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ANALYSIS OF TOTAL IODINE IN SOILS OF SOME AGRO-ECOLOGICAL ZONES OF GHANA

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Abstract

Iodine is beneficial in human nutrition and to a lesser extent in plant nutrition. Availability of this element in the soil is thought to be via ocean-atmosphere precipitation, iodine minerals and redistribution by vegetation, but very little is known about levels of iodine in Ghanaian soils. We analyzed for the content of total iodine alongside pH, organic carbon, total nitrogen, cation exchange capacity, sand, silt and clay in top soils of selected agro-ecological zones. These soils occur at various locations spanning from the coastline to the far interior. Variations in nutrient elements were attributed to diverse parent materials from which these soils originated and the complex interactions of organic matter, type of clay, acidity-alkalinity and leaching processes. The soils recorded low total iodine content of $0.08 - 3.92$ µg g^{-1}. There was a decreasing trend of iodine from the coastal zone inwards in the order of 1.85, 0.84 and 0.66 µg g^{-1} for the coastal savanna, semi-deciduous rainforest and Guinea savanna agro-ecological zones respectively. Iodine very weakly negatively correlated with C and N and showed a moderate positive correlation with clay content and moderate negative correlations with pH and sand content.

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Introduction

Micronutrient deficiency cases were first reported at the end of the 19th century and today it is known that extensive areas of cultivated soils are incapable of supplying soils the needed amounts of micronutrients (Sillanpa, 1972). The realization of the importance of iodine in the healthy growth and development of microbes, plants and animals requires information on its levels in the soil.

The importance of iodine for the agricultural scientist relates to it involvement in animal rather than in plant nutrition. Researchers in the early part of the 20th century established that endemic goiter in man and farm animals were associated with a shortage of iodine in food and water supplied. The number of goitrous cases in the world in 1960 was established as close to 200 million (Underwood, 1971). As the importance of iodine in human and animal nutrition was recognized, it was imperative that studies into the levels of iodine in the soil and its influence on plant growth be initiated. Iodine, a diatomic halogen, is a potential nutrient expected to serve a useful purpose as a soil sanitizer for agricultural fields. The origin of these trace elements comes from physical and chemical evolution of underlying rocks, under the action of different geological, geomorphological and pedological factors. In the course of soil formation, the trace elements contained within the minerals in the rock are partially dissolved and thus liberated, being either eliminated from soil, or precipitated to form a new mineral phase. Information on the forms in which iodine occurs in soils is rather scanty but the following compounds are generally held to be present: iodides, iodates, iodine associated with silicates, iodine sesquioxide complexes, iodine fixed by clay, organically bound iodine, and possibly free iodine (Davies, 1980). In acid soils and water, iodine is present as the iodine ion (I^-), which can be oxidized to I_2 and volatilized. In alkaline conditions the iodine is more likely to be present as IO_3^-, which is not converted to I_2. Soils formed on limestone are enriched in iodine relative to soils formed over other rock types and waters draining limestone areas are similarly enriched. Iodine may be found in primary minerals where it can replace such anions as SiO_4^{4-}, ClO_4^- and even CO_3^{2-}. Solubility characteristics, however, indicate that the contribution of iodine to soils from the weathering of such minerals must be small (Davies, 1980). Plants and mammals possibly derive much of their iodine by direct absorption from the atmosphere and therefore the frequent association of iodine deficiency diseases with limestone areas could be due to the non-volatility of the element in the alkaline conditions (Fuge, 1990).

Iodine is believed to be abundant in brines and Chilean nitrate (an organic form of soluble nitrogen - the nitrate deposits are formed from water soluble saline minerals.). Sea water itself is very different from freshwater. Two of the most important properties of sea water are temperature and salinity, the concentration of dissolved salts. The two properties work in conjunction to control the density of the water. The density of water is a major factor which controls the vertical movement, via condensation, of the ocean waters. The salinity of sea water is the most important factor in the consideration of human use, with the main dissolved constituents being that of sodium and chloride (Advanced Water Systems, 2004). The high levels of iodine in many marine flora and fauna reflect the enrichment of iodine in the oceans. Iodine is derived from the oceans via the atmosphere and near-coastal soils and surface waters are greatly enriched relative to central continental areas.

