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MAPPING AND ASSESSMENT OF VARIATION IN CONTAMINATION LEVEL AND DISTRIBUTION STATUS OF HEAVY METALS IN SOIL OF REGION THAT HAD UNDERGONE DECADES OF INTENSE MINING

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ABSTRACT

Heavy metal pollution in soil has become concerned environmental problem in KGF. Thus an extensive survey has been conducted to determine and map the concentration and distribution status of heavy metals (Cu, Cr, NI, Pb, Zn, Fe, As, CN, Mn) in the soil samples collected from KGF. A total of 10 soil samples were collected and analyzed for major heavy metals. The presences of heavy metals which are the indicators of pollution in the soil were analyzed by inductively coupled plasma (ICP). Though many varieties are there to represent the soil contamination, a simple direct method is adopted in showing the distribution pattern of heavy metals in soil. The result obtained from the ICP and its direct distribution pattern showed excess presence of heavy metals which exceeded the tolerance limit given by WHO. All the heavy metals were widely spread and showed their presence in soil is mainly because of mining and mine dumplings at the study site. The single pollution factor index (SPFI) analyzed showed the average SPFI values of all the heavy metals (As, Cu, Ni, Pb, Zn, Mn) except Iron and Chromium were much higher than 1 indicating excess pollution and were in the decreasing order of Arsenic > Copper> Nickel> Lead> Zinc> Manganese> Chromium> Iron. The Nemerow pollution indices of heavy metals (PI_N) also varied significantly for the soils of different Stations. Copper, Nickel, Arsenic, lead and Zinc are majority indicators of heavy pollution level having PI_N values as 225.22, 35.87, 21.31, 8.29, 5.47 respectively followed by Magnesium, Chromium and Iron with Nemerow pollution indices as 1.67, 1.12 and 0.148 showing light pollution and clean level respectively. All the heavy metals in soil except Iron do not remain a safe level for human being consumption.

KEYWORDS: Heavy Metals, Distributions, Kolar Gold Field, Mining

INTRODUCTION

Kolar Gold Mine (K.G.M) has the tradition of mining that was started in early first millennium BC and was re-established by John Taylor and sons in 1880 (Lynn, 1991). Kolar Gold Field (K.G.F) was one of the major gold mines in India and was considered as the world's second deepest gold mine where the valuable material gold is extracted from the ore body. Kolar Gold Field is situated 340km from Chennai. Extraction of geological or valuable minerals from the ore body, vein, seam or reef which is referred as mining which forms the mineralized package of economic interest to the miner.

Mine tailings obtained during the mining process (surface mining and subsurface mining) contain high concentrations of metals which gain their entry to our environment by polluting the ecosystem (air, water and land). Thus the Crucial key component of rural and urban environments is soil, and its management is the key role to soil quality in both places (soil quality, Sept 2000). This Soil ecosystem is been polluted due to many other major reasons in which one of them is increased number of human population and his new ideas of growth linking with mining activity, Atmospheric deposition, waste/sludge disposal, fertilizer and pesticide applications, industrial waste, and nuclear waste forms some of the other sources of pollution which give rise to various pollutants to enter the ecosystem by creating unsatisfactory conditions. The released pollutants might be organic or inorganic. The most commonly wide spread pollutants during these activities are both cationic and anionic heavy metals like Copper, Chromium, Nickel, Lead, Cadmium, Arsenic, Cyanide, mercury, Zinc and organic pollutants like petroleum, polycyclic aromatic hydrocarbons (PAHs), chlorinated solvents, herbicides and pesticides (Hoffman, 2005, Amor, 2001 Ademola, 2013).

Metalloids released due to mining process is one of the most important environmental concerns from mine tailings as all metalloids are unique in causing toxicity. General collective term applicable for the group of metals and metalloids with an atomic density greater then $6 g/cm^3$ is referred as heavy metals. This term is widely recognized and commonly applied to the elements which are associated with pollution and toxicity problems. As of most organic pollutants, heavy metal also occurs naturally in rock forming and ore mineral. The metal pollutants will be accumulated and biomagnified in the food chains and become magnificently dangerous to human and wildlife. Estimating the natural ability of the pollutants in different components of the ecosystem has become a challenging task in preventing exposing to danger to natural life and public health. These heavy metals enter into the environment mainly via three routes; (i) Deposition of atmospheric particulate (ii) Disposal of metal enriched sewage sledges and sewage effluents and (iii) By-products from metal mining process.

