September 2007 Volume 2 Issue 3

Trade Science Inc.

Environmental Science

An Indian Journal

Current Research Paper

ESAIJ, 2(3), 2007 [145-153]

Nutrients And Alkali Metal Distribution In The Top Soil Of Bauxite Rich Hillocks In Araku Valley, Andhra Pradesh, India

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Received: 19th May, 2007 ; Accepted: 24th May, 2007

ABSTRACT

Spatial variation in the distribution of select nutrients and alkali and alkaline earth metals in the top soil of three hillocks(Raktakonda, Galikonda and Chittamgondi) near Visakhapatnam(Araku valley) India was explored. The study was undertaken during November 2006 to January 2007. The soil samples were collected up to a depth of 10 cm as two 5 cm slices. The soil type in the mine area was acidic with clayey loam texture. Total organic matter(TOM), total nitrogen(TN) and total available sulphur(TAS) ranged from 16.27 to 56.51 %, 3467 to 7829 mg/kg and 3.71 to 332.40 mg/kg respectively. The lowest and highest values for chloride were 153.70 and 342.87 mg/kg. The exchangeable bases were in the order of Ca>Mg>K>Na>Li. Cation exchange capacity(CEC) was in the range of 39.2 to 187.5 meq/kg. Two-way ANOVA for pH, EC, TDS, and alkali and alkaline earth metals showed significant variation($P<0.05$) among sites. Except for TOM, TN, TAS, Na and Li, all other nutrients/elements varied significantly (t-Test, $P<0.05$) between months. Among the alkali metals, K was positively correlated with Ca and Li. K, Ca and Li were positively correlated with TAS in soil, while Na was negatively correlated. Ca was negatively correlated with TN.

KEYWORDS

Acid soil;
Bauxite mines;
Araku valley;
Andhra Pradesh.

INTRODUCTION

Andhra Pradesh, one of the southern states of India, has considerable deposits of bauxite in the Eastern Ghats around Visakhapatnam, East Godavari and West Godavari districts and has an estimated reserve of 455.8 million tones. Araku valley, almost 120 km northwest of Visakhapatnam has deposits of bauxite in different locations (Raktakonda, Galikonda and Chittamgondi), with its hill-tops covered by lateritic bauxite capping over Khondalite. These sites rich in bauxite deposition are likely to be exploited for mineral extraction in near future. However, the opencast mining(a method of ore excavation for certain