It is expected that the ocean will influence deposition of forms of the halogen group of elements in soils nearest to the coast. The exchange of iodine occurs between the ocean and the atmosphere and between the soil as part of the biosphere and the atmosphere (Rankama and Sahama, 1950; Figure 1). Where soil conditions are such as to promote the surface accumulation of organic matter, this component exercises a powerful influence on the profile distribution of iodine. The importance of atmospheric precipitation and

the known affinity of organic matter for iodine ensure that much of the iodine is held in the surface layers of soils. There is very little information on the levels of iodine in soils in Ghana. We therefore investigated the content of iodine in soils as they progressed from the coastline, through the middle belt and to the northern sector of the country. We analyzed representative soils from the coastal savanna ecological zone, the semi-deciduous rainforest zone and the Guinea savanna ecological zone, spanning a distance of about 500 km.

Materials and Methods

We collected 28 top samples (0-20 cm depth) from the three agro-ecological zones. Nine soil series were selected from the coastal savanna, 13 from the semi-deciduous rainforest and 6 from the Guinea savanna. Within each soil series, 5 random spots, with a minimum separating distance of 50 m, were chosen. With the aid of polyvinyl chloride (PVC) tubes (5 cm diameter by 20 cm length) and a mallet, the soil samples from the five spots were bulked into a composite sample to represent each series. Composite sampling was done in triplicate. We then thoroughly mixed each composite sample, air dried them for 5 days and screened them through a 2-mm mesh sieve to obtain the fine earth. The use of the PVC tubes, as against the conventional metal auger, was to avoid possible contamination.

We analyzed the samples for pH, particle size distribution (PSD), organic carbon (C), total nitrogen (N), cation exchange capacity (CEC) and total Iodine (I). We measured pH using a digital pH metre in a 1:1 soil:water suspension. 20 g of air-dried soil was weighed into a 50-ml beaker and 20 ml of distilled water was added and allowed to stand with occasional stirring. After about 30 minutes of stirring, the electrodes of the pH metre were inserted into the partially settled suspension and the reading taken. We determined the physical proportions of the three primary soil particles based on their settling rates in aqueous solution using a hydrometer for the particle size analysis of the samples (Gee and Bauder, 1986). Organic carbon was by the wet oxidation method with normal $K_2Cr_2O_7$ with the aid of H_2SO_4 followed by determination of the excess chromic acid by titration with normal ammonium ferrous sulphate (Walkley and Black, 1934). For total nitrogen, we followed the Kjeldahl procedure (Bremner and Mulvaney, 1982) whereby samples were digested to convert the nitrogen into ammonium nitrogen with the subsequent liberation of the ammonium and titration with hydrochloric acid. The extractable calcium, magnesium, sodium and potassium were determined by extraction with neutral normal ammonium acetate ($1N$ NH_4OAC). Calcium and magnesium were separated with alcohol and determined by EDTA titration. Sodium and potassium were determined on original extracts using flame photometry. The spectrophotometric determination of iodine was done according to the method of Custer and Natelson (1949). One gram of the soil sample was weighed into a centrifuge tube and 5 ml of 95% ethanol added and mechanically shaken for 1 hour. The solution was centrifuged at 200 rpm for 15 minutes and decanted into another labeled test tube. 0.5 ml of the extract was pipetted into a graduated centrifuge tube treated with 0.2 ml of 1% NaOH solution and 0.2 ml solution of 1% $KMnO_4$. The centrifuge tube containing the permanganate was placed in a boiling bath for half-hour and cooled in a refrigerator. In an ice bath, cold 6% H_2O_2 solution was added dropwise to decolorize the permanganate. The solution was then heated to 40 ^{o}C in an oven for 1 hour, allowed to stand at room temperature overnight to decompose the excess H_2O_2. The resulting solution was then diluted to 5 ml with distilled water and centrifuged for 15 minutes. An aliquot of 4 ml was removed into a 12 ml glass-stoppered centrifuge tube. 2 ml of 1% KI solution and then 0.4 ml 5% H_2SO_4 solution were added. Exactly 3.6 ml toluene was added and shaken mechanically for 10 minutes. The resulting solution was centrifuged and the toluene layer transferred into a quartz cuvette. Absorbance was read on the Spectronic-20 Spectrophotometre at 305 nm. [Note: the volumes of the reagents were doubled to enable adequate extraction of the element]. A standard curve was drawn using varying concentrations of KI at 0.0, 0.1, 0.2,

0.3 and 0.4 µg ml^{-1} against absorbance (Figure 2). Values of iodine have been reported on oven-dry weight basis.

