha), phosphorus (179.36 kg/ha), and potassium (469.4 kg/ha), along with the highest calcium (31.2 meq/100g) and organic carbon (2.38%). In contrast, Oorgam opposite the court complex shows poor fertility, with low pH (4.10), minimal organic carbon (0.34%), and the lowest nitrogen (188.66 kg/ha) content, signalling a need for soil amendments. Marikuppam has a high potassium content (818.6 kg/ha), while NIRM and Oorgam areas require monitoring due to varying soil quality indicators.

Environmental concerns emerge from elevated sulphur levels (110.95 ppm) at Oorgam opposite the court complex, suggesting pollution stress, while high electrical conductivity (1.10 dS/m) in the same location points to potential salt accumulation. The findings indicate localized contamination hotspots in some areas, such as Bill Shaft and Oorgam rock area, requiring environmental monitoring. Targeted soil management strategies, including pH correction and nutrient replenishment, are recommended to improve soil quality, particularly in Oorgam regions.

CONCLUSION

This study addresses the prominent issue of heavy metal contamination in soils, specifically within mining areas of Kolar Gold Fields. The findings of the study address that even a trace quantity of heavy metals, when accumulated over time, can result in critical risks to human health and ecosystems. Soils naturally constitute heavy metals as a result of rock weathering, but environmental factors such as soil pH and organic matter can impact their accessibility and toxicity. The contamination recorded in this approach highlights that soils with low initial metal concentrations can still result in substantial bioaccumulation in higher trophic levels, ultimately influencing human health via food and water contamination. The analysis of soil samples from various mining regions, especially from the Oorgam Opposite to Court Complex, showed pronounced acidity and heavy metal pollution, rendering the soil highly unsuitable for agricultural practices. Notably, the Oorgam rock site was free from chromium which caused significant contamination of other metals, emphasizing the pervasive nature of pollution in these regions. The implications of these findings stress the urgent requisite for comprehensive remediation approaches and heightened public awareness concerning the health hazards aligned with soil contamination. Effective public education and targeted intervention are required to eliminate the risks posed by environmental heavy metal pollutants and to ensure the health of local communities. Urgent action is critical to address and resolve the severe pollution issues noted, safeguarding a healthier environment and sustainable future for the impacted sites.

Acknowledgement
The researchers acknowledge the guidance and support of Dr Manjunath B T and Dr Paari K A the faculty members of department of life sciences Christ University in the data collection and in the process of the research.