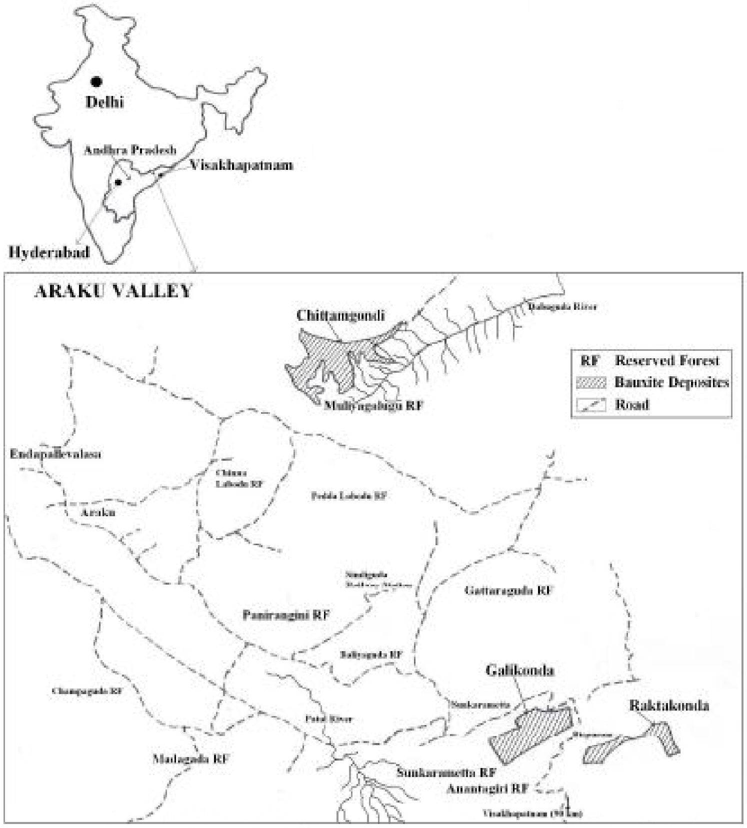

Figure 1 : Study area map

minerals such as bauxite, limestone, etc) in the above three sites may lead to various impacts. In general, opencast mining leads to total change of appearance of the area and its biological and environmental values. Some of the common notable impacts of mining are **(i)** removal of overlying landscapes, disrupting the geology and soil plant stability circuit[1] of the area, **(ii)** effects on human settlements and local ecosystems causing deforestation, and damage to forest flora and fauna[2-4]**, (iii)** augmentation of nutrient export from the system and depletion of soil organic pool[5], **(iv)** accumulation of huge quantity of unfertile overburden(OB) dumped on the nearby land covering vast area of productive soil[6], **(v)** severely affects near by aquatic systems due to release of acid mine drainage etc[7], and **(vi)** alters the chemical form of many mineral deposits and many elements may get dispersed from concentrated ores(resource depletion) into less concentrated wastes(pollution). However, the scale of environmental damage due to mining practices varies depending on the details of the mining schedule, the location, the management of the mines and overburden, and other related activities.

Mining from the earth's crust is the single most important source of several various ores (metallic and non-metallic) and minerals. Aluminium being third most abundant element constitutes approximately 8% of the earth's crust[8]. Alumina industry continues to be the largest consumer of bauxite followed by refractory and cement. Australia, Brazil, Guinea and Jamaica continue to be the major producers of bauxite[9]. India on a fast pace of development, large number of mining projects are undertaken in recent years, bauxite mining being an important one among them. Large spread wild areas are being open up for the purpose of mining. The total estimated recoverable reserves of all grades of bauxite in India are 2,740 million tones.

Araku valley having considerable amount of mineral deposits in several sites is identified as potential mining site for bauxite. In view of the widely noted changes that are likely to happen as opencast mining proceeds it is felt imperative that the baseline habitat characterization of the area is documented, before such activities are initiated. As part of such a study the present investigation was undertaken and

TABLE 1 : Sampling locations, site code and geographic coordinates

Location	Sampling Locations	Code	Coordinates	
			Latitude	Longitude
Raktakonda	Raktakonda-1	R-1	18^{0}16’09.0”N	083^{0}00’09.1”E
	Raktakonda-2	R-2	18^{0}16’16.7”N	083^{0}00’19.1”E
	Raktakonda-3	R-2	18^{0}16’08.3”N	083^{0}00’17.1”E
Galikonda	Galikonda-1	G-1	18^{0}16’29.6”N	082^{0}59’31.1”E
	Galikonda-2	G-2	18^{0}16’25.4”N	082^{0}59’28.7”E
	Galikonda-3	G-3	18^{0}16’20.6”N	082^{0}59’20.1”E
	Galikonda-4	G-4	18^{0}16’19.6”N	082^{0}59’04.5”E
Chittamgondi	Chittamgondi-1	C-1	18^{0}20’53.7”N	082^{0}56’43.2”E
	Chittamgondi-2	C-2	18^{0}21’16.5”N	082^{0}56’42.9”E
	Chittamgondi-3	C-3	18^{0}21’21.9”N	082^{0}56’32.3”E

the present paper discusses only about nutrients and alkali metal distribution in soil in the study area.

Study site

The study was carried out at Araku Valley(Figure 1) almost 120 km northwest of Visakhapatnam city in Andhra Pradesh. The area has huge deposits of bauxite in different locations, with its hill-tops predominantly covered with lateritic soil(bauxite capping over Khondalite). The soil is fine textured and sandy loam to clay in the lower slopes and villages, whereas, it is rocky and red ferruginous loams mixed with quartzite in the hill-tops. The soil is fertile in valleys and characterized by the presence of humus on top. *Phoenix loureiri* Kunth is the dominant vegetation in slopes and hill-tops[10]. The area experiences an average annual temperature variation of 10^{0}C and 37^{0}C. The annual rainfall recorded in the area is about 800-1000 mm in plains and 1000-2000 mm in hills.

