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Iodine, Copper, and Zinc Levels as Indices of Nutritional Status among Residents of Wassa West District, a Mining Impacted Region of Ghana, Using Instrumental Neutron Activation Analysis

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Abstract:
Human hair and nail samples from fifty volunteers were collected from Wassa West district, a mining impacted region of Ghana, and used as biomakers of nutritional status. Activation Analysis (INAA) was employed to analyze for levels of iodine, copper and zinc. The mean concentrations of iodine in hair of experimental subjects was3.34± 0.54µg/g. The control subjects had a mean concentration of 1.21± 0.32µg/g of iodine. These levels were above the ideal level of 1.0µg/g to meet the physiological requirements of the individual. Mean iodine in nails of the experimental subjects was 2.70±0.25µg/g, and that of the control was 1.50±0.12µg/g. Mean Copper levels in hair of experimental subjects were determined to be 28.49±3.40µg/g and the control recorded 15.91±2.15µg/g. Mean copper levels in nail of the experimental subjects was 29.64±1.05µg/g and the control was 19.08±2.21µg/g. Mean zinc levels in hair of the experimental subjects was 105.82±2.12µg/g, and that of the control was 113±3.45µg/g. Mean levels of zinc in the nails of the experimental subjects was 105.51±3.21µg/g and the control was 105.75±2.68µg/g. Generally, there were no striking significant statistical differences between the two groups. The two groups were well nourished
The precision and the accuracy of the analytical technique (INAA) were assessed by simultaneous activation of certified standard human hair reference material GBW 09101. The values obtained compared well with the certified values as Pearson's correlation coefficient was + 0.99. The measurement precision as specified by the relative standard deviation was within ±0.4%. The experimental values were within ±5% of the certified values. T-test was used to establish significant statistical differences(p< 0.05) between the two groups.

Keywords: *Nutrition, human hair, nail, poverty, mining, biomaker, health, diet*

1. Introduction

The history of mining in Africa, in particular, and the third world in general, is a history of land appropriation, displacement of people from their lands, environmental devastation, and further marginalization and oppression of people belonging to the lower economic sectors (Samlafo, 2008). Between 1990 and 1998, mining in Wassa West district led to the displacement of 14 communities, with a total population of more than 30,000 (Yankson, 2010).

Despite the boom in gold mining in the Wassa West district, unemployment and poverty have deepened, partly due to loss of farm lands to surface mining, but more importantly due to limited opportunities for wage employment in the district 's revived gold-mining industry (Yankson, 2010).

The overall effects of the unemployment were greater poverty, due mainly to lack of income-earning opportunities in the district. In Ghana, although the poverty rate is said to be declining, the depth of poverty for those who remain poor has not changed (Yankson, 2010).

Although, Gold field Ghana Limited has initiated corporate social responsibility such as health, water, sanitation and alternative livelihood projects such as batik (tie-and dye) production, bakeries, soap and food production to mitigate the poverty levels, these interventions were met with some challenges. These challenges are: over-dependence on Goldfield Ghana Ltd (GFG) by beneficiaries for nearly their entire livelihood as against limited resources, high preference of beneficiaries for cash assistance rather than the implemented Sustainable Community Empowerment and Economic Development Programme (SEED).Some of the challenges of SEED interventions are: high staff turnover resulting in programme implementation difficulties and inconsistencies, inappropriate market avenues for finished products leading to disappointments and loss of interest in some enterprises by beneficiaries, negative attitudes and mind-sets of some of the group members towards programme interventions and ownership (Yankson, 2010).

Many Ghanaian rural households experience food shortages for at least four months of the year and cannot produce, nor have access to, enough food to meet the household's daily nutritional requirements. Thus malnutrition rates are high. (Yankson, 2010). In an effort to address this pressing food-security need, Goldfield Ghana Limited introduced the Vulnerable Nutrition Enhancement Programme (VNEP) into the SEED programme in 2008. This was expected to reach people living with HIV and AIDS (PLHIVs), orphans and vulnerable children (OVCs). The goal was to enhance the care and support of selected vulnerable groups. The programme had two main objectives: to increase their nutritional intake through the monthly distribution of Breedlove Dehydrated Foods – Plain Harvest Lentil Blend; and to increase health and nutrition awareness through education and counselling (Yankson, 2010).

