BASELINE SURVEY OF TRACE METALS IN CHICKEN AT THE SURROUNDINGS OF THE TUMMALAPALLE URANIUM MINING SITE

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Abstract
The present study is to carry out the baseline survey on evaluation of Aluminium (Al), Chromium (Cr), Manganese (Mn), Iron (Fe), Nickel (Ni), Copper (Cu), Zinc (Zn), Lead (Pb), Vanadium (V), Cobalt (Co), Arsenic (As), Cadmium (Cd) and Uranium (U) concentrations in chicken samples of the surrounding villages of the Tummalapalle uranium mining site, Andhra Pradesh, India. The trace metal concentrations were estimated using Inductively Coupled Plasma Mass Spectrometer (ICP – MS). As per the estimated data, the concentrations of trace metals are found in the range of 23.5 - 309.0 mg/kg for Al, 1.9 – 2.9 mg/kg for Cr, 0.8 – 2.3 mg/kg for Mn, 56.8 – 87.3 mg/kg for Fe, 0.2 – 0.6 mg/kg for Ni, 0.6 – 2.3 mg/kg for Cu, 16.8 – 31.6 mg/kg for Zn, 0.3 – 0.7 mg/kg for Pb, 88.2 – 160.6 µg/kg for V, 30.9 – 55.2 µg/kg for Co, 11.6 – 47.6 µg/kg for As, 7.2 -60.6 µg/kg for Cd and 4.9 – 35.2 µg/kg for U. The average trace metal concentrations of chicken samples are found to be below the permissible limit and are in comparison with the reported literature values from various parts of the world. Further, the estimated trace metal data were subjected to statistical analysis like correlation matrices to examine the interrelationship between the investigated trace elements and source identification of trace metal contamination in chicken samples. The daily intake of trace metals through the ingestion of chicken is also computed.

Keywords: Chicken, Trace metals, Uranium mining, ICP – MS, Correlation.

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1.INTRODUCTION

Chicken and chicken products are important for human diet in all over the world because they contribute to solve the global food problems and provide the well known proteins, essential minerals, vitamins, etc. (Alturiqi et al., 2012). There is a substantial increase of trace metals in chicken and chicken products, due to global environmental pollution, increased population, increased industrialization, etc. (Nisianakis et al., 2009). Contamination with trace metals is a serious threat because of their toxicity, bioaccumulation and biomagnifications in the food chain (Hala et al., 2009, Akan et al., 2010, Iwegbue et al., 2008). Trace metals can be classified as potentially toxic (arsenic, cadmium, lead, mercury, etc.), probably essential (nickel, vanadium and cobalt) and essential (iron, manganese, copper, zinc, selenium, etc.). Toxic metals can be very harmful even at low concentration when ingested over a long time period. The essential metals may also produce toxic effects when metal intake is excessively elevated (Uluozlu et al., 2009, Falandysz et al., 2007, Tuzen, 2003). Hence, knowledge on the mineral content of chicken is very important for many reasons that are related to human health and nutritional value of chicken.

The levels of trace elements in chicken have been widely reported in the literature (Alturiqi et al., 2012, Nisianakis et al., 2009, Hala et al., 2009, Akan et al., 2010, Iwegbue et al., 2008, Uluozlu et al., 2009, Falandysz et al., 2007, Tuzen, 2003). However, the data on the trace metals in chicken samples at the surroundings of mining industry in India are very limited. Therefore, the present study investigates the baseline survey on evaluation of Al, Cr, Mn, Fe, Ni, Cu, Zn, Pb, V, Co, As, Cd and U in chicken samples, which are collected in the surroundings of the Tummalapalle uranium mining site. The trace metals were determined using Inductively Coupled Plasma Mass Spectrometer (ICP – MS). The samples are subjected to open acid digestion before analysis. The estimated trace metal data were subjected to correlation analysis to examine the interrelationship between the investigated trace elements and source identification of trace metal contamination in chicken samples. Further, the daily intake of trace metals through the ingestion of chicken is calculated.

2. MATERIALS AND METHODS

2.1. Study Area

The study area, Tummalapalle uranium mine is located between latitudes 14°18'36” N & 14°20'20” N and longitudes 78°15'16” E & 78°18' 03.3” E as per India Toposheet Nos. 57 J/3 and 57 J/7.