Sampling locations

For habitat characterization three sampling locations were selected namely Raktakonda, Galikonda and Chittamgondi, falling on the Grant’s range of Eastern Ghats. Scarps exposing bauxite and Khondalite mark the peripheries of these hills. Around the hillocks, in the slopes and the valleys small evergreen patches, moist deciduous and dry deciduous tracts are seen. Raktakonda is located about 1400m ASL and gives rise to eight micro-watersheds which feed Sileru river. According to geological survey of India (GSI) and mineral exploration corporation Ltd., (MECL), the mineable reserves of bauxite in Raktakonda are 10.8 million tones[11]. Galikonda is capped with bauxite at the hill-top and presents a characteristic bald appearance due to scanty vegetation. According to MECL and GSI, the mineable reserves of bauxite in Galikonda are 13.60 million tones[12]. Chittamgondi, a part of Eastern Ghats ranges, is characterized by high ridges and intermittent valleys. The slopes and valleys are covered with dense vegetation and forest growth. The region is composed of the rock type of Khondalite and Charnockite groups of Archean age. The rock types are covered by bauxite/laterite on hill-tops. Soil and alluminium are the recent deposits. GSI estimated mineable reserve in Chittamgondi as 24.57 million tones[13].

EXPERIMENTAL

Three sampling sites in each of the sampling locations i.e., Raktakonda(RK), Galikonda(GK) and Chittamgondi(CG), were selected randomly for collection of the soil samples. However, at Galikonda an additional site was selected in view of the human disturbance prevailing around the area. At each site, soil samples were collected from two successive layers, i.e. 0-5 and 5-10 cm depth in triplicate using a plastic scoop. The collected samples were packed in acid-cleaned air-tight plastic bags, labelled properly, and transferred to the laboratory for further processing and analysis.

The field collected soil samples were air-dried under normal room temperature[14]. The air-dried samples were homogenized using an agate mortar and pestle and filtered using a 2mm mesh sieve[15]. The particles with size less than 2mm were retained in pre-cleaned plastic bottles for further laboratory analysis. A portion of the sample was hand crushed and analyzed for the soil texture (isolation of sand, slit and clay) using a series of standard sieves of different mesh sizes and a mechanical sieve shaker.

The portion of the sample meant for chemical characterization was analyzed for the following parameters. pH, pxidation reduction potential(ORP, mV) electrical conductivity(EC, μs/cm), total dissolved solids(TDS, mg/kg) were analyzed in a soil water suspension in the ratio of 1:10 using respective digital electrodes. Total organic carbon(TOC, %) was estimated following wet digestion method[16].

Total nitrogen(TN, mg/kg) and total available sulphur(TAS, mg/kg) were estimated spectrophotometrically using perkin elmer spectrophotometer (Model: Lambda 35). TN was estimated following the persulphate oxidation method[17] and indophenol blue method [18]. TAS was estimated turbidimetrically[20]. The soil was extracted with 0.15% $CaCl_2$ and turbidity was developed using barium chloride and subsequently measured on a spectrophotometer (Model: Perkin Elmer Lambda 35) at 340nm. All the chemicals used in the study were of AR grade and reagents were prepared in double distilled water (prepared using quartz double distillation assembly).

Two-way ANOVA test was performed on the analytical results to assess the variation of the nutrients among sites. t-Test(two-tail) was performed to assess variation between months. A test of correlation (two-tail) was also performed among all the nutrients elements and their respective ratios. The software "MEGASTAT"[20] was used in the present study for the analysis of the analytical data. The significance level was set at 0.05 for all the tests.

RESULTS

Basic characterization and nutrients

The soil was found to be clayey loam in texture. The particle size distribution was as follows; clay> sand>silt in all the sites (TABLE 2) except for R-1 and R-3 sites. The soil in all the locations was acidic with the pH ranging between 4.7 and 6.2 (Figure 2). Except in the case of C-1 and C-2 sites, pH decreased across the layers in all the other sites. Oxidation reduction potential(ORP) of the soil ranged from 58 to 134 mV (Figure 2). The variation of pH and ORP was significant among the sites (Two-Way ANOVA, $P<0.05$) and between the months (t-test, $P<0.05$, TABLE 3).

