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Evaluation of soil contamination in the surroundings of Kerala Minerals and Metals Limited (KMML) industrial area in Kollam District, Kerala, South India

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Toxic trace metals concentration in soil exerts a decisive impact on soil quality in an industrial area. In recent days, industrialization is growing at very faster rate than any other activities. Due to industrialization, the pollution load for water, air and soil is increasing day by day. Metal pollution in soil possess a serious threat to the human health and safety of agricultural production. An attempt is made here to study soil contamination due to industrial effluents and air pollutants in the surroundings of KMML (Kerala Minerals and Metals Ltd.) industrial area in Chavara, Kerala. To find out the soil pollution from the solid and liquid wastes produced due to the manufacturing process of titanium dioxide in the KMML industry, a detailed analysis was conducted on the physico-chemical characteristics of soil samples collected from the surrounding areas. The study on the physical and chemical characteristics of soil in the selected stations of KMML industrial area shows that soils are acidic in nature and the concentration of nutrients like organic carbon, organic matter, nitrogen, total phosphorus, sodium in the study stations near the industry were less than that of the control soils. The present study revealed that the heavy metal concentrations in all the study stations were high compared to the control station. The study shows that the soils in the surroundings of industrial area are contaminated with toxic elements than its normal distribution.

Key words: Soil pollution, heavy metals, industrial area, Kerala minerals and metals limited (KMML)

INTRODUCTION

Soil is an essential component of terrestrial ecosystem because the growth of plants and biogeochemical cycling of nutrients depends up on it. Soil pollution can also be a hazard to human health when potentially toxic substances move through the food chain or reach ground water used for drinking water supplies. In comparison with air and water, the soil is more variable and complex in composition and its function as a sink for pollutants, a filter which retards the passage of chemicals to the ground water and a bioreactor in which many organic

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pollutants can be decomposed.

Environmental pollution caused by heavy metals discharged from industrial area will end up in one of the environmental segments such as air, water, soil and vegetation mainly through pathways of solid wastes, wastewater and waste gases (Haiyan and Stuanes, 2003). Although the soil pollution usually may not be as apparent as that of the air or water, since the late 20th century, the influence of urbanization on the accumulation of heavy metals in soil has aroused more and more concern from scientists all over the world (Govil et al., 2001; Romic and Romic, 2003). The deterioration of the environment quality from heavy metal contamination raising serious concerns existing as non-degradable materials, in long term can accumulate in toxic level at higher concentration and their biotransformation in food chain. A study was carried out by Elbagermi et al. (2013) on the assessment of heavy metals (Pb, Fe, Zn, Ni, Cd, Cr, and Cu) in soil and roadside dust around Misurata City Centre and industrial areas/roads in Libya during the period of October 2011 - May 2012. The study showed overall means metal concentration for main streets was significantly higher ($P < 0.05$) than for other small streets.

Seenivasan et al. (2008) reported that industrial growth is causing an enormous environmental pollution. They also pointed out that industrial activities result in the pollution of soil; as polluted soil can alter plant growth and quality, and the effects are often destructive. Pollution of the environment with heavy metals has increased dramatically since the onset of the industrial revolution. The term ‘heavy metal’ refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. To a small extent they enter our bodies via food, drinking water and air. Soil pollution by heavy metals, such as cadmium, lead, chromium, copper etc. is a problem of concern. Although heavy metals are naturally present in soil, contamination comes from different sources, and among them heavy traffic is an important source in most of the roadside soils. Heavy metals occur naturally at low concentrations in soils. However, they are considered as soil contaminants due to their widespread occurrence, acute and chronic toxicity. Heavy metals get accumulated in soils and plants causing negative influence on photosynthesis, gaseous exchange, and nutrient absorption of plants resulting reductions in plant growth, dry matter accumulation and yield (Devkota and Schmidt, 2000). In small concentrations, the traces of the heavy metals in plants or animals are not toxic. Lead, cadmium and mercury are exceptions; they are toxic even in very low concentrations (Gandhimathi and Meenambal, 2012).