2.2. Materials

All reagents used for the analysis were of analytical grade and Milli – Q water is used for all dilutions. Supra pure grade reagent (Merck, Germany) of nitric acid is used for the open digestion of samples. All the glass wares were cleaned by soaking in dilute nitric acid and were rinsed with distilled water prior to use.

2.3. Sample Collection

The survey area is divided into two parts of the sample collection based on the radial distance from the excavation site as 1) Core Zone – which is covering 10 km radial distance around the mining site and contains two sampling locations C1 and C2 and 2) Buffer Zone – which is spreading over the radial distance from 10 – 25 km around the mining site and contains two sampling locations B1 and B2. The chicken samples were collected in the field area and preserved in the refrigerator. The chicken samples were collected for every six months for two years. The geographical location map indicating with two zones of sampling locations is depicted in Fig. 1.

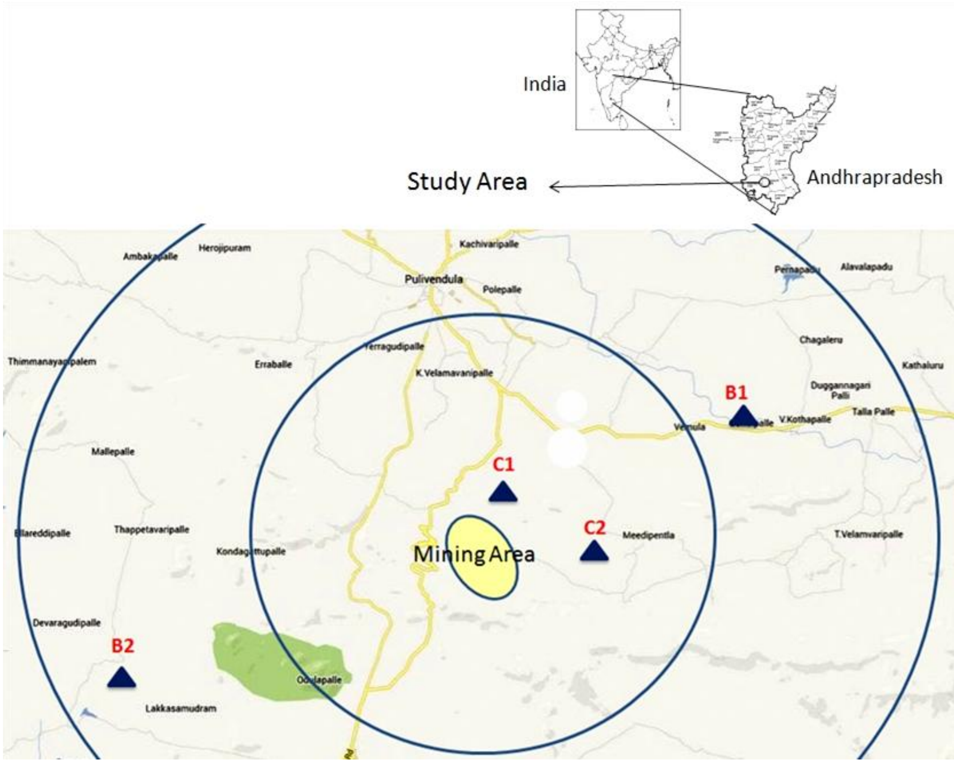

Figure 1: The geographical representation of different sampling location map

2.3. Sample Processing and Analysis

The chicken sample was washed with Milli – Q water and roughly one gram of the sample was weighed using 0.01 mg sensitive weighing balance and transferred to 100 ml glass beaker. To the weighed sample, 15 ml of supra pure HNO_3 and 3 ml of $HClO_4$ were added and covered with the watch glass (Suseela et al., 2001, Tripathi et al., 2002, Tripathi et al 1998). After one hour, the beaker was placed on a hot plate to raise its temperature up to 140^{o}C until the sample completely digested with reducing of its volume to 1 – 3 ml. The digested sample was cooled, diluted with 2 N supra pure HNO_3 and made up to 50 ml in a standard flask. The treated samples have been studied for the estimation of trace metals using Inductively Coupled Plasma Mass Spectrometer (ICP – MS), make Agilent Technologies (Model No. 7700). The instrumental conditions used for ICP – MS operation are given in Table 1.