EC and TDS in the soil-water suspension ranged from 4.67 to 312 μS/cm and 5.33 to 152.67 ppm (Figure 3) respectively. Values for EC were high in almost all the three locations in January than in November. The variation in EC and TDS was significant among the sites (ANOVA, $P< 0.05$) as well as between the months (t-test, $P<0.05$, TABLE 3). Total organic matter (TOM) ranged from 16.27 to 56.51 % (Figure 4) with higher values at the surface layer in most cases. The variation of TOM was not significant among the sites, between the layers (ANOVA, $P<0.05$) and between the months (t-test, $P<0.05$, TABLE 3).

TABLE 2 :The percentage of sand, silt and clay

Site	Depth (cm)	Sand	Silt	Clay
R-1	0-5	40.4	22.5	37.2
	5-10	25.6	17.9	56.6
R-2	0-5	25.2	20.9	54
	5-10	26.1	20.4	53.6
R-3	0-5	26.6	27.8	45.7
	5-10	25.7	23.4	51
G-1	0-5	33	20	46.8
	5-10	27.4	17.4	55
G-2	0-5	31.8	20.3	57.6
	5-10	26.3	18.8	54.5
G-3	0-5	29.1	21.3	49.7
	5-10	28.1	21.3	50.7
G-4	0-5	29.8	17.2	53.1
	5-10	27	17.8	55.2
C-1	0-5	37.3	16.3	46.4
	5-10	34.3	20	45.7
C-2	0-5	32	19.8	48.1
	5-10	26.3	18.4	55.4
C-3	0-5	34.5	24	41.7
	5-10	26.7	20.1	53.2

TABLE 3 : T-test for variation in parameters among months

Parameters	t-stat	t-critical(two-tail)	P(two-tail)
pH	3.64	1.98	0.00046
ORP	-3.82	1.99	0.00028
EC	-3.57	2.00	0.00069
TDS(H_2O extract)	-3.57	2.00	0.00069
TN	-1.97	1.98	0.05118
TAS	1.45	1.98	0.14995*
Cl	-3.20	1.98	0.001782
Na	0.42	1.98	0.67247*
K	-2.41	1.99	0.03533
Li	0.47	1.98	0.63862*
Ca	2.04	1.98	0.04286
Mg	5.35	1.98	6.7E-07