A study was conducted by Sharma and Raju (2013) to know the correlation between soil properties with heavy metal concentrations by cluster analysis in industrially polluted soil in Mysore, Karnataka state in India. The relationship between different physico-chemical properties and heavy metal concentrations were analyzed by Pearson’s correlation coefficient. The study concluded that, the heavy metal contents are introduced by so many sources and human activities which include industrial operations. Atmospheric deposition of contaminated dust and industrial discharge may be the prime cause of heavy metals contamination in soil. The major objectives of present study include the evaluation of physical and chemical characteristics of the soils in KMML industrial area, and to assess the heavy metal concentration in the soils of KMML industrial area.

MATERIALS AND METHODS

Study Area

The study was conducted in the surroundings of Kerala Minerals and Metals Ltd. (KMML) industry, situated at Chavara in Kollam District, Kerala during summer season (March-April 2013). KMML is located at 8°59' 54.2" N latitude and 76°32' 07.5" E longitude near the National Highway-47. The total area of KMML industry is about 210 acres. The location map of study area and study stations are given in the Figure 1. KMML is a leading Titanium dioxide manufacturing industry in India. Through the chloride route, KMML produces rutile grade Titanium dioxide pigment. Indian Rare Earths Ltd (IRE) is situated in the south western direction, 3 km away from the KMML. The IRE mines and separates the mineral sand into ilmenite, rutile, zircon etc. and are used as the raw materials for the manufacture of titanium dioxide pigment and titanium dioxide sponge metal in the KMML industry. The National Highway-47 (now NH 966) passes adjacent to the KMML industry in Chavara area. The Arabian Sea is in the western side of KMML and the other sides are residential areas with vegetation.

Sampling stations

Extensive field survey of the entire study area including Chavara block and Oachira block in Kollam District was conducted and the sampling stations were selected. The soil type of study area is sandy loam. Soil samples were collected from eleven different stations situated in the northern, eastern, southern and west erndirection of the KMML factory. Four sampling stations (S1, S4, S7 and S10) were selected within ½ km from the factory in the northern, eastern, southern, and western directions respectively. The second, fifth and eighth sampling sites (S2, S5, and S8) are located 1½ km away from the factory in the three different directions. The third, sixth and ninth (S3, S6 and S9) were located 3 km away from the factory in the northern, eastern and southern directions respectively. The station, S11 is the control station, 14 km away, in the north western side of the factory, and is in a benign environment. The description of the sampling stations are given in Table 1.

Sample collection

Soil samples were collected during the summer season, in the month of April 2013. Surface soil samples were collected from the study stations at a depth of about 0 to 15 cm using a shovel by Cone and Quarter method (Allen, 1981). Soil samples were collected in thick quality polythene bags and immediately brought to