1.1. Human Hair and Nail as Biological Makers (Biomakers) of Nutritional Status

Biological makers, (biomakers) may be used to refer to quantifiable biological phenomena or states such as physiological responses, cellular or molecular events or alterations, or chemical concentrations in body fluids or tissues(Maruvada, 2004).Biological makers provide information on chemical exposure, nutritional intake and status, the effects of lifestyle, or susceptibility to disease (Decaprio, 1997).

In intervention studies, biomakers can be used to assess the degree of compliance, i.e. the extent to which the test substance is being ingested (Decaprio, 1997). An effective biomaker of nutritional status can identify test subjects who, though apparently healthy, begin to show nutritional deficiency in a study. Often these low baseline value individuals exhibit the greatest disease risk, and their risk shows the greatest response to intervention (Decaprio, 1997).

The traditional methods of determining nutritional intake have centred on dietary questionnaires and food-composition data (Potischman, 2003).However, nutrient levels in foods may vary significantly by source and their bioavailability modified by cooking methods as well as other foods consumed in the meal. The percentage of nutrient absorbed varies in complex ways from person to person and from day to day. Biomakers show the promise of being able to cut through all of these factors and arrive at an actual, measurable, long-term nutritional status (Potischman, 2003).

Biomakers are selected based on practical considerations. They should be sensitive to the larger effects they are intended to measure, and should selectively mirror that effect only (Decaprio, 1997).Using nail, hair and blood as a theoretical example, these biomakers should ideally respond measurably to a subject's intake/status of the element in question, and should only respond to this stimulus, excluding environmental pollutants with which the subject comes in contact but neither ingests nor absorbs (Decaprio, 1997) . An ideal biomaker should be easily and unobtrusively obtained from the subjects. Nail clippings, hair and blood fit this description, and have the additional advantages, that subjects may self-collect and mail the specimens, (except blood) which can then be stored in paper envelopes at room temperature for extended periods. Urine is also a good biomarker that could be used as an alternative to blood samples as an internal biomonitor (Decaprio, 1997).

1.2. Significance of Iodine in Nutrition

Iodine is an essential component of the thyroid hormones, thyroxine (T_4) and triiodothyronine (T_3), necessary for normal growth, development, and metabolism during pregnancy, infancy and throughout life. Recommended daily allowance of iodine is 150μ/day (Driskell, 1981).

When the physiological requirements for iodine are not met, a series of functional and developmental abnormalities occur, including thyroid function abnormalities. Severe iodine deficiency results in hypothyroidism, endemic goiter and cretinism, endemic mental retardation, decreased fertility, increased prenatal death, and infant mortality. High iodine intake may also cause disturbances in the thyroid function (Amar, 2006). Sources of iodine include iodized salts and seafoods.

1.2.1. Significance of Copper in Nutrition

Copper is an essential micro-nutrient necessary for the haematologic and neurologic systems. It is necessary for the growth and formation of bone, formation of myelin sheaths in the nervous system, helps in the incorporation of iron in haemoglobin, assist in the absorption of iron from the gastrointestinal tract (GIT) and in the transfer of iron from tissues to the plasma (Soetan, 2010).Recommended daily allowance of copper is 900μg/day in humans (Driskell, 1981).It is stored mostly in the liver and muscle. Total copper in adult human is 50-80 mg, Liver has 30-50 μg/g of dry tissue.

The copper containing –protein in red blood cells is erythrocuperin, in liver, it is hepatocuperin and in the brain, it is cerebrocuperin. Copper is absorbed mainly in the upper part of the small intestine, where the pH is still acidic. In general, copper is poorly absorbed, and under normal conditions > 90% of the ingested copper appears in the faeces. Most of the faecal copper is unabsorbed dietary copper, but some of it comes from bile, which is the major pathway of copper excretion. (Soetan, 2010). Clinical disorders associated with copper deficiencies include anaemia, bone disorders, neonatal ataxia, depigmentation and abnormal growth of hair, impaired growth and reproductive performance, heart failure and gastrointestinal disturbances, Sources of copper include liver, whole grains, molasses, legumes, nuts, shell fish and other seafoods.

1.2.2. Significance of Zinc in Nutrition

Zinc is distributed widely in plants and animal tissues and occurs in all living cells. It functions as a cofactor and is a constituent of many enzymes such as lactate dehydrogenase, alcohol dehydrogenase glutamic dehydrogenase, DNA and RNA polymerase etc. Zinc dependent enzymes are involved in macronutrient metabolism and cell replication. The primary roles of zinc appear to be in cell replication and gene expression and in nucleic acid and amino acid metabolism. Vitamins A and E metabolism and bioavailability are

dependent on zinc status (Soetan, 2010). Zinc deficiency is common in alcoholics and diabetics, and in malabsorption syndrome, Plasma level of zinc is 70-120µg/dl.