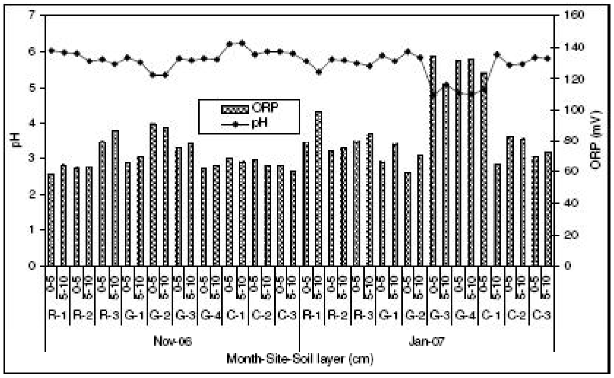

Figure 2 : Monthly and depth profile variation of pH and ORP

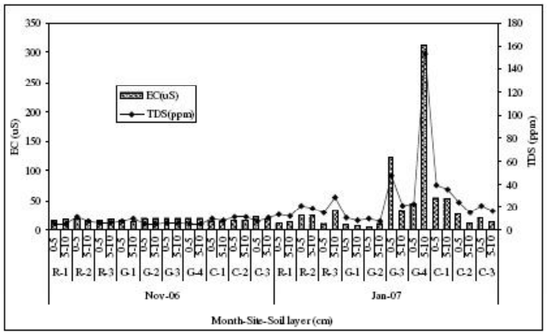

Figure 3 : Monthly and depth wise variation of EC and TDS

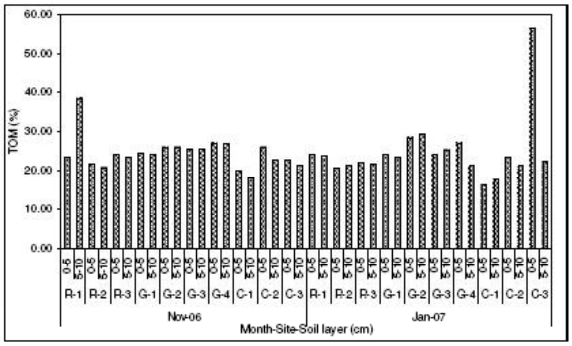

Figure 4 : Monthly and depth wise variation of OC

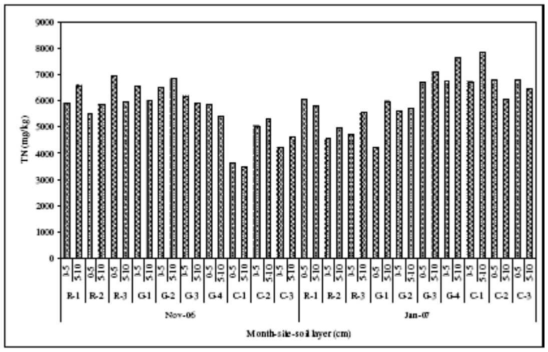

Figure 5 : Monthly and depth wise variation of TN

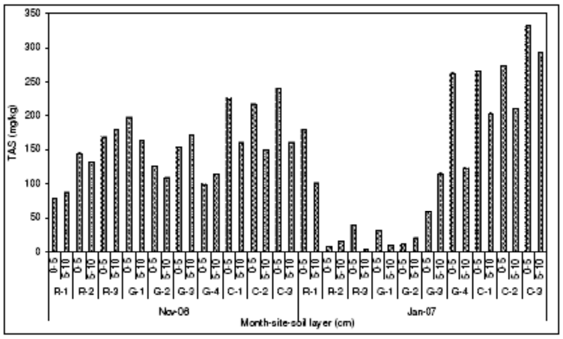

Figure 6 : Monthly and depth wise variation of TAS

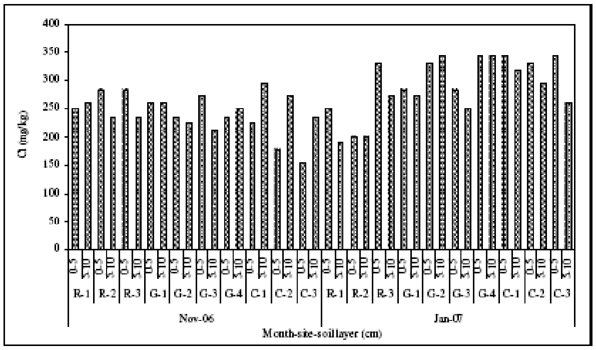

Figure 7 : Monthly and depth wise variation of Cl

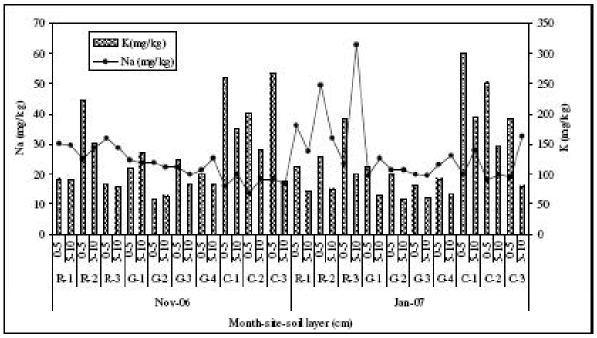

Figure 8 : Monthly and depth profile variation of Na and K

TN varied significantly among the sites (ANOVA, $P<0.05$) and was in the range of 3467 to 7829 mg/kg (Figure 5). During November, CG had lesser soil nitrogen than RG and GK, whereas during January the case was the reverse. The variation of TN in soil varied significantly between the months (t-test, $P<0.05$, TABLE 3). In contrast, TAS was found to be in the range of 3.71 to 332.4 mg/kg (Figure 6). Sulphur content was high in upper layer in CG. TN, TAS and soil organic matter (SOM) had higher values in the upper layer. However, no significant variation in TAS was recorded among the sites, and between the layers as well as months. The lowest and highest values of chloride were 153.70 and 342.87 mg/kg respectively (Figure 7).