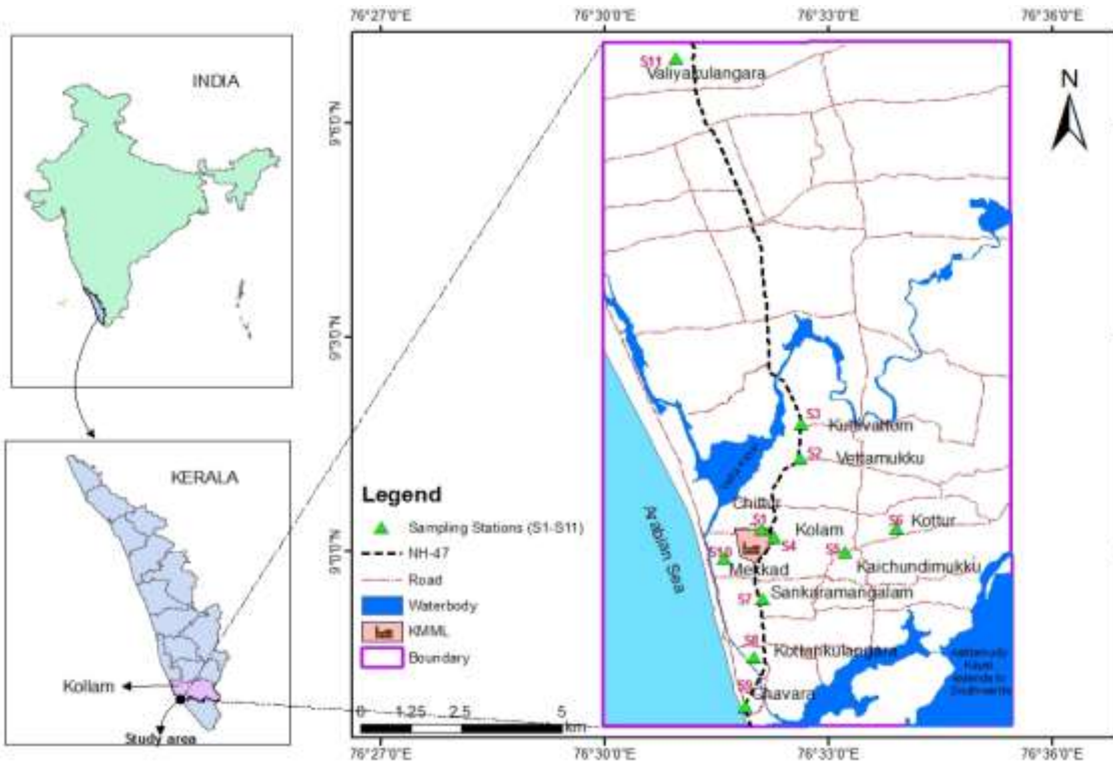

Figure 1. Location map of study area showing sampling stations.

Table 1. Description of stations selected in the study area.

Station	Location	Description of Station
Chittur	S1	Half kilometre away, in the northern side of the factory
Vettamukku	S2	One and half kilometre away, in the north-eastern side of the factory
Kuttivattom	S3	Three kilometre away, in the northern side of the factory and near to National Highway
Kolam	S4	Half kilometre away, in the eastern side of the factory
Kaichoondimukku	S5	One and half kilometre away, in the eastern side of the factory
Kottur	S6	Three kilometre away, in the eastern side of the factory
Sankaramangalam	S7	Half kilometre away, in the southern side of the factory and near to National Highway
Kottamkulangara	S8	One and half kilometre away, in the south western side of the factory
Chavara	S9	Three kilometre away, in the southern side of the factory and near to National Highway.
Mekkadu	S10	Half kilometre away, in the western side of the factory, near the effluent discharge area.
Valiyakulangara	S11 (Control)	Fourteen kilometre away in the north western direction of the factory

the laboratory for further analysis of physico-chemical parameters and heavy metals.

Soil analysis

The various physico-chemical parameters of soil samples collected were analysed following the procedures described by Trivedy and Goel (1986), Gupta (1999) and Saxena (1998). Soil pH was determined by potentiometric method using a digital pH meter. Electrical conductivity was determined by conductometric method using a conductivity meter. The soil organic carbon (OC) was determined by wet chemical oxidation method of Walkley and Black (1934). Total nitrogen content in the soil sample was determined by Kjeldhal distillation method. The chloride content in the soil samples were determined by argentometric titration. Concentration of total phosphorus in the soil samples was determined after acid digestion by spectrophotometric method. The concentration of potassium and sodium in soil extract were determined using a Flame Photometer (Elico CL-360), based on the procedure suggested by Gupta

Table 2. Physico-chemical characteristics of soil samples.

