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Distribution of Chemical Elements and Certain Rare Earths in Termite Mounds: A Case Study from Nellore Mica Belt, Andhra Pradesh, India

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Abstract Termites are important components of biologically mediated feedback to land-use change in the tropics. Termites build some conspicuous earthen mounds which constitute an important feature of the landscape in tropical and subtropical regions. The large earthen mounds constructed by termites are a distinctive feature of the semi-arid region of Nellore mica a belt. The distribution of chemical elements Ca, Mg, Fe, Al, K, Na, Cr, Ni, V, Y, Ce, and La and were studied both in termite soils and their adjacent surface soils in the Nellore mica belt. This study showed that the increasing content of chemical elements is due to the activity of termites which have induced significant chemical changes in the materials that they use to build their nests. The importance of 'Biological Absorption Coefficient' (BAC) of the termite mounds is also discussed. The sequence of BAC for different elements are Ca>Mg>K>Al>Fe>Ni>Na>Cr>Ce>La>V>Y.

Keywords Termite mounds, Nellore mica belt, Chemical elements, Rare earth elements

1. Introduction

Termites descend through covered runways and subterranean galleries ramified over wide tract, and sample the sub-surface geological formations for their construction material. They move and mix large quantities of soil from different horizons during mound building[1][2][3]. Abundant literature can be found related to effects of termites on the mobility of a number of soil elements, but the focus is largely on those few elements that are generally considered to be essential for the support or growth of all forms of life[4][5]. Detailed studies on ecological[1][6][7][8][9][10][11][12] aspects of mounds have been discussed.

Earlier workers have discussed the physical and chemical changes, involved in the formation of termite soils[1][15]. There is an extensive literature on termites and their structures[16] dealing with their biological[17][3], agricultural[18], microbiological[19], and paleoclimatological[20] aspects. In Russia, geochemical features of termite mounds have been studied[21]. It is stated that the termites can bio-accumulate essential metals to reinforce cuticular structures and utilize storage detoxification for other metals including Ca, P, Mg and K[22].

The studies on the influence of termites on the spatial distribution and dynamics of vegetation have been discussed by[23]. Termite mounds are among the most conspicuous figures of many tropical ecosystems. Termites process considerable quantities of material in their mound building activities, strongly influencing the soil properties as compared to surrounding soils[1][7][8][9][24]. These modifications have a great impact on the vegetation, through spatial and temporal effects, even when the termite colony is dead and the mound material subject to erosion[23][25]. Thus the termites have been referred to as large soil builders and ecosystem engineers[26][12][18]. The role of termite mounds in soil and geomorphic processes has been discussed by Whitford and Eldridge[27].

The influences of termites on soils range from physical effects to changes in the chemical properties of soil organic matter, changes in soil texture and structural stability, and C/N ratios[28][8][29]. Termite mounds, commonly occurring in tropical regions, from an important feature of the landscape. Recent studies have demonstrated that termite mound is an important feature in geochemical exploration for mineral deposits[1][30][31][32][33][34][10][35][8][9][36][37]. Termite hills were used to locate uranium mineralization which was located in a lacustrine paleodelta in the Main Karoo Basin of South Africa[38].

The large earthen mounds constructed by termites are a distinctive feature of the semi-arid region of Nellore mica mining area. These mounds are known to be the product of the burrowing activity of termites, and the mineral explorers interested in the nature of subsurface regolith materials.

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Although termitaria have been sampled by mineral explorers in a range of landscape settings and only few published works are available. This study aims to answer whether termite mounds built by termite species have significantly different geochemical characteristics, and cause variations in the expression of the buried mineralization.

Termites have potential to be developed as a mineral exploration sampling medium for the following reasons.

- They are widespread and abundant across large regions of Nellore mica belt area, making them readily available for geochemical studies.
- They result from subsurface burrowing activity of termites and therefore their chemistry may reflect the chemistry of subsurface materials.
- Samples can be prepared and analysed with techniques similar to those used for traditional soil geochemistry.