REFERENCES

1. Abdul-Wahab, S., & Marikar, F. (2011). The environmental impact of gold mines: pollution by heavy metals. Open Engineering, 2(2). https://doi.org/10.2478/S13531-011-0052-3/HTML
2. Akter, S., Jolly, Y. N., Kabir, M. J., & Mamun, K. M. (2023). Analysis of Heavy Metals and Other Elements in Soil Samples for its Physicochemical Parameters Using Energy Dispersive X-Ray Fluorescence (EDXRF) Techniques. Austin Journal of Environmental Toxicology, 9(1), 1045. www.austinpublishinggroup.com
3. Assunção, A. G. L., Cakmak, I., Clemens, S., González-Guerrero, M., Nawrocki, A., & Thomine, S. (2022). Micronutrient homeostasis in plants for more sustainable agriculture and healthier human nutrition. *Journal of Experimental Botany*, *73*(6), 1789. https://doi.org/10.1093/JXB/ERAC014
4. Bojić, Aleksandar. (n.d.). Determination of heavy metals in soil by atomic absorption spectrometry (AAS).
5. Brady, N.C., & Weil, R.R. (2002). The Nature and Properties of Soils. Prentice Hall.
6. Cakmak, I., & Yazici, A.M. (2010). Magnesium deficiency in plants: An urgent problem. The Crop Journal, 4(2), 83-91. DOI: 10.1016/j.cj.2015.11.003
7. Cao, J., Xie, C., & Hou, Z. (2022). Ecological evaluation of heavy metal pollution in the soil of Pb-Zn mines. Ecotoxicology, 31(2), 259–270. https://doi.org/10.1007/S10646-021-02505-3/TABLES/5
8. Collin, M. S., Venkatraman, S. K., Vijayakumar, N., Kanimozhi, V., Arbaaz, S. M., Stacey, R. G. S., Anusha, J., Choudhary, R., Lvov, V., Tovar, G. I., Senatov, F., Koppala, S., &
9. Compaore, W. F., Dumoulin, A., & Rousseau, D. P. L. (2019). Gold Mine Impact on Soil Quality, Youga, Southern Burkina Faso, West Africa. Water, Air, and Soil Pollution, 230(8), 1–14. https://doi.org/10.1007/S11270-019-4257-Z/FIGURES/5
10. Genchi, G., Carocci, A., Lauria, G., Sinicropi, M. S., & Catalano, A. (2020). Nickel: Human Health and Environmental Toxicology. *International Journal of Environmental Research and Public Health*, *17*(3), 679. https://doi.org/10.3390/IJERPH17030679
11. Guan, Y., Shao, C., & Ju, M. (2014). Heavy metal contamination assessment and partition for industrial and mining gathering areas. International Journal of Environmental Research and Public Health, 11(7), 7286–7303. https://doi.org/10.3390/IJERPH110707286
12. Guo, W., Nazim, H., Liang, Z., & Yang, D. (2016). Magnesium deficiency in plants: An urgent problem.The Crop Journal, 4(2), 83-91.DOI: 10.1016/j.cj.2015.11.003
13. Havlin, J.L., Tisdale, S.L., Nelson, W.L., & Beaton, J.D. (2013). Soil fertility and fertilizers: An introduction to nutrient management.Pearson Education.Link
14. Jenkinson, D.S. (1988). Soil organic matter and its dynamics. The Chemistry of Soil Processes, 563-607.
15. Kim, K. K., Kim, K. W., Kim, J. Y., Kim, I. S., Cheong, Y. W., & Min, J. S. (2001). Characteristics of tailings from the closed metal mines as potential contamination source in South Korea. Environmental Geology, 41(3–4), 358–364. https://doi.org/10.1007/S002540100396
16. Kiran, Bharti, R., & Sharma, R. (2022). Effect of heavy metals: An overview. Materials Today: Proceedings, 51, 880–885. https://doi.org/10.1016/J.MATPR.2021.06.278
17. Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. Science, 304(5677), 1623-1627. DOI: 10.1126/science.1097396