Results

Table 1 shows that soils formed on limestone are enriched in iodine, 1.545 µg ml^{-1}, relative to soils formed over other rock types, typically the igneous rocks, with an overall average of 0.521 µg ml^{-1}. Shales and argillites are the most endowed in iodine, averaging 2.180 µg ml^{-1}. However, in derived soils igneous rocks dominate in iodine reserves, particularly reaching an average of 10.172 µg ml^{-1} in the basic igneous rocks.

The soils from the three agro-ecological zones have diverse parent material sources and have been classified according to set guidelines (FAO, 2002). These are mineral soils that have largely been conditioned by humid tropical climate, parent material and topography (elevation and aspect) of the terrain. Table 2 shows that these soils are dominated by acrisols, acid soils with accumulation of low activity clay, which may be found on old erosional or depositional surfaces. The parent material is extensively acid rocks. In the humid tropical regions, the acrisols are associated with nitisols, which are hard when dry, very friable to firm when moist and sticky and plastic when wet. Nitisols tend to be deep, dusky red or dark red in colour and are well-drained soils with a clayey subsurface horizon. In valleys, acrisols are to be expected on the higher terraces with luvisols on the lower terraces. Luvisols are characterized by marked textural differentiation within the soil profile, with the surface horizon being depleted of clay and accumulation of clay in a subsurface argic horizon. Luvisols have activity clays, swelling and shrinking towards the dry end of their climatic zone. On a much smaller scale is the arenosols, which have textures of loamy sand or coarser either to a depth of at least 100 cm from the soil surface. These coarsely-textured soils hold much greater proportion of their 'available' water at low suctions than finer soils. Other important soils within the study region are the vertisols, which are heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out. The solonetz accommodates soils with a dense, strongly structured, clayey subsurface horizon that has a high proportion of adsorbed Na^+ and/or Mg^{2+} ions.

Table 3 shows a range of textures of the soils with varying proportions of the primary mineral fractions, sand, silt and clay. Majority of the soils were sandy loams (57%) with sandy clay loams representing 25% and the remaining 16% made up of loams, clay loams and clays.

The soils of the semi-deciduous rainforest zone and the coastal savanna zone are relatively more acidic than soils of the Guinea savanna zone. Following from Tables 4, 5 and 6, organic carbon, which forms about 58% of the organic matter in the soils, ranged from a minimum of 0.07-5.17%. Means of 2.25%, 3.13% and 1.03% were computed for the coastal savanna, semi-deciduous rainforest and the Guinea savanna zones respectively. A similar trend was observed for N in which case the means calculated for the three zones were 0.15%, 0.30% and 0.07% for the coastal savanna, semi-deciduous rainforest and the Guinea savanna zones. N ranged from 0.03% - 0.44%. The forest soils had higher amounts of CEC compared to the other two zones. With a range of 4.23 – 55.45 cmol$_c$ kg^{-1}, it can be said of the soils that they represented very diverse nature in the retention of cations. The most acidic soil with pH of 4.8 showed a CEC of 12.25 cmol$_c$ kg^{-1} whilst the very basic soil, pH = 7.3, occurring in the Guinea savanna agro-ecological zone recorded the lowest CEC of 4.3 cmol$_c$ kg^{-1}. The largest record of CEC occurred in the semi-deciduous rainforest zone at a value of 55.45 cmol$_c$ kg^{-1}. The pH of the soil was 7.2.

The iodine content ranged between 0.08 – 3.92 µg g^{-1}, with zonal means of 1.85, 0.84 and 0.66 µg g^{-1} for the coastal savanna, semi-deciduous rainforest and Guinea savanna ecologies respectively (Table 5, Table 6). Large records in the coefficient of variation were observed for CEC and I, being 81.9% and 107.1% respectively. Correlation coefficients amongst the soil properties have been presented in Table 7.