Termites and their bioturbation of the regolith during termite mound construction have long been recognized as a significant influence on the chemical and physical properties of soils[1][39][40]. This may include chemical additions to surface soils through the upward transport of buried components of the regolith such as key ore indicator minerals[41][42][32][43][34][44][45][46][47][37]. It is noted that the mound-building activity of termites resulting in an upward transfer of clay, silts and fine particles to the ground surface[48]. Termite mounds are utilized at present in mineral exploration programmes in Africa, largely as a result of published accounts of termitaria there hosting indicator minerals from subsurface mineralization[34][49][48]. It is also discussed the upward movement of clays, silt and sand particles as this material is deposited in termitaria, and observed micro-aggregates of kaolinite and quartz derived from the upper saprolite in the soil surface layer[49].

In addition to being an economically important pest, termites are also important ecologically to forest ecosystems. They are closely linked with biogeochemical (nutrient) cycling. The major biogeochemical cycles are: hydrologic, carbon, oxygen, nitrogen, sulfur, and phosphorus[50]. Components of each conceptually belong to "reservoir pools". Depending on the scale, reservoir pools may include all or part of the atmosphere, the ocean, the sediments, and living organisms. In general, the biota and their activities dominate flux between reservoirs. Elements are exchanged slowly between some reservoirs over a long period of geological time[51]. They are important in the carbon cycle through their roles as consumers and detritivores[52]. The termite gut is host to protozoan and bacterial symbionts that are able to digest wood cellulose and thus release the energy otherwise unavailable to the insects[53]. Termite foraging and tunnelling redistributes soil and increases the surface area available to bacteria and fungi[54]. The enzymatic secretions of fungi primarily facilitate the breakdown of lignin and cellulose found in wood[55]. The role of mutualistic fungus in lignin degradation in the fungus-growing termites has been discussed by Hyodo[56]. Fungi are also able to liberate various elements such as nitrogen, phosphorus, potassium, sulfur, iron, calcium, magnesium, and zinc[55]. The ability of termites to influence the physical structure and chemical nature of their environment impacts vegetation and other components of the ecosystem[54]. Their effect on the nitrogen cycle has traditionally been recognized as returning nutrients to the ecosystem. However, recent studies indicate that termites may play a larger role in the cycling of nitrogen than was once thought.

Termites have a keystone role in controlling carbon and nitrogen fluxes both, in semiarid and humid ecosystems such as savannas and tropical rain forests[57][58][59][60]. Also their potential impact on agriculture is receiving increasing attention[18]. Different species of a termite consume wood and litter in different stages of decay and humification, and more than half of all termite genera are considered humivorous[61][62][60].

Hence in the present investigation, an attempt has been made to study the accumulation of chemical elements viz., Ca, Mg, Fe, Al, K, Na, Cr, Ni, V, La, Ce and Y in the Nellore mica belt in termite mounds and their associated elements in adjacent surface soils.

Geology and topography of the study area: The Nellore mica belt is in the Nellore district in Andhra Pradesh is famous for green and ruby mica associated with various industrial minerals such as feldspar, beryl, and tourmaline and other atomic minerals. This mica belt is about 36 km south west of Nellore and is included in the Survey of India topo sheet No. 57 N/11. The region is limited within a zone bounded by latitudes 14º 10' - 14º 15' N and longitudes 79º 40 - 79º 45' E and forms an important mica mining centre of Nellore mica belt..

The important geological formations are of Archaean age consisting of pegmatite, quartz veins, granites, biotite gneiss, kandhra volcanic suite and schistose rocks[63]. The pegmatites are widely distributed throughout the schistose rocks.