Many of the earlier studies have showed that the trace metals at low concentration in soils are essential nutrients essential for plants and microbes but become toxic at higher concentration levels. Low concentrations of some metals will strongly interact with soil component and result in nutrient deficiency for living systems. The discharge of excessive amounts of heavy metals into the soils, affect soil matrices involving metal-soil interactions and this will further affect metal transport. As the metal concentrations in soils increase, the soils will become more toxic to plants and animals. These metal toxicity level in the environment depends on the metal and its chemical form that controls both its mobility and reactivity. These trace heavy metal concentration in the soils is a major concern because of their toxicity and threat to human life and the environment. Studies on heavy metals are important to evaluate both soil/sediment and ground water contamination. Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in Biosystems mainly in contaminated soil followed by water and air (K. G. Pujar, 2011). Thus an attempt is made to quantify the contamination level and distribution status of heavy metal in soil collected from the study site of KGF.

MATERIALS AND METHODOLOGY

Study Site Description

The gold mine is located in the Bangarpet which was set up in early 19th century for the extraction of Gold. The total area K.G.F. where the mining was carried for an area of 65.64 sq.km showing its latitude 12°54'- 13°00 and longitudes 78°13'-78°17' in the Kolar District. After the extraction process, million tonnes of impoundments obtained are dumped in this region and has an approximate height of about 30 meters (http://memoriesofkgf.blogspot.in/2009/08/cynaide-dumps.html).

Soil Sample Collection

The soil samples were also collected in post monsoon (October –November) season by adopting standard procedure from waste dump mine sites (Jesus, 2010) and residential area of Kolar Gold Field, Karnataka, India. The total area of gold mine, distance covered and the locations of soil samples which were collected randomly from ten different sampling points of the study area are shown in Figure 1 which consisted of total KGF area of 65.64 sq.km with the total distance of 34.07 km that had different elevation at each sampling points and was named as SS1, SS2, SS3, SS4, SS5, SS6, SS7, SS8, SS9 and SS10. Collection of soil samples from sampling points covering total sampling area of 7.0sq.km is as shown in Figure 1.The geological characteristics of ten locations investigated in the region are shown in Table 1. The contaminated soil was collected form the selected sampling location by marking 1m x 1m initially followed by cleaning of debris from the top soil. The soil sample was collected from the depth of about 1 -1.5m using tools and was stored in in a thick quality self – locking polythene bags transferred immediately to the laboratory and were air dried, powdered and sieved through 2 x 2 mm mesh in order to break soil clumps and to remove large soil particles. The sieved soil was then stored in thick quality self – locking polythene bag at 40C for subsequently used for analysis.

Table 1: Characterization of Sampling Locations

Location	Places	Latitude (North)	Longitude (East)	Elevation (ft)
SS1	Masid road	12.96639	78.27432	2744
SS2	BEML Bus Stand	12.97124	78.24375	2918
SS3	Bharath Gold mine	12.91677	78.28343	2874
SS4	Beml Factory	12.8554	78.2351	2890
SS5	KGF	12.9617	78.2707	2790
SS6	Robertson pet	12.95429	78.25991	2763
SS7	Cynaide mountain	12.95863	78.26554	2888
SS8	PWD guest house	12.95851	78.27103	2902
SS9	Bemlnagar	12.99215	78.23266	2850
SS10	Oorgumpet	12.95263	78.26719	2814

Preparation of Soil Samples and Characterization

The aim of the preliminary part of this work is to characterize the soil residue collected from study site, thus the residue was collected and air dried for two days at 150° C. The dried soil samples is then ground and sieved through 2mm mesh sized sieve and then manually homogenized in a bucket. Physical condition of the soil is governed by the mechanical fraction of the soil, thus the sieved samples were characterized for their physicochemical properties such as tested for measurement of pH, Electrical conductivity, Bulk Density, Nitrogen, Phosphorous and was analyzed for the presence of heavy metal according to the standard method.