In humans, deficiency diseases or symptoms include growth failure, impaired wound healing, decrease taste and smell acuity. Sources of zinc are red meat, fish meals, liver, eggs, dairy products, vegetables and some seafoods. (Soetan, 2010).

It is against this background that this paper looks at human hair and nails as biomakers of nutritional status among the residents of Wassa West district.

2. Materials and Methods

2.1. Sample Collection

The hair and nail samples were collected from volunteers at barbering shops and hair dressing saloons at Bogoso, Aboso, Tarkwa Township, Nsuta, Teberebie, Bonsaso, Prestea and Agona, at random on three occasions with ethical approval from the Ghana Health Service. The hair and nail samples were cut using pre-cleaned stainless steel scissors and blades respectively. The hair samples were cut to about 1.0 cm to the scalp from the back of the inhabitants (Vasconcellos, 1994) and coded H_n for experimental samples where $_n$=1-50. The toenails and fingernails were put into separate plastic containers and labelled. The toenails were coded TN_x, where $_x$=1-20 while the fingernails were coded $FN_{y,}$ where $_y$ =1-30. A total of 50, each of hair and nail samples were collected from all the sampling towns.

Similarly, control samples (hair and nail) were taken from subjects at Akatsi and its environs in the Volta region on three occasions. The distance between Akatsi and Tarkwa is about 480 Km by road, where there are no known mining or industrial activities. The hair samples for control subjects were coded CH_a, where $_a$ = 1-25 and fingernail samples were coded CFN_e where $_e$= 1-19 and toenails were coded $CTN_{d,}$ where$_d$= 1-6 . The samples were collected from Avenorpeme, Abor and Akatsi. All the subjects were made to respond to a detailed questionnaire regarding dietary habits, gender, age, occupation etc.

2.2. Preparation of the Hair and Nail Samples

All reagents (BDH chemicals Limited, England) used for sample treatment were of analytical grade unless otherwise stated. The hair samples ((both experimental and control) were washed separately first with deionized distilled water (DDW), followed by acetone to remove organic based contaminants from the hair surfaces, and re-washed five times with deionized distilled water, and dried at 30°C under laboratory condition (Vasconcellos, 1994). Five sub-samples of the hair, (experimental and control) each of 100 mg were weighed and wrapped into transparent polyethylene films together with sample paper identification code and heat sealed.

The nails of both the experimental and control samples were washed in 4 stages, of 15 minutes each. The nails were treated in turns: in 20.0 mL of acetone twice, in 40.0 mL of distilled water twice and then again in 20.0 mL of acetone. After washing, they were dried at 30 ºC under laboratory condition(Baranowska, 2004).Five sub-samples of the nail (experimental and control) each of 100 mg were weighed and wrapped into transparent polyethylene films together with sample paper identification code and heat sealed. The same mass of single I, Cu and Zn comparator standards were also weighed and heat sealed. A certified standard reference hair material GBW 09101(certified by Shangai Institute of Nuclear Research, China) was also heat sealed for irradiation.

The prepared hair and nail samples of experimental and control subjects, together with the certified reference hair material GBW 09101 were packed into polyethylene vials and heat sealed for irradiation. The certified reference material was used as quality control to validate the analytical technique. This certified reference material was irradiated on per batch basis in order to monitor the irradiation and counting efficiency.

2.3. Sample Irradiation and Counting

Irradiation and counting of samples using the Ghana Research Reactor-1 facility has been described earlier (Nyarko, 2003). The packed nail, hair, and the certified reference hair material GBW 09101 were irradiated at the inner irradiation sites of the Reactor-1 facility, using a pneumatic transfer system at a thermal neutron flux of $5.10^{11}n.cm^2s^{-1}$ and a pressure of 1. 723 bars. Different timing schemes for irradiation, counting and delay time for safe handling and optimization of analysis time of the samples were investigated for the different nuclides. The irradiation time (t_i), decay time (t_d) and counting time (t_c) were chosen according to half-life of the radionuclides of interest and the sample matrix, as well as the safe handling of radioactive samples. The whole irradiation scheme was divided into two categories depending on the half-lives ($t_{1/2}$) of the radionuclides. Short-lived radionuclides with half-lives less than one hour (Cu, and I,) were irradiated for 2min, delayed for 10sec and counted for 10min (t_i=2min t_d=10 sec, t_c=10min).Long-lived nuclides with half-lives longer than two hours (Zn,) was irradiated for 4hours, decayed for 5 days and counted for 12 hours (t_i=4hrs, t_d=days and t_c=12hrs)