The termites build conspicuous earthen mounds that are found in various topographical conditions, viz., plains, valleys, slopes, altitude and on the bunds of agricultural lands. They are conical, elongate, bald, rounded and irregular. The general topography of the area exhibits more or less a flat land, seldom attaining a height greater than 122 m above sea level, and low ridges consisting of hard and rocks punctuate plain lands. The ridges broadly for linear tends and are traceable in the area that run north to south. There are about 100 abandoned as well as operating mines in addition to innumerable trial pits dug primarily for exploration and exploitation of muscovite.

Table 1. Minimum, maximum and average values of different constituents of Termite Soils (TS) and Adjacent Soils (SS)

S. No.	Constituents	Termite soils				Surface soils			
		Min	Max	S.D	Mean±S.E	Min	Max	S.D	Mean±S.E
1	pH	8.20	8.80	0.14	8.54±0.02	7.7	8.3	0.15	7.94±0.02
2	Calcium (Ca) (%)	0.15	9.68	2.12	2.38±0.36	0.03	4.75	1.20	0.97±0.20
3	Magnesium (Mg) (%)	0.07	1.25	0.25	0.46±0.04	0.04	0.50	0.12	0.26±0.02
4	Iron (Fe) (%)	0.69	3.28	0.72	2.01±0.12	0.35	2.70	0.69	1.47±0.11
5	Aluminum (Al) (%)	0.35	2.35	0.44	1.07±0.07	0.21	1.83	0.37	0.74±0.06
6	Potassium (K) (ppm)	199	3734	690.27	1221.71±116.67	125	1930	480.87	829.11±81.28
7	Sodium (Na) (ppm)	68	980	165.54	231.45±27.98	52	354	72.48	153.14±12.25
8	Chromium (Cr) (ppm)	8	57	9.11	21.97±1.54	5	29	6.72	15.80±1.13
9	Nickel (Ni) (ppm)	7	33	6.48	18.85±1.09	5	26	5.64	12.91±0.95
10	Vanadium (V) (ppm)	10	55	11.10	27±1.87	6	54	10.62	19.82±1.79
11	Yttrium (Y) (ppm)	15	35	3.96	25.77±0.67	11	23	2.78	14.42±0.47
12	Cerium (Ce) (ppm)	18	39	5.72	27.91±0.97	10	22	3.36	15±0.57
13	Lanthanum (La) (ppm)	14	29	3.89	22.60±0.66	7	19	3.08	14.51±0.52

Table 2. Minimum, maximum and average values of different constituents of Biological absorption coefficient (BAC) Values

S. No.	Constituents	Termite soils			
		Min	Max	S.D	Mean±S.E
1	Calcium (Ca) (%)	0.96	13.04	2.80	3.95±0.47
2	Magnesium (Mg) (%)	1.07	5.50	0.92	1.92±0.15
3	Iron (Fe) (%)	1.01	4.43	0.86	1.60±0.14
4	Aluminum (Al) (%)	0.83	4.75	0.95	1.67±0.16
5	Potassium (K) (ppm)	0.80	4.84	0.86	1.67±0.14
6	Sodium (Na) (ppm)	0.50	3.94	0.67	1.52±0.11
7	Chromium (Cr) (ppm)	1.05	3.60	0.61	1.51±0.10
8	Nickel (Ni) (ppm)	1.05	4.00	0.75	1.63±0.12
9	Vanadium (V) (ppm)	0.77	2.86	0.50	1.50±0.08
10	Yttrium (Y) (ppm)	1.25	2.55	0.31	1.83±0.05
11	Cerium (Ce) (ppm)	1.29	2.92	0.38	1.91±0.06
12	Lanthanum (La) (ppm)	1.13	2.86	0.34	1.61±0.06

2. Materials and Methods

In the Nellore mica belt the termite mounds ranging from 1.2 to 1.9 m in base diameter and 0.7 to 1.5 m in height. Samples of termite mound from different parts of the exterior of the mound were combined to form a composite sample. Similarly, with reference to the termite mound, adjoining ground surface soils un affected by termites were collected. Thus a total of thirty five termite mounds along with their adjacent surface soils were collected in the Nellore mica belt.