Station	pH	Moisture content (%)	Bulk density (g/cm^3)	Specific gravity (g/cm^3)	EC (mS/cm)	Organic Carbon (%)	Organic Matter (%)	Nitrogen (%)	Total Phosphorous (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)	Chloride (mg/kg)	Sulphate (mg/kg)	C/N ratio
S1	5.26	5.53	1.28	1.38	0.053	0.039	0.067	0.042	56	30	1780	781	327.6	0.9285
S2	6.18	3.96	1.34	1.43	0.052	0.199	0.343	0.056	59	70	960	497	279.3	3.5535
S3	6.27	4.38	1.54	1.58	0. 108	0.596	1.027	0.064	76	130	1470	481.5	213.6	9.3125
S4	5.59	1.91	1.42	1.53	0.082	0.071	0.122	0.021	62	230	1560	532.5	195.3	3.3809
S5	6.02	2.16	1.49	1.57	0.073	0.181	0.312	0.0266	100	370	1700	487	136.6	6.8045
S6	6.13	5.11	1.4	1.51	0.084	1.199	2.067	0.0566	221	1320	5540	471.5	91.8	21.1837
S7	5.71	3.61	1.57	1.6	0.181	0.125	0.216	0.0118	59	360	2850	745.5	83.2	10.5932
S8	6.71	4.03	1.32	1.33	0.041	0.149	0.257	0.0126	168	460	3440	639	58.2	11.8253
S9	7.29	2.45	1.55	1.61	0.194	0.099	0.17	0.046	207	2630	6870	923	82.4	2.1521
S10	4.97	8.47	1.31	1.37	0.074	0.093	0.16	0.0112	47	60	3340	938	359.8	8.3035
S11	6.93	8.68	1.34	1.38	0.04	1.256	2.165	0.0652	369	490	8050	461.5	18.2	19.2638
Average	5.96	4.161	1.422	1.491	0.0982	0.2751	0.4741	0.03754	105.5	566	2951	649.6	182.78	8.8455
Minimum	4.97	1.91	1.28	1.33	0.04	0.039	0.067	0.0112	47	30	960	461.5	18.2	0.9285
Maximum	7.29	8.68	1.57	1.61	0.194	1.256	2.165	0.0652	369	2630	8050	938	359.8	21.1837

(1999). The soil samples were subjected to diacid digestion (Gupta 1999; Alloway, 1995) and the heavy metal content (Pb, Zn, Cd, Cr, Mn, Fe) in the samples were estimated using an Inductively Coupled Plasma Atomic Emission Spectrometer (model IRIS intrepid II XSP).

RESULTS AND DISCUSSION

Physical characteristics of soil

The results of various physical characteristics of soil moisture, bulk density, and specific gravity of the soil samples analysed in the different samplings stations are given in Table 2.

Soil moisture

The moisture content in the soil samples ranged from 1.91% (S4) to 8.68% (S11), with an average of 4.161% during the study period. Moisture content in the soils samples recorded maximum value in station 11 (control station) followed by S10 (Mekkadu) that is close to effluent discharge point from the KMML industry. The least value was recorded at station 4 (Kolam).

Bulk density

The result of bulk density in the soil samples ranged from 1.28 g/cm^3 (S1) to 1.57 g/cm^3 with an average of 1.422 g/cm^3 (S7) during the study period. The bulk density in the sample soils recorded maximum values present in station 7. The least value reported at station 1 near the northern side of the factory. Bulk density in the soil samples showed increasing values with respect to that of the control station during the study period.

Specific gravity

The results specific gravity in the soil samples ranged from1.33 g/cm^3 (S8) to 1.61 g/cm^3 (S9) with an average of 1.491 g/cm^3 during the study period. Specific gravity of the control station (S11) was 1.38 g/cm^3 during the study period. The specific gravity in the sample soils recorded maximum value at station 9 and minimum at station 8. Specific gravity in the soil samples showed varying values. The specific gravity of soil samples in Station-8 and Station-10 in the study area was found less than that of the control station during the study period.

Chemical characteristics of soil

The results of various chemical characteristics like pH, electrical conductivity, chlorides, sulphate, organic carbon, organic matter, total nitrogen, total phosphorus, sodium, potassium and C/N ratio of the soil samples analysed in the different samplings stations are given in Table 2.

Soil pH

The results of pH in the soil samples ranged from 4.97 to 7.29. The lowest pH value was recorded at S10 that is 4.97, which shows that the soil nearest to the industry is highly acidic. At the control station (Station-11), the soil pH is near neutral (6.93) during the study period. The study show that, 90% of the selected stations of the study area are with acidic pH.

There is noticeable increase in pH in the stations S3, S6 and S9 which show that there is a reduction in acidity as the distance from the factory increases. In the southern side, alkaline pH (7.29) was noticed in the station 9, which is 3 km away from the KMML industry and is near to the Arabian Sea.

Electrical conductivity

Electrical conductivity (EC) is a measure of ions present in water. The conductivity of a solution increases with the increase in amount of ions. In the agricultural field electrical conductivity plays an important role, because of salinity aspect.