Discussion

Mineralogical and chemical composition of the parent materials

Most acrisols have little weatherable minerals left and poor chemical properties. The clay fraction consists almost entirely of well-crystallized kaolinite and some gibbsite. The levels of plant nutrients are low and Al toxicity and P-sorption are strong limitations. Moderately to strongly weathered soils are the luvisols and the nitisols. They may contain less Al-, Fe- and Ti-oxides than in related counterparts as the lixisols and the ferralsols. Although weathering-resistant minerals (notably quartz) predominate, minor quantities of more easily weatherable minerals, for example, feldspars, apatite and amphiboles may still be present. The CEC of nitisols is high. This is mainly attributed to the relatively high clay content of the soils even though these are low-activity clays and also to soil organic matter which makes a considerable contribution. pH of nitisols may range between 5.0 and 6.5. The principal minerals found in the sand and silt fractions of arenosols are quartz and feldspars and to a lesser extent, micas ferromagnesian minerals such as pyroxenes, amphiboles and olivines. The nature of the clay fraction is conditioned by weathering processes and composition of parent rock. Certain clay minerals, for example, vermiculites, chlorites and cemented kaolin, may sometimes be large enough to belong to the sand or silt fraction of the soil. Most arenosols in humid tropical regions are deeply leached and decalcified soils with a low capacity to store bases. Their A-horizons are shallow and/or contain little or poorly decomposed organic matter. With the vertisols, important morphological characteristics such as soil colour, texture, element composition are all uniform throughout the solum. Most of the vertisols have a high CEC and a high base saturation. The soil reaction, pH, varies from weakly acid to weakly alkaline. The presence of high Na saturation is an indication of the characteristic nature of the solonetz soils. Typically, these soils have a thin, loose litter layer resting on black humified material about 2-3 cm thick (FAO, 2002).

Variations in soil properties

The overall characteristic nature of the soils is that they are dominated by low activity clays and are inherently poor in nutrients. Differences reported are supported largely by heterogeneity in the influx and site factors controlling soil formation. The soils of the coastal savanna and the semi-deciduous agro-ecological zones are characteristically acidic and these are attributed to the high rate of leaching of basic cations and the dominantly acid parent material from which these soils have formed. Also of significance is crop removal of the basic cations without the corresponding replenishment of inorganic fertilizers. The greatest input of litter fall is within the semi-deciduous rainforest zone. With a low rate of decomposition, organic matter builds up within this zone. Nye and Greenland (1960) put the rate of mineralization of organic carbon in the forest zone to be around 2.2% whilst the Guinea savanna hits 4.0%. Similar rates may be applied to the coastal savanna. The content of C and therefore total N are much lower in the Guinea savanna due to low litter fall. Sandy soils are regarded to have less organic matter content than clay soils (Biswas and Mukherjee, 1994). The low contents of C and N are also be due to the fact that the sites have been intensively cultivated or are young fallow areas (2-5 years), where basically organic matter production or accumulation is low. Contributing to this low organic matter content may also be the continual removal of plant material for human and animal consumption with relatively little returned to the land, respiration losses due to high temperature and erosion losses due to high intensity rains (Brady and Weil, 1996). According to Atkinson and Wright (1968) the humus or organic matter contents of soils generally decrease with continuous cropping. Dalal and Mayer (1990) also reported similar findings.

Similarly, CEC in the semi-deciduous rainforest zone were higher than in the other two zones, principally due to content of organic matter and hence organic carbon. Fluctuations in the content of clay

are also associated with levels in CEC and most especially FitzPatrick (1983) noted that for most tropical soils the CEC of the whole soil is very low due to the greater amounts of low activity clays, particularly, kaolinite. CEC correlates moderately well with C and N.