After sampling the, the soil samples were shifted to the laboratory and stored at 4ºC before particle size fractionation. All the samples were dried at 110ºC, and were finely powdered using a Wiley Mill (Wiley Mini-Mill, Model No. 3383-L10, Thomas Scientific, USA). Further, these samples were ignited at 450ºC in muffle furnace for three hours. About 0.5 gm of sample passed through 0.15 mm nylon sieve was used for soil chemical analysis. The soils were digested with aqua regia (1:3 HNO_3 and HCl) and analysed for Ca, Mg, Fe, Al, K, Na, Cr, Ni, V, Y, Ce, and La by inductively coupled plasma spectrometry (ICP). Soil pH was tested using a soil water ratio (v/v) 1:25 with Elico pH meter and the data is shown in Table 1. The range of Biological absorption coefficient values are depicted in Table 2.

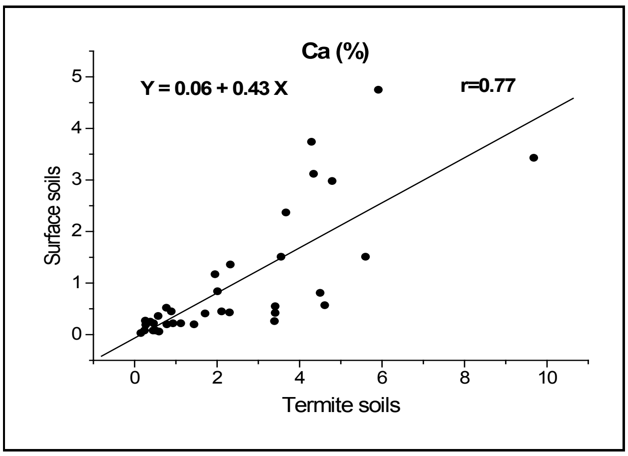
3. Data Analysis

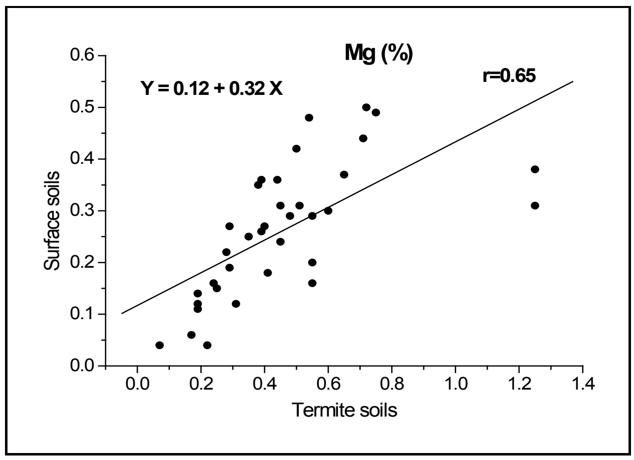
The average concentrations and standard errors were calculated by employing Microcal Origin software for the analytical data of thirty five samples of termite soils and their adjacent surface soils. These are important because they reflect how much sampling fluctuation a statistic will show, i.e. how good an estimate of the population.