The results of electrical conductivity in the soil samples ranged from 0.04 mS/cm to 0.194 mS/cm, with an average of 0.0982 mS/cm during the study period, the lowest value was noted at control station and highest value was noticed at S9, near to Arabian Sea. The electrical conductivity of soils at the sampling stations in National Highway-47 (S3, S7, and S9) showed higher values compared to other stations during the study period. A similar study conducted by Sharma and Raju (2013) found that the presence of large amount of ionic substance and soluble salts have resulted in increased value of EC in the industrial effluents treated soil samples in comparison to the others. The higher values of electrical conductivity is toxic to the plants.

Chlorides

The chloride content in the soil samples ranged from 461.5 mg/kg (S11) to 938 mg/kg (S10), with an average of 649.6 mg/kg during the study period. The chloride content in the sample soils recorded maximum values in station 10, in the western side of the factory, near the effluent discharge point. The lowest value (461.5 mg/kg) was recorded at control station. High chloride content was also noted in the soils of Stations 1, 7, and 9 of the study area. Studies by Shaji et al. (2009) revealed that well waters in the surroundings of KMML industrial area was polluted. It exhibited high BOD, COD, TDS, total hardness, calcium, chloride, nitrate, phosphate and free CO_2 which are sourced to industrial wastes being discharged into the surrounding areas.

Sulphates

The sulphate content in the soil samples ranged from 18.20 mg/kg (S11) to 359.8 mg/kg (S10), with an average of 182.78 mg/kg. The sulphate content recorded maximum values in station 10 soils, near the western side of the factory and the least value was reported at control station (S11). The sulphate content in the soil samples in all the other stations showed high values with respect to that of the control station soils during the study period.

Organic Carbon and organic matter

Soil carbon is the last major pool of the carbon cycle. The carbon that is fixed by plant is transferred to the soil via dead plant matter including dead roots, leaves and fruiting bodies (Lal, 2008). Soil carbon is primarily composed of biomass and non-biomass carbon sources. Soil organic carbon improves the physical properties of soil. It increases cation exchange capacity and water holding capacity of sandy soil and it contributes to the structural stability of clays soil by helping to bind particles in to aggregates (Leeper and Uren, 1993). Organic carbon contents play a crucial role in sustaining soil fertility, crop production and environmental quality due to their effect on soil physical, chemical and biological properties, such as soil water retention, nutrient cycling, gas flax and plant root growth (Saiju and Kalisz, 1990).

The soil organic carbon content in the study area ranged from 0.039% (S1) to 1.265% (S11), with an average 0.2751%. Maximum organic carbon content was detected in the control station (S11) and minimum organic carbon was noted at station S1. Gradual increase in organic carbon in the study stations were observed, and is in the pattern S3 >S2 >S1 and S6 >S5>S4, which suggest distance from factory brings in increased organic carbon due to the increase in vegetation. The lowest value was noted in the southern side at station (S9), three kilometres away from the southern side of the factory and also the Arabian Sea is near this station. Soil organic matter of nutrients, cations and trace elements are important for plant growth. It prevents the nutrient leaching and if integral to the organic acids that make minerals available to plants. It also buffers the soil form strong changes in pH (Leu, 2007).

The soil organic matter of the study stations ranged from 0.067% (S1) to 2.165% (S11) with an average 0.4741% during the study period. Organic matter less than 2% is not good for any plant growth. In the present study most of the soil sample contains less than 2% organic matter. Maximum organic matter content (2.165%) was detected in control station (S11) and minimum organic matter is noted at the station S1. Gradual increase in organic matter was recorded in northern and eastern sides with respect to increase in distance of study stations from the KMML industry, and is in the pattern S3> S2> S1 and S6> S5 >S4. Minimum organic matter content was recorded at S1 and S4 which can be attributed to the low soil microbial activity due to the industrial wastes in this area. The soil productivity is determined primarily by organic matter. The organic matter provides food for micro organisms, takes part in chemical reactions such as ion exchange, governs the physical properties of soil and sometimes contributes to the weathering of mineral matter (De, 1987).

Total Nitrogen

The total nitrogen content in the soils varied from 0.0112% (S10) to 0.0652% (S11) with an average of 0.03754% during the study period. The concentration of total nitrogen in the soil samples showed the maximum values at control station and minimum at station 10 (Mekkadu).