Mapping of Presence of Heavy Metals

General process of nonferrous mining activity includes mining, transportation and selective smelting which give rise to huge amount of waste in the form of solid, liquid and gas. According to liao2008, some of the metals produced during crushing, gain its way to earth surface by means of polluted wind mainly because of chiselling and explosion which latter settle by air diffusion to water and soil environment. This might further step down to the surface and underwater by sap drainage, drop or dust during transportation both on and under the ground. The final process that is the selection process produce high amount of tailings which mainly include toxic metals and are stored in mine drainage recycles or used for irrigation leading to deleterious complex pollution of the surrounding environment. Thus the sources of heavy metals pollution are mine drainage, settling dust in wind, tailings, vehicle transporting etc. All the sources will cause soil pollution and thus the contaminated land area is considered as a single zone with 10 different sampling point with included all the types of sources mentioned.

According to Loghman2013, assessing soil quality and locating pollution level by means of distribution is the primary significance. Thus the objective focus on heavy meal dispersion and distribution patterns at various sampling stations where the assessment of metals present in the soil serve as an important sink to understand the overall status of contamination level/pattern and associated environmental risk of selected region (Yuanan Hu, 2013) as they are detrimental to the environment because of their non-biodegradable and persistent nature (El-Sayed E. Omran et al., 2012). One of the common methods of assessing pollution levels in soil and quantifying it is by comparing the identified concentrations with its tolerance limit (Mindaugas, 2012). Thus the results obtained will be helpful for the environmental management in areas undergoing fast transformation. The dynamic component soil contaminated with metals is due to chemical, hydrological and geological processes and is collected randomly from 10 different locations of mining area. Though various number of monitoring programs have generated, this method seems to have lesser interactive influences. Literature survey shows that there is no much study have been carried out for metal pollution in soil residue of Kolar Gold Mine because the mine area is restricted for public and Research purpose.

This study investigates, for the first time, the heavy metal pollution of soils from all ten sampling sites of KGF. The study further proceeds with the aim of mapping the distribution level of heavy metals at different sampling stations. At this stage land use aspect of the study area has to be considered (Yiyun Chen, 2012). The sampling stations were selected on the basis of accessibility and consist (i) Masid road and were named as SS1 (ii) BEML Bus Standand were named as SS2 (iii) Bharath Gold mine and were named as SS3 (iv) Beml Factory and were named as SS4 (v) K.G.F and were named as SS5 (vi) Robertson pet and were named as SS6 (Vii) Cyanide mountain and were named as SS7 (viii) PWD guest house and were named as SS8 (ix) Bemlnagar and were named as SS9 (x) Oorgumpet and were named as SS10 which covered an total area of 7.0 sq.km. The random distribution pattern of sampling points is as in Figure 1. The coordinates (latitude, longitude, elevation) of the sample points were detected using GPS and were plotted on a map with a scale of 1cm = 1km (Keli Zhao, 2015). Contaminated soil residues collected were analyzed the presence of heavy metals' such as Chromium, Copper, Arsenic, Cyanide, Nickel, Manganese and Lead. The presence of heavy metal concentration was due to geology and mining activity (Sun 2001). The concentration distribution pattern of the heavy metals in the soil collected at 10 sampling locations was mapped.

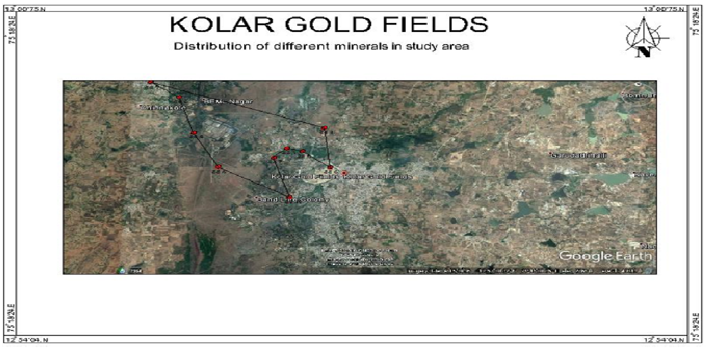

Figure 1: Distribution Pattern of Sampling Points

Evaluation of Pollution Level in Soil

The pollution level of heavy metals in the soil is evaluated by single pollution factor index (SPFI) at first which quantifies only individual heavy metal pollution in soil and is calculated as the ratio of the metal concentration (Ci) in a soil sample and its reference value (Si)