The counting of samples was done using a gamma-ray spectroscopy system. The system was made up of N-type HPGe detector model GR2518, and HV Power Supply Model 3103, a spectroscopy Amplifier Model 2020, an ACCUSPEC Multi-channel Analyzer (MCA) emulation software card, all manufactured by Canberra Industries, Inc, and a 486 micro-computer. The efficiency of the detector was 25%. Each sample was placed at a distance of 2.6 cm from the detector surface and counted (Nyarko, 2003).

The accumulated spectra intensities were analysed qualitatively and quantitatively. The qualitative analysis involved the identification of ^{66}Cu using the 1039.2k,^{128}I using 442.3KeV and ^{65}Zn using 1115.5 KeV. The quantitative analysis was done by converting the counts (area) under the photopeak of the radionuclides by comparator INAA method using pure Cu,I and Zn single standards(Nyarko, 2003). Cobalt-60, Caesium-137 and Barium- 133 sources were used to calibrate the detector periodically whenever counting is going

to be done and between counting of the samples. Statistical analysis of the data was performed using Microsoft office excel, window 2007.

3. Results and Discussions

The precision and accuracy of the analytical technique (INAA) were assessed by simultaneous activation of reference material GBW 09101. Table 1 shows the analytical results obtained for As, Hg, Cu, Mn, K, I, Co. in the reference material compared with the experimental samples.

The levels of the elements in the standard reference materials were in good agreement with the certified values as the Pearson's correlation coefficient was +0.99 for GBW 09101. The results of the analyzed samples were within ±4% of the certified values.

Element	This Work	Certified Value
As	0.60±0.03	0.59 ±0.07
Hg	2.10±0.05	2.16±0.21
Cu	22.50±1.6	23.0±1.4
Mn	2.92±0.01	2.94±0.2
K	10.89±1.5	11.8
I	0.90±0.02	0.875
Co	0.40±0.02	0.135±0.008

Table1: Mean trace element concentrations (μg/g) of human hair in this study compared with standard reference material GBW 09101 with standard deviations (n=5)

An independent one- tailed student t-test was used to compare the means of both the experimental and the control groups in order to establish significant statistical differences between the two groups. The level of probability at which significant differences existed between the groups was set at $p < 0.05$ at 95% confidence level.