Table 1: Operation conditions for the analysis of trace metals by ICP – MS

Parameter	Value
RF Power (W)	1500
RF Matching (V)	2.1
Sample Depth (mm)	6.8
Carrier gas flow rate (L/min)	0.7
Makeup gas flow rate (L/min)	0.57
Nebulizer pump rare (rps)	0.1
Data acquisition	Peak Hoping
Replicates	6

2.4. Quality Assurance

The quality assurance of the operation for the estimation of heavy metals in chicken samples by ICP – MS has been assessed by calibrating the instrument using multi element calibration standard 2A (Lot No. 28 – 68 JB) obtained from Agilent Technologies. The validity of the method was further ascertained by spike recovery and replicate analysis.

3. RESULTS AND DISCUSSION

All the trace metal concentrations are calculated on the fresh wet weight basis. The calculated trace metal content in chicken samples at all sampling locations in the environs of the mining site along with the reported literature values from various regions of the globe and the calculated intake of trace metals from the average consumption of 100 g chicken per day per person is summarized in Table 2. The obtained metal concentration in chicken is divided into two categories namely macro (Al, Cr, Mn, Fe, Ni, Cu, Zn and Pb) and micro (V, Co, As, Cd and U) concentration, based on concentration levels obtained.

3.1. Macro Concentration Metals

The estimated macro concentration metals in chicken samples were found in the range of 23.5 – 309.0 mg/kg for aluminium (Al), 1.9 – 3.9 mg/kg for chromium (Cr), 0.8 – 2.3 mg/kg for manganese (Mn), 56.8 – 87.4 mg/kg for iron (Fe), 0.2 – 0.6 mg/kg for nickel (Ni), 0.6 – 2.3 mg/kg for copper (Cu), 16.8 – 31.6 mg/kg for zinc (Zn), 0.3 – 0.7 mg/kg for lead (Pb). From the macro concentration metal data obtained, Al has the highest mean concentration obtained followed by Fe, Zn, Cr and Mn, whereas Ni and Pd has the lowest mean concentration. The obtained mean macro concentration of metals is found to be comparable to the reported literature values from various regions of the globe.

The average calculated intake of macro concentration metals based on consumption of an average of 100 g chicken per day were determined 8.32 mg/day for Al, 0.3 mg/day for Cr, 0.15 mg/day for Mn, 7.37 mg/day for Fe, 0.04 mg/day for Ni, 0.13 mg/day for Cu, 2.46 mg/day for Zn and 0.04 mg/day for lead. The maximum permissible intake of an adult is 60 mg per day for Al, 35 µg per day for Cr, 4.1 mg per day for Mn, 15 mg per day for Fe, 15 mg per day for Zn, 3 – 32 µg per day for Pb, 1 – 2.5 mg per day for Cu, 100 µg per day for Ni (Nordberg et al., 2005). Approximately 0.5 – 10 % of each macro concentration metal contributing dietary intake through 100 g consumption of chicken per day. The obtained macro concentrations of these metals in the chicken samples are below the permissible intake limits.

Table 2: Observed trace metal concentrations in chicken with study region and the reported literature values from around the world and the intake from consumption of an average of 100 g chicken/day