Alkali and alkaline earth metals

Among the alkali metals, Na and K were in the range of 13.7 to 63 mg/kg and 57.6 to 300 mg/kg respectively and both varied significantly among the study sites (ANOVA, $P<0.05$, figure 8). The level of Na was higher at RK compared to the other sites, where as, K showed lesser values at GK site than the other two sites. In most of the cases K was high in the upper layer. The variation between months was significant only for Na (t-Test, $P<0.05$, TABLE

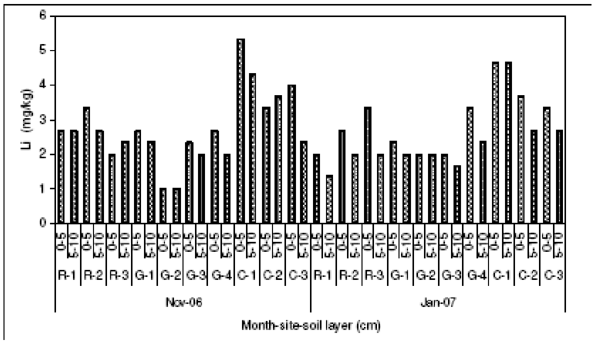

Figure 9 : Monthly and depth wise variation of Li

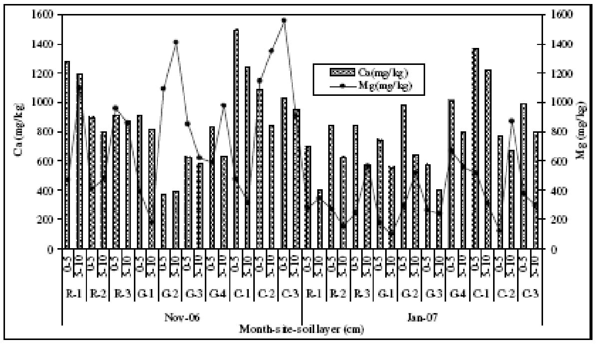

Figure 10 : Monthly and depth wise variation of Ca and Mg

TABLE 4 : Range of elements in soil samples

Parameters	Present concentration	Concentration range	Authors reported
TOM (%)	16.2-56.2	0.48-14.92	Prusty et al.[55]
Total N (mg/kg)	3467-7829	2479-2765	Saha[56]
TAS(mg/kg)	3.7-332.4	1070-2650	Wesemael[57]
Chloride(mg/kg)	153.7-342.8	1-40(excl.saline)	Allen[58]
Na(mg/kg)	13.7-63	4.6-6.9	Aluko[35]
K(mg/kg)	57.6-300	960-3110	Wesemael[57]
Li(mg/kg)	1.0-5.3	10.2-44.9	Haddadin et al.[46]
Ca(mg/kg)	366-1493	40-793	Aluko[35]
Mg(mg/kg)	101-1556	1242-4920	Allen[58]
CEC(meq/kg)	39.2-187.5	13.21-34.72	Sahu et al.[59]

3). Li was found in low levels in the soil and ranged between 1.0 and 5.3 mg/kg (Figure 8). The level of Li was high at CG than the other two sites and in most of the cases Li was seen in higher concentration in surface layer. Two-way ANOVA shows that Li was significantly different among the sites ($P<0.05$), while no significant variation was seen between the months (t-test, $P<0.05$, TABLE 3).

Ca and Mg varied widely and significantly among the sites(ANOVA, $P<0.05$). The lowest and highest recorded concentration of Ca was 366 and 1493 mg/kg. In the case of Mg, the concentration ranged between 101 and 1556 mg/kg(Figure 10). In most of the cases Ca level was low in lower layer. Ca level was recorded high in CG than RK and GK locations. Invariably, the level of Ca and Mg remained higher in November in all the sites. Both Ca and Mg varied significantly between the months(t-test, $P<0.05$, TABLE 3). The CEC values of the soils varied from 39.2 to 187.5 meq/kg.