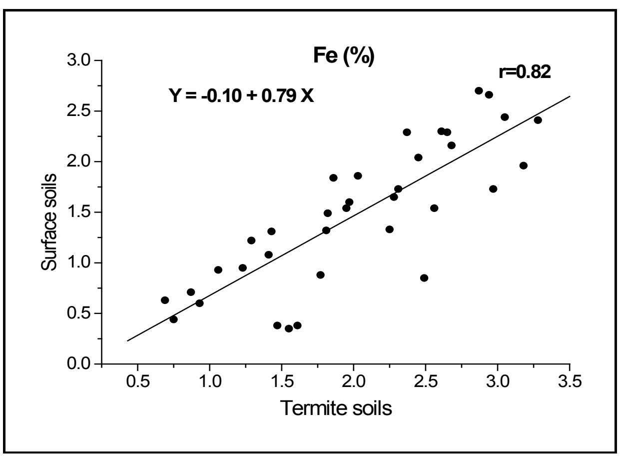
4. Results and Discussion

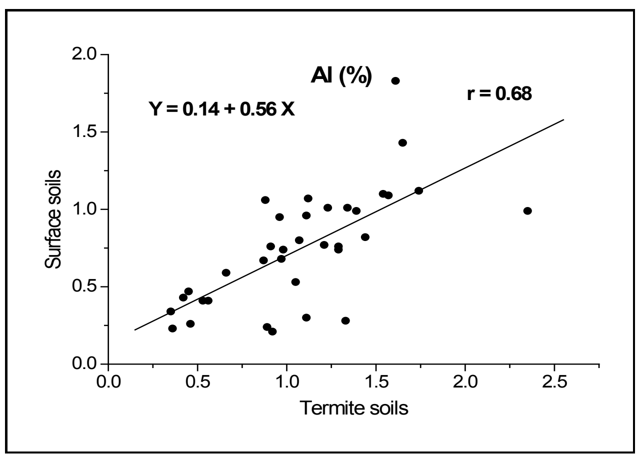
Rare earth element (REE) viz., Y, Ce, La and other chemical elements, Ca, Mg, Fe, Al, K, Na, Cr, Ni, V for thirty five termite mounds and adjacent top soil from Nellore mica belt were studied to find out the processes underlying the alteration of soil chemical and physical properties by termites (Table 1). The concentration of Y ranges from 15 to 35 ppm (mean value of 25.77 ppm), Ce concentration ranges from 18 to 39 ppm (average value of 27.91 ppm), and La varies from 14 to 29 ppm (mean value of 22.60 ppm) is accumulated in termite soils. In the adjacent surface soils the concentration of Y vales ranges from 11 to 23 ppm (mean value of 14.42 ppm), Ce varies from 10 to 22 pm (average value of 15), and La ranges from 7 to 19 ppm (mean value of 14.51 ppm) is accumulated. The absolute concentrations of Y, Ce and La and the chemical elements were greater in termite mounds compared to topsoil. Similarly, rare earth element (REE) and trace element concentrations of termite mounds and adjacent topsoil from central and northeastern Namibia were studied by Aboubakar Sako[64] and concluded that the accumulation of micro-nutrients in the mounds was of particular interest because of the ecological implications of the enhanced availability of these scarce elements. The absolute concentrations of REE and trace elements, including nine micro-nutrients (B, Fe, Mn, Ni, Cu, Zn, Se, Mo and Cd), were greater in termite mounds compared to topsoil, suggesting a possible external supply of enriched materials or accumulation of in situ weathering products of the underlying bedrock. The termites play an important role in the in remobilization of the termite weathering profiles[48][65].

The Ca is enriched huge about of about 9.68 % in termite soils and it is 4.75 % in its adjacent soils. In the present study the pH is generally higher in termite soils than the adjacent surface soils (Table 1). The high pH values in the mounds indicate calcrete aggradations as a result of burrowing activities of the termites and evaporation from mounds[66]. The impacts of the changes in environmental conditions and the termite activities on the mound geochemistry are highlighted by light REE (LREE) are likely to coprecipitate with carbonate complexes and Fe. The study indicated the suitability of LREE and other chemical elements geochemistry for assessing the influence of termite mounds on the physico-chemical properties of semi-arid soils. Organisms such as termites have direct associations with the pedolith, and research into their burrowing behaviour shows the recycling of buried materials from depth to and surface. The biogeochemical characteristics and the nature of their expression of buried mineralization have been discussed by Petts et al[67][68]. These mounds showed significant use in mineral exploration especially in areas under cover[34][37].