Sampling Time	Sampling Zone	Sampling Location	Al	Cr	Mn	Fe	Ni	Cu	Zn	Pb	V	Co	As	Cd	U
			mg/kg (Macro concentration elements)								µg/kg (Micro concentration elements)				
2010	Core Zone	C_1	60.0	3.1	1.2	73.6	0.4	1.5	26.7	0.3	93.7	41.3	12.8	7.2	9.8
		C_2	23.5	1.9	0.8	76.0	0.2	1.2	16.8	0.3	98.7	31.5	23.9	17.5	5.5
	Buffer Zone	B_1	90.4	2.7	1.3	82.6	0.4	2.3	19.1	0.3	99.4	52.7	11.8	13.6	4.9
		B_2	309.0	3.1	1.8	87.4	0.3	1.2	20.9	0.4	94.6	37.6	11.6	9.7	11.8
2011	Core Zone	C_1	28.4	3.0	1.2	56.8	0.3	0.8	31.6	0.4	88.2	30.9	40.3	19.6	7.1
		C_2	40.4	3.9	2.1	82.7	0.5	1.4	26.8	0.6	155.5	41.2	36.9	38.2	11.4
	Buffer Zone	B_1	53.9	3.3	2.3	63.1	0.6	1.6	31.4	0.7	160.5	55.2	47.6	60.6	11.5
		B_2	60.2	2.8	1.5	67.7	0.4	0.6	23.5	0.3	160.6	39.3	39.3	8.1	12.2
Minimum			23.5	1.9	0.8	56.8	0.2	0.6	16.8	0.3	88.2	30.9	11.6	7.2	4.9
Mean - Present study in India			83.2	3.0	1.5	73.7	0.4	1.3	24.6	0.4	118.9	41.2	28.0	21.8	9.3
Maximum			309.0	3.9	2.3	87.4	0.6	2.3	31.6	0.7	160.6	55.2	47.6	60.6	12.2
Intake of Trace metal from consumption of an average of 100 g chicken/day			8.32 mg	0.3 mg	0.15 mg	7.37 mg	0.04 mg	0.13 mg	2.46 mg	0.04 mg	11.89 µg	4.12 µg	2.8 µg	2.18 µg	0.93 µg
Literature Values from various parts of the world															
Turkey (mg/kg) (Uluozlu et al., 2009)			-	0.07	0.23	8.2	2.08	1.2	19.9	0.4	-	0.01	0.07	-	-
Bangladesh (mg/kg) (Nisianakis et al., 2009)			-	0.69	-	60.3	1.13	10.3	169	42	-	2.3	0.08	5.2	-
Soudi Arabia (mg/kg) (Alturiqi et al., 2012)			-		34.4	290	-	7.88	36.9	10	-	-	-	1.68	-
Egypt (mg/kg) Hala et al., 2009)			370	-	-	-	-	9.4	49	5	-	-	-	1.52	-
Nigeria (mg/kg) (Akan et al., 2010)			-	0.43	3.2	2.9	0.22	0.24		0.1	-	0.32	0.13	0.29	-
Southern Nigeria (mg/kg) (Iwegbue et al., 2008)			-	4.83	0.9	92.7	9.02	2.91	33.2	4.6	-	-	-	1.27	-

The graphical representation of mean macro concentration of evaluated metals is shown in Fig. 2.

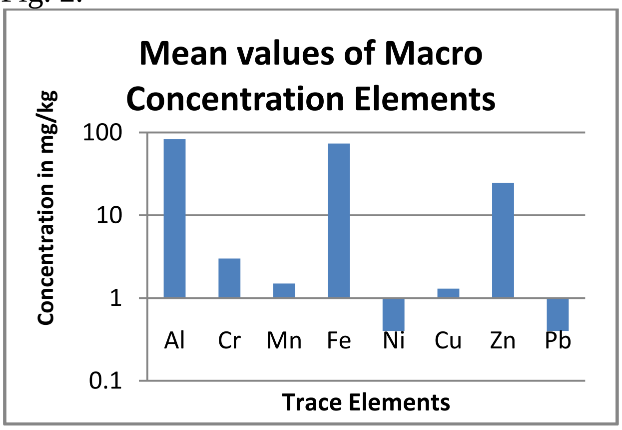

Figure 2: Graphical representation of mean macro concentration metals in chicken sample

3.2. Micro Concentration Metals

On the basis of the estimated concentration of metals in collected chicken samples, vanadium (V), cobalt (Co), arsenic (As), cadmium (Cd) and uranium (U) are categorized as micro concentration metals. Among these five metals, V and Co are probably essential metals whereas, As, Cd and U are toxic metals. The calculated micro concentration metals in chicken samples were found in the range of 88.2 – 160.6 µg/kg for V, 30.9 – 55.2 µg/kg for Co, 11.6 – 47.6 µg/kg for As, 7.2 – 60.6 µg/kg for Cd and 4.9 – 12.2 µg/kg for U. According to obtained mean micro concentration metal data, V is primarily noticed with high concentration followed by Co, As, Cd and U.