C/N ratio

The results of C/N ratio in the soils varied from 0.9285% (S1) to 8.8455 (S6), with an average of 7.336% during the study period. C/N ratio in the soil samples showed the maximum values at station S6 and minimum at station 1, near KMML industry and is half kilometre away from northern side (S1) of the factory.

Total Phosphorus

The concentration of total phosphorus ranged from 47 mg/kg (S10) to 369 mg/kg (S11) with an average of 105.5 mg/kg during the study period. The highest value reported at control station and minimum showed in station 10 near the western side of the factory. A direct relationship could not be established between the sampling stations as there is much variability in phosphorous content.

Potassium

The potassium content in the soil samples varied from 30 mg/kg (S1) to 2630 mg/kg (S9) with an average of 566 mg/kg during the study period. The highest value noted at the station 9 and lowest result shown at station 1. Gradual increase in potassium level is noticed in three sides in relation with distance from the factory. The pattern can be noted as S3 > S2 >S1, S6 >S5 >S4, and S9 >S8 >S7. In the control station (S11) the soil potassium content is 490 mg/kg.

Potassium is not an integral part of any major plant component but it plays a key role in a vast array of physiological process vital to plant growth from protein synthesis to maintenance of plant-water balance. Potassium is a macro nutrient that is present in high concentration in soils, but is not bio-available because it is bound to other compounds (Greenwood, 1997).

Potassium deficiency occurs frequently in plants grown on sandy soils resulting in a number of symptoms including browning of leaves, curling of leaf tips and yellowing (chlorosis) of leaves, as well as reduced growth and fertility. Potassium is required at high level by growing plants. The present study revealed decrease in soil potassium content in the KMML industrial area. Potassium has a number of important functions within plants, including balancing the charges of cellular anions, enzyme activation, and control of stomata opening and closing. Potassium activates some enzymes and plays a key role in the water balance in plants and for carbohydrate transformation (William et al., 2008).

Sodium

Sodium content in the soil samples collected from the sampling stations during summer season of the study period varied from 960 mg/kg (S2) to 8050 mg/kg (S11), with an average value of 2951 mg/kg. The highest value was noted at station 11 (control station) and lowest value at station 2.

Heavy metal content in soils

The results of the concentration of lead, zinc, cadmium, chromium, manganese and iron in soils samples analysed in the different samplings stations are given in Table 3.

Lead

The species of lead vary considerably with soil type. It is mainly associated with clay minerals, Manganese oxides, Fe and Aluminium hydroxides and organic matter. In some soil types, lead may be highly concentrated in calcium carbonate particles or in phosphate concentrations. Typical mean Pb concentration for

Table 3. Concentration of heavy metals in soil (mg/kg dry weight).

Station No.	Pb	Zn	Cd	Cr	Fe	Mn
S1	41	110	BDL	292	18180	197
S2	38	49	BDL	279	16995	215
S3	112	57	0.4	276	19345	276
S4	59	85	0.5	306	27320	286
S5	50	94	BDL	404	41435	537
S6	35	77	BDL	277	27175	193
S7	66	210	0.4	330	31800	390
S8	59	104	BDL	252	22530	306
S9	68	132	0.6	250	28815	485
S10	84	107	0.4	318	26860	389
S11 (Control)	40	58	BDL	231	19755	153
Average	**61.2**	**102.5**	**0.27**	**298.4**	**28021**	**327.4**

surface soils worldwide averages 32 mg/kg and ranges from 10 to 67 mg/kg (Pendias, 2001).

The results of lead content in the soil samples varied from 35 mg/kg (S6) to 112 mg/kg (S3), with an average of 61.2 mg/kg during the study period. The lead concentration in the road side soil samples S3 and S9 showed high values with respect to that of the control station during the study period. Lead in the soils of study stations are in the order S3> S10> S9> S7> S4, S8> S5> S1> S11> S2> S6.

Lead is not an essential element. It is well known to be toxic and its effects have been more extensively reviewed than the effects of other trace metals. Lead can cause serious injury to the brain, nervous system, red blood cells, and kidneys. Pb accumulates in the body organs which may lead to poisoning or even death. Children exposed to lead are at risk for impaired development, lower IQ, shortened attention span, hyperactivity, and mental deterioration, with children under the age of six being at a more substantial risk. Adults usually experience decreased reaction time, loss of memory, nausea, insomnia, anorexia, and weakness of the joints when exposed to lead (Baldwin and Marshall, 1999).