Element	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
I	1.95±0.03	2.92±0.44	1.25±0.19	0.97±0.15	0.25±0.04	9.03±1.36	0.69±0.10	2.16±0.32	2.37±0.36	0.46±0.01
Cu	10.74±1.61	3.41±0.51	11.16±1.67	8.66±1.30	6.51±0.98	62.15±16.08	10.53±1.58	41.10±12.89	7.41±1.11	1.71±0.26
Zn	122.45±6.32	76.56±4.67	134.78±7.34	136.24±8.57	98.20±5.32	112.23±8.32	102.27±3.40	96.29±4.94	109.30±5.30	104.23±8.23
Element	**H11**	**H12**	**H13**	**H14**	**H15**	**H16**	**H17**	**H18**	**H19**	**H20**
I	1.60±0.24	1.02±0.15	1.93±0.29	0.7±0.11	2.0±0.03	1.08±0.16	3.23±0.48	1.75±0.26	10.66±1.60	1.29±0.19
Cu	33.98±10.97	4.87±0.73	120.94±18.14	67.76±11.83	7.94±1.19	5.89±0.88	64.55±9.68	18.56±2.78	57.85±8.68	7.54±1.13
Zn	126.12±10.21	80.24±5.32	124.23±6.72	82.45±5.98	121.23±9.21	86.46±8.20	119.36±7.23	96.12±5.23	120.25±6.21	88.20±9.23
Element	**H21**	**H22**	**H23**	**H24**	**H25**	**H26**	**H27**	**H28**	**H29**	**H30**
I	1.23±0.18	1.64±0.25	2.16±0.32	4.62±0.69	0.89±0.13	3.05±0.46	1.01±0.15	2.86±0.43	1.23±0.18	0.89±0.13
Cu	2.94±0.44	11.50±1.72	16.45±2.47	32.95±4.94	4.84±0.73	11.73±1.76	18.69±2.80	48.98±7.35	4.64±0.70	23.37±3.50
Zn	118.68±6.98	91.20±4.30	117.20±4.89	103.34±7.20	102.39±6.30	90.12±8.29	116.20±9.23	99.20±6.30	100.30±4.90	98.97±5.30
Element	**H31**	**H32**	**H33**	**H34**	**H35**	**H36**	**H37**	**H38**	**H39**	**H40**
I	1.20±0.18	0.59±0.09	2.62±0.39	0.95±0.14	3.62±0.54	5.44±0.82	0.86±0.13	0.77±0.12	7.38±1.11	1.04±0.16
Cu	31.14±4.67	15.66±2.35	19.33±2.85	8.08±1.21	58.46±8.77	18.17±2.72	14.60±2.19	17.55±2.64	15.96±2.39	8.25±1.24
Zn	106.39±7.40	103.49±5.59	105.39±7.17	97.39±6.38	105.23±8.73	107.37±10.22	88.30±5.21	121.34±8.02	120.12±7.29	98.34±8.43
Element	**H41**	**H42**	**H43**	**H44**	**H45**	**H46**	**H47**	**H48**	**H49**	**H50**
I	5.45±0.82	2.0±0.30	0.25±0.04	0.06±0.01	57.84±8.68	2.22±0.33	0.40±0.01	1.18±0.18	1.05±0.16	5.18±0.77
Cu	296.0±14.64	19.27±2.89	6.43±0.96	13.12±1.97	16.65±2.50	5.94±0.89	42.81±6.42	18.49±2.77	10.85±1.63	58.55±8.78
Zn	114.23±7.98	119.39±9.49	97.39±7.34	89.20±6.32	114.12±9.34	121.34±8.32	101.39±5.98	98.89±4.96	104.56±5.36	102.34±6.39

Table 2: Mean concentrations of elements in experimental hair samples with standard deviation (μg/g dry weight), n=5

Element	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10
I	1.28±0.19	0.61±0.05	0.34±0.03	0.80±0.07	0.18±0.01	0.30±0.03	0.33±0.03	1.80±0.023	0.30±0.04	3.88±0.58
Cu	18.35±2.82	8.87±1.56	11.06±2.76	20.51±0.56	9.21±2.50	6.89±1.56	7.60±1.25	20.22±3.76	5.27±1.20	6.45±1.46
Zn	158.0±5.25	89.65±7.34	104.23±3.58	145.23±6.21	136.35±8.92	70.34±5.87	79.86±5.82	102.11±4.63	148.18±6.34	136.71±9.23
Element	**CH11**	**CH12**	**CH13**	**CH14**	**CH15**	**CH16**	**CH17**	**CH18**	**CH19**	**CH20**
I	1.0±0.15	0.64±0.09	0.40±0.04	0.79±0.11	1.0±0.16	1.31±0.17	1.19±0.18	0.61±0.09	1.66±0.24	2.26±0.34
Cu	8.54±2.76	1.80±0.89	3.04±0.26	6.57±0.34	23.99±5.29	17.75±3.91	4.93±1.26	40.36±5.78	27.76±4.21	18.61±3.96
Zn	96.12±590	105.23±6.23	115.34±7.94	125.29±8.56	138.28±9.12	86.19±5.67	148.11±12.32	92.14±6.82	87.25±7.23	125.23±8.54
Element	**CH21**	**CH22**	**CH23**	**CH24**	**CH25**					
I	2.81±0.35	1.68±0.25	2.41±0.41	1.68±0.26	0.89±0.13					
Cu	9.14±2.56	38.15±4.89	9.25±1.26	38.18±2.80	35.36±4.70					
Zn	139.13±6.11	143.27±7.24	84.23±4.96	104.44±5.78	72.85±8.92					

Table 3: Mean concentrations of elements in control hair samples with standard deviation (μg/g dry weight), n=5