$$PI_i = C_i / S_i$$

The referred guideline Si values for Cu, Cr, Ni, Pb, Fe, Zn, as and Mn is based on Standards given by WHO and FAO for soil quality. P_i stand for pollution index of pollutant i, Ci is the measured value of i. Table 2 summarize for Standard value by WHO and FAO. If the ratio C_i / S_i less than 1, implies no heavy metal pollution and ratio showing value greater than 1 leads to metal pollution in the soil. Secondly, overall heavy metal pollution status of soil is assessed by the Nemerow pollution factor index (PI_N) and is given by

$$PI_N = \textit{square root}\ (PI^2_{avg} + PI^2_{max}) /2$$

Where I is Nemerow Pollution factor index at location i,

$PI_{avg\ and}$ PI_{max} represent the average and maximum values of SPFI of heavy metals respectively.

According to Nemerow pollution factor index, the soil environmental quality is divided into five levels and is as shown in Table 3

Table 2: Summarize for Standard Value by WHO and FAO

Sl. No	Heavy Metal	Standard Value (mg/kg)
1	Copper	100
2	Chromium	100
3	Nickel	50
4	Lead	100
5	Iron	50000
6	Zinc	300
7	Arsenic	20
8	Manganese	2000

Table 3: Assessment Criteria of Soil Pollution Indices

Classification	Single Pollution Factor Index (SPFI)		Nemerow Pollution Factor Index Pollution Grade	
I	I ≤ 1.0	Clean level	I ≤ 0.7	Clean level
II	1.0 < I ≤ 2.0	Light pollution level	0.7 < I ≤ 1.0	Precaution level
III	2.0< I ≤ 4.0	Moderate level	1.0< I ≤ 2.0	Light pollution level
IV	4.0 < I ≤ 6.0	Heavy level	2.0 < I ≤ 3.0	Moderate level
V	I > 6.0	Extreme Pollution level	I > 3.0	Heavy Pollution level

(Yang cao, 2013, Yuanan, 2013 andKeli Zhao, 2015)

RESULTS AND DISCUSSIONS

Soil Samples and Characterization

According to Rajanna 2010, the soil of KGF is classified as red and clayey loam soil with patches of black soil in few regions. But the nature of the soil residue collected at the sampling site is found to be almost uniform at all the regions apart from Cyanide Mountains. The selected properties and the total metal concentration of the contaminated residue is as shown in the table 4 and 5.

The pH of the soil samples varied from the range of acidic to alkaline showing the mean pH value of gold field as slightly 5.3. Indicated that the sampled soil is acidic which is attributed to continuous dispersion/ weathering action at the region. It is obvious that the presence of different heavy metals in different sampling locations is different but they don't vary much from each other. The mine area covered along with dump tailings is approximately 58sq. km, had elevated levels of heavy metals with lowered pH at most of the sampling stations. The soil sampled in and around the mine area showed the maximum concentration range and its standard deviation for Cu, Cr, Ni, Pb, Zn, Fe, Mn, CN and As as 2828 ±251.35 mg/kg, 158±14.04 mg/kg, 1900±168.87mg/kg, 920±51.22mg/kg, 2044±113.80 mg/kg, 9652±537.40mg/kg, 4323±216.15mg/kg, 0mg/kg and 5396±300.4 mg/kg respectively. The concentration of the metals (Co, Cr, Ni, Pb, Zn, Fe, Mn, CN and as) in the study soil is found above the permissible limits of environment quality standard values in many sampling sites.

Table 4: Characterization of the Soil Samples for Physical and Chemical Properties

Sl. No	Places	pH	EC	Bulk Density	N	P
SS1	Masid road	8.24	23	2.71	0	0.083
SS2	BEML Bus Stand	8.14	42.74	3.30	0	0.088
SS3	Bharath Gold mine	4.01	106.3	2.84	0	0.279
SS4	Beml Factory	8.02	37.49	2.85	0	0.274
SS5	KGF	5.39	56.87	3.62	1.72	0.721
SS6	Robertson pet	3.68	77.26	2.6	2.14	0.556
SS7	Cynaide mountain	3.39	122.1	2.23	0	0.297
SS8	PWD guest house	6.02	42.31	2.28	0	0.312
SS9	Bemlnagar	6.15	36.52	2.7	0	0.233
SS10	Oorgumpet	6.1	52.27	2.9	0	0.711