A great dispersion in the content of iodine was observed. Iodine has a tendency to become incorporated into silicate structures rather than form discrete iodine minerals such as marshite, miersite, jadargyte and coccinite (Wedepohl, 1972), but if they are present in soils the amounts are likely to be quite small and possibly associated with lead-zinc and copper-silver mineralization (Davies, 1980). Iodine has been detected in such common rock-forming minerals as biotite, muscovite, hornblende, olivine and apatite. Clay minerals may also fix iodine but while the amounts retained by bentomite and kaolinite were found to be quite small, fixation appears to be more marked in the case of illite (Wedepohl, 1972). In common with molybdenum and selenium, iodine also seems capable of adsorption on sesquioxides. High correlations have been obtained between the amounts of iodine dissolved and the contents of 'free' Fe_2O_3 and 'free' Al_2O_3, which are indicative of sorption by sesquioxides. Sorption of iodine on sesquioxides has been found to be important only at pH < 6.0 above which sorption appears to be negligible. The sorption of iodine by the clay-humus complex of soils is also accepted and clay soils are characteristically higher in iodine than soils of lighter texture. Iodine, however, is sorbed only at pH<6.9. At higher pH values iodine is presumably displaced from clay surfaces by hydroxyl ions. This was observed for some of the soils with pH > 7.0. With increased acidity of clay suspensions, there was a progressive increase in iodine sorption. The amount of clay is an enriching factor in that the adsorptive capacity of clays for iodine is quite appreciable. The association between iodine and organic matter has been noted, with high contents recorded for organic soils and peats. The capacity of organic matter to sorb iodine appears to increase with decomposition (Vinogradov, 1959). Contents of iodine and organic carbon in the soils were very weakly negatively correlated. Numerous studies have confirmed that the iodine content of soils is greater than that of the rocks from which the soils have formed. While sedimentary rocks as a group are richer in iodine than igneous rocks, the soils formed from the former are much poor. It has been suggested that the relative porosity of the disintegration products of most sedimentary rocks has been responsible for this. Wide variations in texture may be found in soils derived from sedimentary and igneous rocks as well as in their mineralogical content. The effect of vegetation is essentially one of the redistribution in that plants, through their roots extract iodine from subsurface layers and following death and decay, deposit on the humus-rich surface. Foliar absorption of airborne iodine is considered to be of considerable importance.

Variations in the soils properties have been observed. The variations are largely due to the heterogeneity of the parent materials of the three agro-ecological zones studied and the likely influence of ocean-atmosphere precipitation of iodine. Content of iodine progressively decreased from the coastal savanna zone with a mean of 1.85 μg g^{-1}, the semi-deciduous rainforest zone with a mean of 0.84 μg g^{-1} to the Guinea savanna zone with a mean of 0.66 μg g^{-1}. The major contributing factors to these variations are climatic factors, principally intensity and distribution of rainfall; topography, namely elevation and aspect; dominance of low-activity clays and sesquioxides; organic matter input; acidity-alkalinity; leaching of nutrients and vegetation responsible for the re-distribution of these elements.

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Table 1 Iodine content of igneous and sedimentary rocks and of derived soils

Rock	Parent material ($\mu g\ ml^{-1}$)	Derived soil ($\mu g\ ml^{-1}$)
IGNEOUS ROCKS (ALL)	0.521	9.338
Basic	0.495	10.172
Intermediate	0.523	8.342
Acid	0.542	6.105
SEDIMENTARY ROCKS (ALL)	1.545	3.850
Limestones	1.179	4.506
Sandstones	1.743	3.647
Shales and argillites	2.180	2.221

Source: Chilean Iodine Educational Bureau (1956).

Table 2 Classification of the soils

Agro-ecological zone	Series	Classification
Coastal savanna	Edina	Haplic acrisol
	Atabadzi	Haplic acrisol
	Benya	Haplic acrisol
	Udu	Haplic acrisol
	Hake	Haplic arenosol
	Yoyo	Haplic arenosol
	Agawtaw	Gleyic solonetz
	Akuse	Calcic vertisol
	Amo	Calcic vertisol
Semi-deciduous rainforest	Kumasi	Orthic-Ferric acrisol
	Bekwai	Orthic-Ferric acrisol
	Nzima	Orthic-Ferric acrisol
	Akumadan	Ferric acrisol
	Asikuma	Ferric acrisol
	Mawso	Ferric acrisol
	Juaso	Orthic acrisol
	Asuboa	Haplic nitisol
	Akroso	Haplic nitisol
	Debia	Ferralic nitisol
	Kokofu	Eutric nitisol
	Sutawa	Gleyic arenosol
	Bediase	Dystric nitisol
Guinea savanna	Murugu	Luvisol
	Nyankpala	Ferric luvisol
	Damongo	Luvisol
	Changnayili	Luvisol
	Wenchi	Luvisol
	Kpelesawgu	Ferric luvisol

Table 3 Particle size distribution of soils from the coastal savanna agro-ecological zone