Two-tail test of Pearson's correlation(TABLE 5) was performed to evaluate the association of certain parameters examined during the study. As expected, pH was negatively correlated with ORP. Among the major nutrients, TN was positively correlated with TAS. Among alkali and alkaline earth metals, K was positively correlated with Ca and Li. K, Ca and Li were positively correlated with TAS in soil, while Na was negatively correlated. Ca was negatively correlated with TN. However, the negative correlation of EC with TDS, although, not significant; and lack of significant correlation between TOM and TN needs further investigation. Of all the nutrients and metals examined in the present study,

TABLE 5 : Correlation matrix of nutrient elements

	pH	ORP	EC	TDS	Cl	TOM	TN	TAS	Na	K	Ca	Li	Mg
pH	1.000												
ORP	-.937*	1.000											
EC	-.074	.083	1.000										
TDS	-.397*	.413*	-.002	1.000									
Cl	-.025	.033	.073	.045	1.000								
TOM	-.012	-.003	-.019	-.020	-.029	1.000							
TN	-.271*	.226*	.140	.196*	.015	.148	1.000						
TAS	-.047	.095	.084	.041	.182*	.058	.229*	1.000					
Na	-.041	.032	-.010	.053	-.224*	-.071	.028	-.218*	1.000				
K	.114	.075	-.046	-.044	.099	-.058	.015	.347*	-.172	1.000			
Ca	.262*	-.183*	-.132	-.017	.053	-.005	-.186*	.302*	-.126	.383*	1.000		
Li	.198*	-.107	-.078	.005	.127	-.105	-.045	.376*	-.167	.773*	.699*	1.000	
Mg	.031	-.051	-.097	-.048	.154	.017	.133	.147	-.131	.021	-.024	-.015	1.000

120 Sample size, ±0.179, Critical value 0.05(Two-tail), *Significant

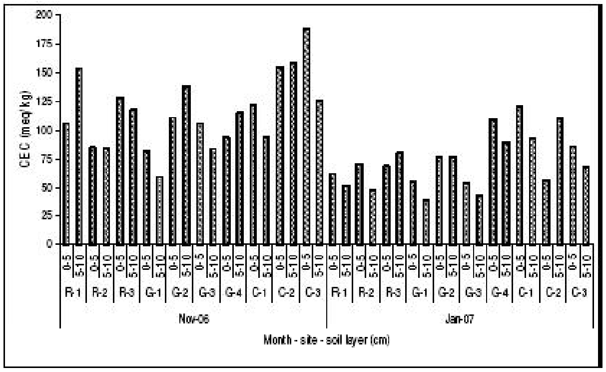

Figure 11 : Monthly and depth wise variation of CEC

only TAS, K, Li and Mg were found below the levels reported elsewhere (TABLE 4).

DISCUSSION

In the present study almost all the nutrients showed wide spatial variability owing to the type of land use pattern in the area, topography and the vegetation composition. The relatively higher clay content in the soil might be due to the in situ alteration of weatherable minerals[21]. Sharma and Sharma[22] reported that deforestation activities may also lead to high percentage of clay under mixed vegetation. The previous studies report the soil texture to be rocky along the slopes. However, since our sampling sites fall in the plateau region(near the hill-tops) a higher proportion of clay and silt were seen in the soil. Soil reaction was acidic in all the sites, which according to Smyth[23] is a characteristic feature of lateritic soil. The acidity in soil might be also in part due to the existence and gradual accumulation of organic matter in the forest soil. The decomposition of falling detritus on the soil generally makes the condition acidic through the production of several weak acids. pH (reaction) is a property inherited from the parent materials and can vary widely depending on the amount of acid-producing or acid neutralizing material[24] present in the parent materials. Acidic soil conditions can directly inhibit plant growth and make most of the elements, including toxic metals, in soil bioavailable and also induce production of toxic soluble-aluminum in the soil-water solution[25-26]. The decreasing trend in EC and TDS from the surface layer to the next lower layer as seen in January at CG site is suggestive of the diminishing quantity of salts such as chlorides, sulphates, nitrates, carbonates, and phosphates along the depth[27]. The variation of both EC and TDS were similar probably because of their interrelation. The higher values as recorded in certain sites might be due to the availability of inorganic mineral ions resulting from mineralization processes.