18. Li, Z., Ma, Z., van der Kuijp, T. J., Yuan, Z., & Huang, L. (2014). A review of soil heavy metal pollution from mines in China: Pollution and health risk assessment. Science of the Total Environment, 468–469, 843–853. https://doi.org/10.1016/J.SCITOTENV.2013.08.090
19. Maas, E.V., & Hoffman, G.J. (1977). Crop salt tolerance—current assessment. Journal of the Irrigation and Drainage Division, 103(2), 115-134.
20. Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. Frontiers in Public Health, 8, 505570. https://doi.org/10.3389/FPUBH.2020.00014/BIBTEX
21. Manyiwa, T., Ultra, V. U., Rantong, G., Opaletswe, K. A., Gabankitse, G., Taupedi, S. B., & Gajaje, K. (2022). Heavy metals in soil, plants, and associated risk on grazing ruminants in the vicinity of Cu–Ni mine in Selebi-Phikwe, Botswana. Environmental Geochemistry and Health, 44(5), 1633–1648. https://doi.org/10.1007/S10653-021-00918-X/TABLES/8
22. Marschner, H. (1995). Mineral Nutrition of Higher Plants. Academic Press.DOI: 10.1016/C2009-0-22598-3
23. Mengel, K., & Kirkby, E.A. (2001). Principles of plant nutrition. Springer Science & Business Media. DOI: 10.1007/978-94-010-1009-2
24. Nyiramigisha, P., Komariah, & Sajidan. (2021). Harmful Impacts of Heavy Metal Contamination in the Soil and Crops Grown Around Dumpsites. Reviews in Agricultural Science, 9, 271–282. https://doi.org/10.7831/RAS.9.0_271
25. Ogola, J. S., Mitullah, W. V., & Omulo, M. A. (2002). Impact of gold mining on the environment and human health: A case study in the Migori Gold Belt, Kenya. Environmental Geochemistry and Health, 24(2), 141–157. https://doi.org/10.1023/A:1014207832471
26. Organic Matter determination (Walkley -Black method). (n.d.). Retrieved April 13, 2024, from https://www.researchgate.net/publication/339941885 Organic Matter determination Walkley Black method
27. Pettigrew, W.T. (2008). Potassium influences on yield and quality production for maize, wheat, soybean, and cotton. Physiologia Plantarum, 133(4), 670-681. DOI: 10.1111/j.1399-3054.2008.01073.x
28. Rabinovich, A., Di, R., Lindert, S., & Heckman, J. (2024). Nickel and Soil Fertility: Review of Benefits to Environment and Food Security. *Environments 2024, Vol. 11, Page 177*, *11*(8), 177. https://doi.org/10.3390/ENVIRONMENTS11080177
29. Raun, W.R., & Johnson, G.V. (1999). Improving nitrogen use efficiency for cereal production. Agronomy Journal, 91(3), 357-363. DOI: 10.2134/agronj1999.00021962009100030001x
30. Saboor, A., Ali, M. A., Hussain, S., El Enshasy, H. A., Hussain, S., Ahmed, N., Gafur, A., Sayyed, R. Z., Fahad, S., Danish, S., & Datta, R. (2021). Zinc nutrition and arbuscular mycorrhizal symbiosis effects on maize (Zea mays L.) growth and productivity. *Saudi Journal of Biological Sciences*, *28*(11), 6339. https://doi.org/10.1016/J.SJBS.2021.06.096
31. Sims, J.T., Simard, R.R., & Joern, B.C. (1998). Phosphorus loss in agricultural drainage: Historical perspective and current research. Journal of Environmental Quality, 27(2), 277-293. DOI: 10.2134/jeq1998.00472425002700020006x
32. Smil, V. (1999). Nitrogen in crop production: An account of global flows. Global Biogeochemical Cycles, 13(2), 647-662. DOI: 10.1029/1999GB900015
33. Swamiappan, S. (2022). Bioaccumulation of lead (Pb) and its effects on human: A review. Journal of Hazardous Materials Advances, 7, 100094. https://doi.org/10.1016/J.HAZADV.2022.100094
34. Vance, C.P., Uhde-Stone, C., & Allan, D.L. (2003). Phosphorus acquisition and use: Critical adaptations by plants for securing a non-renewable resource. New Phytologist, 157(3), 423-447. DOI: 10.1046/j.1469-8137.2003.00695.x
35. Varvel, G., Liebig, M., analysis, J. D. soil science and plant, & 2002, undefined. (2007). Soil organic matter assessments in a long-term cropping system study. *Taylor & FrancisGE Varvel, MA Liebig, JW DoranCommunications in Soil Science and Plant Analysis, 2002 • Taylor & Francis*, *33*(13–14), 2119–2130. https://doi.org/10.1081/CSS-120005752
36. White, P.J., & Broadley, M.R. (2003). Calcium in plants. Annals of Botany, 92(4), 487-511. DOI: 10.1093/aob/mcg164
37. Wyszkowska, J. (n.d.). *The effects of copper on soil biochemical properties and its interaction with other heavy metals*. Retrieved March 7, 2025, from https://www.researchgate.net/publication/279716192
38. Zhao, F.J., & McGrath, S.P. (2009). Sulphur in agriculture. Advances in Agronomy, 102, 1-44. DOI: 10.1016/S0065-2113(09)01001-5
39. Zhao, H., Xia, B., Fan, C., Zhao, P., & Shen, S. (2012). Human health risk from soil heavy metal contamination under different land uses near Dabaoshan Mine, Southern China. Science of the Total Environment, 417–418, 45–54. https://doi.org/10.1016/J.SCITOTENV.2011.12.047
40. ZHOU, J. M., DANG, Z., CAI, M. F., & LIU, C. Q. (2007). Soil Heavy Metal Pollution Around the Dabaoshan Mine, Guangdong Province, China. Pedosphere, 17(5), 588–594. https://doi.org/10.1016/S1002-0160(07)60069-1