Soil series	% Sand	% Silt	%Clay	Texture
Edina	51.7	17.8	30.8	Sandy loam
Atabadzi	49.7	17.2	33.1	Sandy clay loam
Benya	51.0	14.5	34.5	Sandy clay loam
Udu	28.6	13.7	57.7	Sandy clay loam
Hake	58.0	39.0	3.0	Sandy loam
Yoyo	70.0	15.0	14.5	Sandy loam
Agawtaw	73.3	10.5	16.2	Sandy loam
Akuse	59.6	5.4	35.0	Sandy clay loam
Amo	26.5	40.5	33.0	Clay
Kumasi	59.5	13.1	27.4	Sandy clay loam
Bekwai	43.3	28.9	27.8	Loam
Nzima	49.6	37.6	12.8	Loam
Akumadan	34.5	37.0	28.0	Loam
Asikuma	60.5	30.0	9.5	Sandy loam
Mawso	60.1	30.0	9.9	Sandy loam
Juaso	44.5	27.5	28.0	Clay loam
Asuboa	54.5	22.8	22.7	Sandy clay loam
Akroso	76.0	14.3	15.7	Sandy loam
Debia	59.1	15.9	25.0	Sandy clay loam
Kokofu	60.2	36.0	3.8	Sandy loam
Sutawa	75.2	18.3	6.5	Sandy loam
Bediase	75.5	17.0	7.5	Sandy loam
Murugu	70.0	18.0	12.0	Sandy loam
Nyankpala	72.5	17.5	10.0	Sandy loam
Damongo	81.1	13.0	5.1	Loamy sand
Changnayili	66.0	25.0	9.0	Sandy loam
Wenchi	67.3	20.9	11.8	Sandy loam
Kpelesawgu	64.0	34.0	2.0	Sandy loam

Table 4 Some chemical properties of the soils

Soil series	pH	%C	%N	CEC (cmol$_c$ kg^{-1})
Edina	4.9	3.91	0.25	11.49
Atabadzi	5.2	1.28	0.12	5.91
Benya	5.9	3.06	0.27	10.57
Udu	4.9	4.53	0.41	13.69
Hake	5.4	1.61	0.08	12.06
Yoyo	5.2	2.28	0.11	13.42
Agawtaw	6.4	0.07	0.03	4.40
Akuse	6.9	1.96	0.11	28.47
Amo	5.0	1.54	0.04	11.21
Kumasi	4.8	4.65	0.29	12.25
Bekwai	5.2	5.17	0.41	20.37
Nzima	7.2	3.93	0.41	55.45
Akumadan	4.9	3.17	0.39	10.77
Asikuma	5.4	3.61	0.31	14.24
Mawso	4.9	2.24	0.24	7.66
Juaso	6.8	4.86	0.44	23.59
Asuboa	5.8	2.75	0.29	10.18
Akroso	5.4	1.53	0.29	5.86
Debia	5.0	3.47	0.28	8.77
Kokofu	5.9	2.39	0.36	8.85
Sutawa	5.2	1.16	0.07	8.42
Bediase	6.6	1.79	0.15	11.25
Murugu	6.6	0.70	0.04	4.41
Nyankpala	7.2	2.10	0.07	4.28
Damongo	7.3	0.66	0.05	4.23
Changnayili	5.7	1.18	0.09	7.41
Wenchi	5.9	0.46	0.06	10.00
Kpelesawgu	7.1	1.10	0.08	8.01

Table 5 Content of iodine in the soils

Soil series	Iodine ($\mu g\ g^{-1}$)	
Edina	0.24	
Atabadzi	3.92	
Benya	0.40	
Udu	2.76	
Hake	0.36	
Yoyo	3.72	
Agawtaw	1.63	
Akuse	0.16	
Amo	3.44	
		Mean 1.85
Kumasi	0.72	
Bekwai	0.08	
Nzima	0.08	
Akumadan	1.60	
Asikuma	0.32	
Mawso	0.24	
Juaso	0.60	
Asuboa	0.16	
Akroso	0.64	
Debia	3.44	
Kokofu	1.68	
Sutawa	0.90	
Bediase	0.40	
		Mean 0.84
Murugu	0.40	
Nyankpala	1.16	
Damongo	0.08	
Changnayili	0.80	
Wenchi	0.40	
Kpelesawgu	1.24	
		Mean 0.66

Table 6 Summary statistics of the physical and chemical properties of soils

Parameter	Sand	Silt	Clay	pH	C	N	CEC	I
Mean	58.6	22.5	18.9	5.81	2.40	0.21	12.40	1.13
StdDev[a]	14.2	9.8	13.2	0.84	1.44	0.14	10.15	1.21
StdError[b]	2.68	1.86	2.49	0.16	0.27	0.03	1.92	0.23
CV[c]	24.2	43.6	69.8	14.5	60.0	66.7	81.9	107.1
95% CL[d]	5.5	3.8	5.1	0.33	0.56	0.05	3.93	0.47
Skewness	-0.65	0.44	0.91	0.53	0.38	0.28	3.16	1.33
Minimum	26.5	5.4	2.0	4.8	0.07	0.03	4.23	0.08
Maximum	81.1	40.5	57.7	7.3	5.17	0.44	55.45	3.92

[a]Standard deviation [b]Standard error of the mean

[c]Coefficient of variation [d]Confidence level (95%)

Table 7 Pearson's correlation coefficient, *r*, among the soil properties studied.