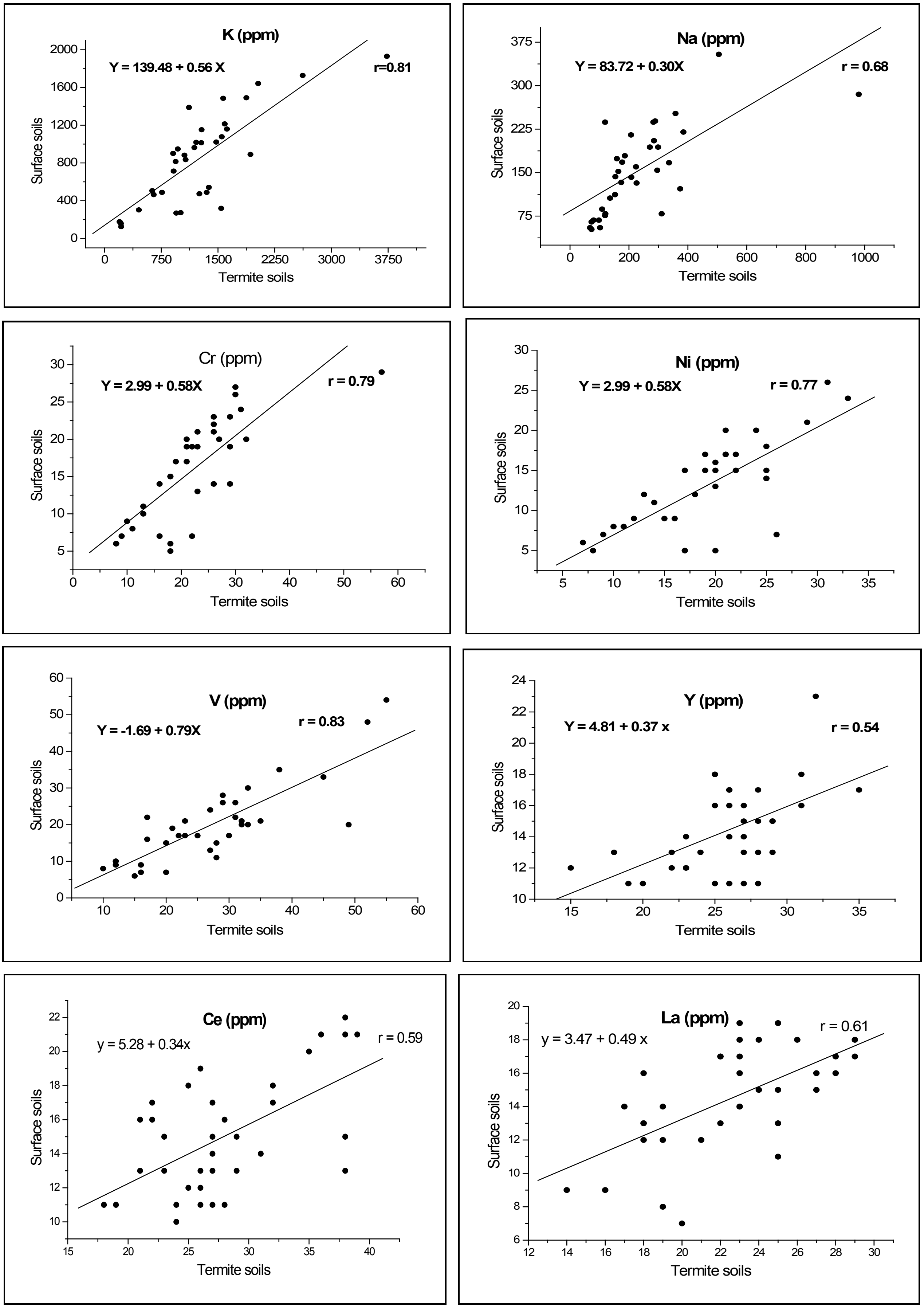


Figure 1. Graphical representations of termite soils versus surface soils for various elements