Table 5: Comparison between Recommended and Observed Concentration of Metals in Soil Residue Collected from KGF

Sl.No	Copper (mg/kg)	Chromium (mg/kg)	Nickel (mg/kg)	Lead (mg/kg)	Iron (mg/kg)	Zinc (mg/kg)	Cyanide (mg/kg)	Arsenic (mg/kg)	Manganese (mg/kg)
SS1	1734 ±45.8	0 ± 0.0	1800 ±47.62	700 ±18.52	8156 ±215.78	1435 ±37.96	0 ±0.0	4826 ±127.684	1090 ±28.83
SS2	2123 ±118.2	0 ±0.0	1876 ±104.45	920 ±51.22	9652 ±537.40	1368 ±76.16	0 ±0.0	4367 ±243.14	203 ±11.30
SS3	1903 ±105.95	0 ±0.0	1860 ±103.56	890 ±49.55	8029 ±447.0	1283 ±71.43	0 ±0.0	3876 ±215.80	1364 ±75.94
SS4	1111 ±61.85	45 ±2.5	1100 ±61.24	670 ±37.30	2352 ±130.95	2044 ±113.80	0 ±0.0	5396 ±300.4	2637 ±146.82
SS5	2583 ±229.58	0 ±0.0	1870 ±166.20	440 ±39.10	1150 ±102.2	685 ±60.88	0 ±0.0	3826 ±340.	1410 ±125.32
SS6	2141 ±190.29	0 ±0.0	1900 ±168.87	710 ±61.10	2376 ±211.18	280 ±24.88	0 ±0.0	3987 ±354.3	2632 ±233.93
SS7	2828 ±251.35	158 ±14.04	1213 ±107.81	540 ±47.99	9075 ±806.60	1185 ±105.32	0 ±0.0	4286 ±380.9	1617 ±143.72
SS8	119 ±5.95	0 ±0.0	1730 ±86.5	760 ±38	2250 ±112.5	902 ±45.1	0 ±0.0	2146 ±107.3	4228 ±211.4
SS9	112 ±5.6	0 ±0.0	1692 ±84.6	830 ±41.5	1937 ±96.85	1040 52±	0 ±0.0	2010 ±100.5	3944 ±197.2
SS10	1019 ±50.95	0 ±0.0	1772 ±88.6	810 ±40.5	2038 ±101.9	904 ±45.2	0 ±0.0	2190 ±109.5	4323 ±216.15

The result witnessed the elevated heavy metals concentration in the soil were found everywhere in the vicinity of the Kolar mine (Zhuang, 2009). The higher concentration of these heavy metals in the study area was a result of gold mining activities in which continuous downstream dispersal took place from the dumped tailings. Study by Keshav Krishna also supported the presence of the heavy metals in soil at elevated levels in and around the K.G.F mining area soil.

Mapping of Presence of Heavy Metals

Delineating contamination level of the soil pollutants is essential and the soil properties of the sample obtained is as summarized in table 4. The coefficients variations of EC implies that metals had substantially greater variation values than their background values in the soil samples, suggesting mining pollution. The average soil pH of 5.3 indicating acidic condition. The basic statistics involving mean value and standard deviation of heavy metals investigated are present in table 5. The mean decreasing order of heavy metal concentration is in order CN<Cr<Pb<Zn<Cu<Ni<Mn<As<Fe. The micronutrient Cr found to be absent in most of the stations, whereas other trace metals were present at higher values apart from cyanide. As seen from the table 5, it is obvious that the metal content at 10 different location is not same mainly because of continuous dumplings of tailing waste that supporting the highest concentration of Iron and Arsenic that exceeds upto 9000 mg/kg and 4000mg/kg respectively. From the figure 2 we can easily make out that all the all the points of sampling are polluted heavily by Copper, Chromium, Nickel, Lead, Iron, Zinc, Arsenic and Manganese. The concentration distribution map shows that the origin of metals is purely because of geogenic action and according to Loghman 2013; distribution of these metals is controlled by natural factors.