Cadmium

Cadmium is very mobile and bio available metal which may accumulate in crops and humans (Alloway, 1995). The cadmium content in the soil samples ranges from 0.4 mg/kg (S3, S7, S10) to 0.6 mg/kg (S9) with an average of 0.27 mg/kg. The cadmium concentration in the soil samples in S1, S2, and S5 showed BDL including control station (S11) during the study period. The results of the present study show that cadmium content in all the stations of KMML industrial area soil are within the standard permissible limit of Indian standards (Awashthi, 2000).Cadmium content in the soils of study stations are in the order S9> S4> S3, S7, S10>S1, S2, S5, S6, S8, S11. The previous studies (Mathew and Venugopal, 2006) conducted on the status of heavy metals in samples of selected soils of Kerala show that retention of Cadmium was more in the top soils than in the bottom layers.

Zinc

Zinc belongs to a group of trace metals, which are essential for the growth of humans, animals and plants and are potentially dangerous for the biosphere when present in high concentrations. The main sources of pollution are industries and the use of liquid manure, composted materials and agrochemicals such as fertilizers and pesticides in agriculture (Romic and Romic, 2003).

The zinc content in the soil samples varied from 49mg /kg (S2) to 210mg /kg (S7) with an average of 102.5mg /kg during the study period. The zinc concentration in the soil samples of study station S7 (Sankaramangalam) was showed increase. Zinc content in the soils of study stations are in the order S7> S9> S1> S10> S8> S5> S4> S6> S11> S3> S2. In the present study the soil zinc content in the different study stations in the surroundings of KMML industrial area were below the upper limits of 300 mg/kg prevention of food adulteration act (PFA) standards (Awashthi, 2000).

Chromium

Chromium is a low mobility element, especially under moderately oxidizing and reducing conditions. The normal range of chromium in soil is 100 mg/kg as reported by Ewers (1991). The chromium content in the soil samples ranged from 231 mg/kg (S11) to 404 mg/kg (S5) with an average of 298.4 mg/kg during the study period. The chromium concentration in the soil samples all other stations showed increasing values with respect to that in the control station. Chromium content in the soils of study stations are in the order S5> S7> S10> S4> S1> S2> S6> S3> S8> S9> S11.

Iron

The iron content in the soil samples varied from 16995 mg/kg (S2) to 41435 mg/kg (S5) with an average of 28021 mg/kg during the study period. The iron concentration in the soil samples in all the study stations (except station 1, 2 and 3) showed increasing values with respect to that in the control station. Iron content in the soils of study stations are in the order S5> S7> S9> S4>

S6> S10> S8> S11> S3> S1> S2.

Manganese

The manganese content in the soil samples varied from 153 mg/kg (S11-control) to 537 mg/kg (S5) with an average of 327.4 mg/kg during the study period. The manganese concentration in the soil samples in all the study stations showed increase in its value with respect to that in the control station. Manganese content in the soils of study stations are in the order S5> S9> S7> S10> S8> S4> S3> S2> S1> S6> S11.

Conclusion

Life on earth exists in a very delicate balance, where soil, air and water sustain not only human life, but the entire eco-system. Any imbalance in this ecosystem due to environmental pollution results in contamination and sets off a chain of disruption that affects all patterns of existence. Heavy metal content in the soils of study stations are in the order iron > manganese > chromium > zinc > lead > cadmium. The concentration of heavy metals Pb, Zn, Cd, Cr and Mn in the stations, S1, S4, S7 and S10 nearest (within half kilometre distance) to the KMML industry were found higher than that in the control station. The results of the study also show that soils in the vicinity of KMML industrial area have been contaminated with heavy metals at levels above the background concentrations in soil, which may give rise to various health hazards. There should be a provision to measure toxic metals in industrial effluents before dumping. Soil pollution is a reality today with as severe repercussions as water and air pollution. Soil pollution facts need to be understood, and more importantly controlled. The effects of pollution on soil are quite alarming and may cause huge disturbances in the ecological balance and health of living creatures on earth.

Conflict of Interests

The authors have not declared any conflict of interests.

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