5. Graphical Representations and Computations

The range of elemental concentration of various elements in termite soils and its adjacent surface soils are shown in Table 1. It is shown that termite play a major role in both physical and chemical properties of soil as well as nutrient cycling and soil metabolism[14][13][66]. The termite soils and their adjoining surface soils were plotted and correlation coefficient (r) values along with linear fit were calculated for each element (Figure 1). From the graphical representation of each element in soils and termite soils, it was observed that the concentrations of both major and trace elements in termite soils are directly proportional to those of surface soils suggesting enrichment of these elements in the termite mounds. They are also showing statistically significant differences between termite mounds and its adjacent surface soils(virgin soils not affected by termite activity). This may be attributable to increased organic matter resulting from incorporation of faecal or saliva materials with saliva during nest construction.

6. Biological Absorption Coefficient

Biological absorption coefficient (BAC) is used to characterize the intensity of chemical element by plants from their substrate, Kovaleskii[69] has defined the biological absorption coefficient (BAC) as follows.

$$BAC = Cp / Cs. \quad \ldots\ldots\ldots \quad (1)$$

Where Cp is the concentration(%/ppm) of elements in plants ash and Cs is the concentration of the same element in the substrate. The biological absorption coefficient (BAC) can be applied when using termite mounds in mineral exploration[43]

The range of BAC values of studied mounds and their standard errors are shown in Table 2. From this it is inferred that the BAC values of Ca ranged from 0.96 to 13.04 with an average value of 3.95; Mg varying between 1.07-5.50 with a mean value of 1.92; Fe varies from 1.01 to 4.43 with a mean value of 1.60; Al varies from 0.83 to 4.75 (average value of 1.67); K varies from 0.80 to 4.84 (mean value of 1.67); Na ranges from 0.50 to 3.94 (mean value of 1.52); Cr varies from 1.05 to 3.60 (average value of 1.51); Ni from 1.05 to 4 (mean value of 1.63); V varies from 0.77 to 2.86 (average value of 1.50); Y ranges from 1.25 to 2.55 with a mean value of 1.83; Ce varies from, 1.29 to 2.92 with a mean value of 1.91; La varies 1.13 to 2.86 with average value of 1.61. Amongst the BAC values Ca is showing highest factor values which indicates that the concentration of Ca is in more amounts in termite soils than the adjacent surface soils. Thus the BAC of termite mounds, rather than absolute values, is found to more significant biogeochemical parameter.

7. Conclusions

The REE group undergoes fractionation in igneous processes and homogenisation in sedimentary and soil forming processes. It is pointed out that “during the processes of weathering, soil formation and sedimentation, all rare earth elements are again assembled nearly completely[70]. The REE mobilization occurs during the intense chemical weathering typical if warm humid conditions[71]. The REE are derived from the underlying inorganic detrital particles and are incorporated by exchange processes by co precipitation from inorganic particles or from biogenic carrier phases[72][73]. In the present study cerium was the most abundant REE in both soils and termite soils when compared to lanthanum and yttrium. Similarly, Semhi[74] states that the activity of termites induced significant chemical changes in the materials that they use to build their nests, increasing the contents of most major elements, as a mechanism by which increased amounts of Eu and Ce are linked to termite activity seems to relate to the occurrence of some reducing agent or agents that are released by the termites.

The current study using termite mound as sample medium, however, isolated the real anomalies from the false anomalies. The sampled materials came from in-situ materials representing bed rock minerlisation; making good results from termitaria more dependable than the surficial soils. Further, termites possess several features that make them good indicators in mineral exploration. The study demonstrated the suitability of REE and trace element geochemistry for assessing the influence of termites on the physico-chemical properties of semi-arid soils of Nellore mica belt. It is concluded from the study that termite mound geochemical surveys provided cost effective method of defining prospective anomalous areas especially in areas covered by transported overburden.

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