Element	FN1	FN2	FN3	FN4	FN5	FN6	FN7	FN8	FN9	FN10
I	2.09±1.43	4.47±0.67	0.41±0.62	1.69±0.25	9.90±2.14	0.51±0.08	1.79±0.27	0.32±0.05	1.47±0.23	0.58±0.09
Cu	24.10±3.61	35.64±5.35	2.64±0.40	3.37±0.51	4.05±0.61	3.01±0.45	2.84±0.43	39.47±5.92	4.80±0.72	9.43±1.41
Zn	116.49±5.39	108.39±6.89	112.30±5.30	98.23±6.89	87.48±4.90	102.30±7.90	111.34±5.98	105.37±6.39	109.29±3.69	92.29±5.87
Element	**FN11**	**FN12**	**FN13**	**FN14**	**FN15**	**FN16**	**FN17**	**FN18**	**FN19**	**FN20**
I	1.91±0.29	5.17±1.69	44.03±6.60	0.13±0.02	0.51±0.08	1.06±0.16	4.07±0.61	0.64±0.10	1.62±0.24	0.54±0.08
Cu	17.71±2.66	49.61±7.44	108.06±15.2	12.93±1.94	17.27±2.59	19.24±2.88	12.38±1.86	8.83±1.32	33.44±5.02	1.89±0.28
Zn	119.29±9.20	88.40±6.20	97.48±4.86	89.29±6.98	101.29±8.96	111.38±6.89	115.29±9.12	106.31±7.29	95.20±5.49	99.10±4.79
Element	**FN21**	**FN22**	**FN23**	**FN24**	**FN25**	**FN26**	**FN27**	**FN28**	**FN29**	**FN30**
I	1.23±0.18	2.04±0.31	0.79±0.12	0.19±0.03	1.17±0.17	0.59±0.09	0.27±0.04	2.40±0.36	2.47±0.37	2.26±0.34
Cu	31.70±4.76	17.89±2.68	24.97±3.75	15.65±2.35	4.42±0.63	11.78±1.77	21.15±3.17	1.94±0.29	15.91±2.39	79.07±11.86
Zn	106.25±5.78	105.26±6.84	87.39±5.39	91.50±6.93	118.45±5.98	119.25±6.11	120.12±9.50	113.39±5.89	109.29±9.29	95.39±6.49
Element	**TN1**	**TN2**	**TN3**	**TN4**	**TN5**	**TN6**	**TN7**	**TN8**	**TN9**	**TN10**
I	0.92±0.14	0.29±0.04	1.22±0.18	0.19±0.03	1.89±0.28	4.88±0.73	0.32±0.01	1.20±0.18	1.43±0.22	1.75±0.26
Cu	17.03±2.55	19.67±2.95	40.89±6.13	18.52±2.78	30.04±4.51	48.60±7.29	28.69±4.30	21.88±3.28	3.36±0.50	26.17±3.93
Zn	98.30±5.30	107.39±7.93	116.29±8.28	114.29±5.29	107.29±3.10	103.19±8.10	102.12±4.89	103.29±5.97	97.29±3.91	99.20±7.30
Element	**TN11**	**TN12**	**TN13**	**TN14**	**TN15**	**TN16**	**TN17**	**TN18**	**TN19**	**TN20**
I	0.09±0.01	2.01±0.31	0.70±0.11	2.67±0.40	1.53±0.23	3.94±0.59	1.58±0.24	3.01±0.46	4.60±0.69	4.58±2.05
Cu	4.22±0.63	350.46±52.5	24.85±3.73	18.08±2.82	24.63±3.69	44.58±6.69	7.91±1.19	58.61±8.79	51.89±7.78	7.08±1.06
Zn	97.20±6.39	115.56±5.30	117.39±6.30	105.23±5.93	107.12±4.20	110.20±7.21	112.34±4.93	115.28±6.29	111.39±5.39	102.29±8.20

Table 4: Mean concentrations of elements in experimental nail samples with standard deviation (µg/g dry weight), n=5