Copper

Figure 2 shows the distribution of copper in the study area of K.G.F. The maximum and minimum concentration of copper in the soil is found at cyanide mountain and guest house and is 2828 mg/kg and 112 mg/kg respectively. The average concentration of copper at study site is found to be 1567.3mg/kg. According to Keshav 2010, maximum concentration of copper at KGF is found to be 128.8 mg/kg. The copper concentration in and around the mining area is due to the presence of chalcopyrite, spharelite and Galena where the concentration is found to be not less than 1g/kg.

Chromium

According to Keshav 2010 study, the maximum concentration of chromium is found to be 979.9 mg/kg in both 2004 and 2005 but the distribution pattern of my study showed the evidence for the absence of metal chromium in major study sites. Only two stations (BEML Factory and Cyanide Mountain) marked their presence for chromium concentration in which SS7 showed the concentration slightly above the tolerance limit (158mg/kg) and SS4 concentration was within the limit (45mg/kg) respectively.

Nickel

According to WHO, the maximum concentration level of nickel in soil 50mg/kg? Nickel, the component of pyrite and pyrrhoite showed the variation ranging from1100 to 1876 mg/kg with maximum at SS2 (BEML bus stand) and minimum at SS4 (BEML factory) respectively. The distribution pattern of nickel is mapped in figure 2. Kesav 2010 study also marked highest nickel concentration (304mg/kg) and average concentration of this metal in my study is 1681.3mg/kg which is very high to its tolerance limit.

Lead

Concentration distribution of Lead in the soil samples of KGF shown in figure 2. Found to vary between 440 to 920mg/kg at BEML bus stand and KGF respectively which is very high compared to threshold limit (100 mg/kg). Highest concentration of lead in the soil collected is found to be 920 mg/kg. Previous study by Keshav et al also supported with high concentration of lead near the mine site. Lead may be due to the presence of chalcopyrite, spharelite and galena which is the major source.

Iron

Iron concentration in the soil samples is found to be very high in and around the mining area. The maximum concentration distribution of metal iron found to be 9652mg/L at BEML bus stand and the average concentration is 4701 mg/kg which is comparatively low. The variation in the concentration of metal iron from the soil collected in and around the tailings dumps are as shown in the Figure 2.

Zinc

The distribution pattern of zinc is as mapped in figure 2. The trace element Zinc showed its maximum and minimum presence at BEML factory and Robertsonpet respectively. The tolerance limit of Zinc is 300mg/kg and the concentration level of Zinc was within the tolerance limit only at the sampling site SS6. As the main ore deposits were very high in soil environment, the concentration level was not in control.

Cyanide

The maximum tolerance limit of Cyanide in the soil should be 3mg/kg. Though the Cyanide, a cyano group triple-bonded carbon and nitrogen with the chemical formula CN has been dominant in gold extraction technology by the process called cyanide leaching, their presence and their distribution in and around the soil collected from various locations of the study area was found to be nil. This is majorly because the metal cyanide can undergo natural degradation process.