	SAND	SILT	CLAY	pH	CARBON	NITROGEN	CEC	IODINE
SAND								
SILT	-0,44							
CLAY	-0,73	-0,29						
pH	0,41	-0,10	-0,39					
CARBON	-0,59	0,14	0,52	-0,31				
NITROGEN	-0,54	0,24	0,41	-0,26	0,86			
CEC	-0,34	0,26	0,16	0,26	0,48	0,46		
IODINE	-0,30	-0,03	0,34	-0,38	-0,07	-0,11	-0,23	

Figure 1   The Iodine Cycle
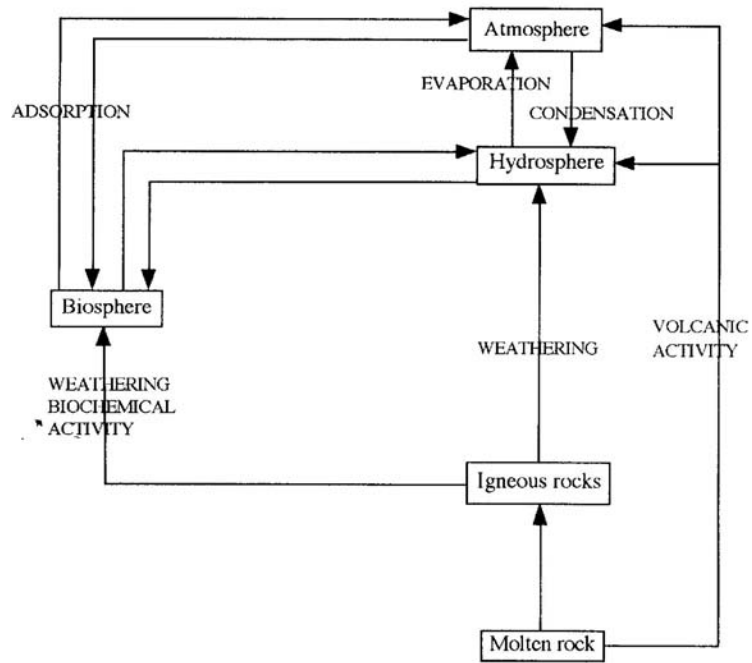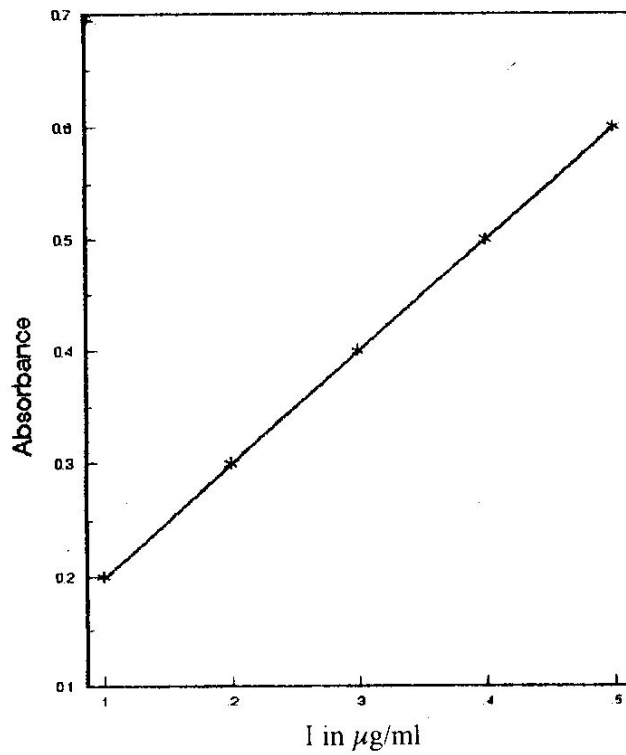*(after Rankama and Sahama, 1950)*

Figure 2 Standard curve for Iodine