Plant roots are known to have important role in nutrient cycling and maintenance of soil organic matter[28-29]. In general, the present results about the TOM and TN indicate relatively higher accumulation of organic matter in the soil. In specific places higher levels of TAS as in the case of CG during January (Figure 6) is likely to be associated with intermittent fire incidents in the forest, either due to natural phenomenon or due to intentional human activities. The Araku Valley experiences fire incidents after the month of December, and are mainly anthropogenic in origin. Fire incidents are known to have considerable influence on the nutrient dynamics in soil. Marco et al.[30] opines that TOM, TN and Sulphur content was higher in burnt soil than that of the control one. The increase in the TN after fire incidents is suggestive of the contribution of organic nitrogen in ash to the total content in soil[30-31]. This changes the nutrient cycling pattern in the forest which in turn change the equilibrium of production of biomass, accumulation of organic matter and decomposition and absorption of minerals[32]. Spatial variations in decomposition rates, constrained by clay content, affects soil organic matter more strongly than plant C inputs[33]. Clay interacts with organic compounds and protects organic carbon from microbial decay[34].

The higher values of TN, TAS and soil organic matter (SOM) in the upper soil layer than the next lower layer indicated that N and S were largely associated with the SOM, which disappeared relatively fast through rapid decomposition[35], mediated by microbes[36-37] and abiotic processes[38]. The positive correlation of TN with TAS is indicative of their possible simultaneous release from the decomposed plant material in soil. The positive correlation of TN with TDS is suggestive of the contribution of non-halide compounds such as nitrates to the total dissolved salt content in the soil. N and S carried to forests by wet and dry deposition have been shown to bring about changes in soil properties[39-40]. The higher concentration of N in the upper layer may be due to the presence of immobilized nitrogen in the detritus on the soil surface[32,41], which is prone to microbial decomposition in subsequent layers[42-43]. The decrease in N may be attributed to the stimulation of nitrogen mobilization in the plant available form[44-45]. The low levels of base cations such as K, Ca and Mg may be due to the low weathering potential of parent material and marked leaching of soils[35]. Though the soil was fine textured, considerable K loss by leaching was expected. The low Li concentration may be due to the high organic matter content[46]. The organic matter content in the present investigation ranged between 16.2 and 56.2%. Studies by Balakrishnan[47] have shown that the content of Ca is very low in the sandy soil of humid region and highly weathered soils of humid tropics, whereas, it is generally high in arid region regardless of texture of the soil, as a result of low rainfall and low leaching. The lowest and highest values of chloride were 153.70 and 342.87 mg/kg respectively (Figure 7). The higher values of chloride in the surface layer could be attributed either to the accumulation of salts or to the upward movement of salts in soil moisture during the dry periods of the year[48-51]. Chloride, although an essential micronutrient[52], is toxic to plants at high concentrations[53]**.** Plants with high levels of chloride are likely to have specific ion toxicity effects that occur when certain ions such as chloride, sodium or borate, are absorbed and accumulated in excessive levels in plant tissues, mainly the leaves[54].

In the view of the status of the area as a proposed mine site, the findings of the present study is of significance as in the due course of time the state of the soil system will be considerably altered as mining activity progresses. Further long-term seasonal investigations are required to better understand the nutrient cycling in soil in different vegetation stands so that certain indicator species could be identified for the purpose of reclamation of the area after the mining. Conservation of soil in these hill-slopes is of utmost importance in order to restrain the siltation in rivers and reservoirs.

ACKNOWLEDGEMENTS

The authors are thankful to M/S Kaliraj, Sumesh Kumar, Vanitha and Muthu Kumar for their helps during soil sampling and laboratory analysis.

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