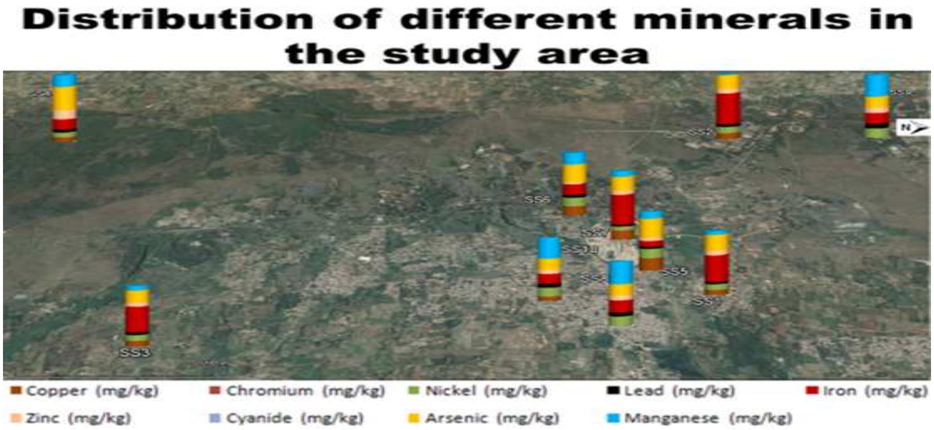

Figure 2: Concentration Distribution Pattern of Heavy Metals in KGF Mine Soil

Arsenic

Concentration of metal arsenic in the soil residues which were collected from the study area of K.G.F is mapped. The distribution pattern of Arsenic content in all soil samples from the 10 sampling locations can be seen in figure 2. The mapped concentration values of the arsenic clearly declared the exceeded concentration of metal in all the 10 samples. Concentration of arsenic at Robertsonpet had the maximum concentration of 5396 mg/kg and lower concentration 2010 mg/kg being at BEML nagar with the average being 3691mg/ kg. Previous study by Keshav2010, supported for high concentration of Arsenic in Robertsonpet and Andorsonpet. Arsenic content may be due to the presence of arsenopyrites in the mining area or may be ascribed during leaching of dumps.

Magnesium

Magnesium values are been mapped in figure 2. The concentration distribution pattern of magnesium tells the metal in the soil collected from the 10 sampling points of the mining study area showed average concentration of 2344.3 mg/kg with the maximum and minimum being found at oorgampet and PWD guest house as 4323 mg/kg and 4228 mg/kg respectively.

Evaluation of Pollution Level in Soil

Table 6 shows the values of pollution Indices for individual metal at all the 10 sampling points of KGF. Comparing the background and availed concentration of the study region, the average SPFI values of all the heavy metals (As, Cu, Ni, Pb, Zn, Mn) except Iron and Chromium were much higher than 1 indicating excess pollution according to the guidelines shown in table 3. Overall accumulated heavy metal pollution ratio concentration increased in order Arsenic > Copper> Nickel> Lead> Zinc> Manganese> Chromium> Iron. Highest pollution indices is found for Copper, Arsenic, Nickel and Lead in soil residue collected from 10 different stations which is majorly influenced by mining activity and followed by dispersion by natural means. The Nemerow pollution indices of heavy metals (PI_N) also varied significantly for the soils of different land use types (Table 7). Copper, Nickel, Arsenic, lead and Zinc are majority indicators of heavy pollution level having PI_N values as 225.22, 35.87, 21.31, 8.29, 5.47 respectively followed by Magnesium, Chromium and Iron with Nemerow pollution indices as 1.67, 1.12 and 0.148 showing light pollution and clean level respectively. According to the result obtained all the heavy metals in soil except Iron are in high concentration and the study site soil does not remain safe.

Table 6: Single Pollution Factor Indices (PI) of Individual Metals

Stations	PI_{Cu}	PI_{Cr}	PI_{Ni}	PI_{Pb}	PI_{Fe}	PI_{Zn}	PI_{As}	PI_{Mn}
SS1	173.4	0	36	7	0.163	4.73	241.3	0.54
SS2	212.3	0	37.52	9.2	0.193	4.56	218.35	0.101
SS3	190.3	0	37.2	8.9	0.160	4.27	193.8	0.682
SS4	111.1	0.45	22	6.7	0.047	6.81	269.8	1.31
SS5	258.3	0	37.4	4.4	0.023	2.28	191.3	0.70
SS6	214.1	0	38	7.1	0.047	0.93	199.35	1.316
SS7	282.8	1.58	24.26	5.4	0.181	3.95	214.3	0.808
SS8	11.9	0	34.6	7.6	0.04	3.00	107.3	2.114
SS9	11.2	0	33.84	8.3	0.038	3.46	100.5	1.97
SS10	101.9	0	35.44	8.10	0.040	3.01	109.5	2.16

Table 7: Nemerow Pollution Factor Index (PI_N) of Individual Metals

Samples	Copper	Chromium	Nickel	Lead	Iron	Zinc	Arsenic	Manganese
Average	146.54	0.203	33.62	7.27	0.093	3.7	184.55	1.1
PI_N	225.22	1.12	35.87	8.29	0.148	5.47	21.31	1.67

CONCLUSIONS

The findings obtained are the important implication for prevention of pollution and reduction strategies of heavy metal at various metal polluted regions. Based on the guideline values given by WHO and FAO for heavy metal tolerance limit, the residue of KGF soil showed presence of Copper, Arsenic, Nickel, Lead, Zinc, Magnesium, Chromium and Iron contaminants while the concentration of chromium and Iron where at precaution level and at a safe level. The long-term deposition of mine tailings at dump site remains the main pollution sources in the study area.

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