Element	CFN1	CFN2	CFN3	CFN4	CFN5	CFN6	CFN7	CFN8	CFN9	CFN10
I	0.70±0.08	1.07±0.20	2.17±0.31	1.22±0.11	0.70±0.11	1.31±0.25	0.67±0.26	2.05±0.61	1.59±0.17	2.58±0.19
Cu	32.11±3.92	17.08±2.66	28.84±3.04	18.61±2.66	2.20±0.10	14.45±2.45	4.94±1.20	94.23±18.60	4.23±1.30	37.84±3.04
Zn	123.12±5.97	98.86±4.65	146.21±4.22	128.64±6.98	111.23±7.97	102.45±8.43	89.46±6.90	84.95±5.67	136.68±6.43	144.23±9.21
Element	**CFN11**	**CFN12**	**CFN13**	**CFN14**	**CFN15**	**CFN16**	**CFN17**	**CFN18**	**CFN19**	**CTN1**
I	1.0±0.02	1.90±0.35	2.84±0.41	0.85±0.35	1.0±0.01	1.38±0.34	1.13±0.41	1.34±0.36	1.04±0.27	1.90±0.29
Cu	19.38±4.12	10.51±2.81	5.70±0.51	4.60±0.21	13.86±0.82	18.58±3.12	6.03±0.08	13.03±2.27	16.76±3.09	19.06±4.87
Zn	136.78±6.43	131.67±6.45	106.34±8.34	102.48±6.29	79.23±9.21	89.12±6.32	76.45±5.97	105.38±6.92	102.14±7.46	109.11±5.34
Element	**CTN2**	**CTN3**	**CTN4**	**CTN5**	**CTN6**					
I	1.74±0.39	2.04±0.51	1.56±0.52	2.17±0.42	1.58±0.35					
Cu	16.92±3.18	20.63±4.21	13.24±2.12	10.54±3.06	33.76±5.09					
Zn	98.20±6.87	96.61±5.27	82.34±6.89	81.68±2.60	80.45±4.98					

Table5: Mean concentrations of elements in control nail samples with standard deviation (µg/g dry weight), n=5

The mean iodine levels in hair of experimental subjects (table 2) were 3.34± 0.54µg/g and that of the control group was 1.21± 0.32µg/g (table3). There was no significant statistical difference between the experimental subjects and the control subjects since (p=0.99>0.05). The iodine levels in the diet of the two groups were generally above the ideal value of 1.0µg/g in a normal healthy individual(Wilson, 2013). This level reflects the amount necessary for physiological activities in a normal healthy individual. The mean levels of iodine in nails of experimental subjects was 2.70±0.25µg/g (table 4) compared with that of the control subjects 1.50±0.12µg/g (table 5). Human nails have no reference value. The perception that mining increases the poverty levels of the community members and hence poor nutrition may not be applicable to Wassa West district of Ghana, because there is no significant statistical difference between the levels of iodine in nails of experimental and control subjects. Indeed, the mean iodine levels in experimental and the control group may be due to the education on the use of iodide salt as identified by (Yankson, 2010).

Mean copper levels in hair of experimental subjects (table2) was 28.49±3.40µg/g and that of the control was 15.91±2.15µg/g (table3). There was no significant statistical difference between the two groups. However, 25.0µg/g copper in hair is ideal to meet normal physiological processes in a normal healthy individual (Wilson, 2013). Although the mean copper levels of the control subjects was below the ideal level, there was no significant statistical difference between the two groups (p=0.87> 0.05). Mean copper levels in nails of experimental subjects was 29.64±1.05µg/g (table4) and the control was 19.08±2.21µg/g (table5). Significant statistical differences did not exist between the two groups as (p=0.16>0.05).One study reported 27.62µg/g of copper in toenail among some inhabitants of Kano in Nigeria. The same study quoted toenail values of Copper in Brazil as 29-175µg/g and 4.33-5.21µg/g in USA (Ayodele, 2009).

A reverse trend was observed in zinc levels in hair of experimental and control subjects (tables 2 and 3). Mean zinc levels in hair of experimental subjects was 105.82±2.12µg/g (table2) and that of the control was 113.35±3.45 µg/g (table3). The control subjects gave higher levels of zinc compared with the experimental subjects. The ideal level of zinc necessary to meet physiological activities was 150µg/g(Wilson, 2013). Both subjects had zinc levels below the recommended ideal levels. However, there was no significant statistical difference between the control and the experimental group (p=0.06>0.05).Mean level of zinc in nails of experimental subjects was 105.51± 3.21µg/g(table4) and the control was 105.75 ± 2.68 µg/g (table5). No significant statistical differences exited between the two groups as (p= 0.47> 0.05). Thus these levels of Zn correlates well with soil zinc levels in the soils of the two study areas as staple food crops grown in these soils indicated zinc deficiency.

4. Conclusion
With the exception of zinc levels which fell a little below the ideal level in human hair, both the experimental and the control subjects can be said to have adequate minerals in their diet that is required to meet the physiological processes in a healthy individual. Malnutrition thus, does not prevails in the Wassa West district of Ghana or the control area as speculated by (Yankson, 2010).Thus the residents in these districts based on this study, can be said to be well nourished.

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