The evaluated micro concentration metals are showing good comparison with reported literature from various regions of the world (Table 2) which are within the bounds.
The uptake of micro concentration metals is calculated based on consumption of an average of 100g chicken per day per person. The intake of micro concentration metals is found to 11.89 µg/day for V, 4.12 µg/day for Co, 2.8 µg/day for As, 2.18 µg/day for Cd and 0.93 µg/day for U. The allowable limit and dietary intake range of various metals V: 6 – 30 µg/day; Co: 5 – 50 µg/day; Cd: 10 – 60 µg/day; As: 0.07 – 0.37 mg/day and for us: 0.9 - 1.5 µg/day (Nordberg et al., 2005). Approximately 5 – 30 % of these micro concentration levels are contributing dietary intake through the consumption of an average of 100 g chicken per day per person. The reported literature values from various parts of the globe are in the range of 0.01 – 2.3 mg/kg for Co, 0.07 – 0.13 mg/kg for As and 0.29 – 5.2 mg/kg for Cd.1-6 The main sources of obtaining higher levels of these micro concentration metals are feeding behavior of hens, anthropogenic activities, environmental pollution etc. The graphical representation of mean micro concentration metals is shown in Fig. 3.

3.3. Interrelation between the trace metals - Correlation Analysis

A linear regression correlation test was performed to investigate the interrelation

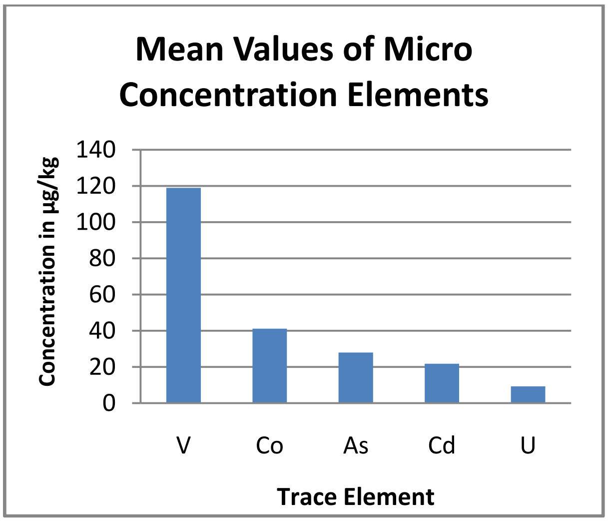

Figure 3: Graphical representation of mean micro concentration metals in chicken sample

between all the investigated trace metals and to determine the likely sources of contamination of the chicken samples. The values of the correlation coefficients between metal concentrations are given in Table 3. The trace metals Cr, Mn, Ni are showing a strong correlation with all the investigated trace metals (Table 3). This correlation indicates that, the sources of these metals have a common ancestry. Poor and negative correlation indicates that multisource origin. The transfer of metals in chicken samples is likely to be takes place in the sequential order of Soil → Local Feed → Hen.

Table 3: Correlation between the metal concentrations of chicken samples

	Al	*Cr*	*Mn*	*Fe*	*Ni*	*Cu*	*Zn*	*Pb*	*V*	*Co*	*As*	*Cd*	*U*
Al	1.0												
Cr	0.1	1.0											
Mn	0.2	**0.8**	1.0										
Fe	**0.6**	0.1	0.1	1.0									
Ni	-0.2	**0.7**	**0.8**	-0.1	1.0								
Cu	0.0	0.1	0.1	**0.5**	0.3	1.0							
Zn	-0.3	**0.7**	**0.5**	-0.7	**0.6**	-0.2	1.0						
Pb	-0.1	**0.7**	**0.9**	-0.2	**0.7**	0.1	**0.6**	1.0					
V	-0.3	**0.5**	**0.7**	-0.2	**0.7**	-0.1	0.3	**0.6**	1.0				
Co	0.0	0.3	**0.6**	0.1	**0.8**	0.7	0.2	0.4	0.4	1.0			
As	-0.5	0.3	0.4	-0.7	**0.5**	-0.5	**0.7**	0.6	**0.7**	0.0	1.0		
Cd	-0.3	**0.5**	**0.7**	-0.3	**0.7**	0.2	**0.6**	**0.9**	**0.6**	**0.5**	**0.7**	1.0	
U	0.3	**0.7**	**0.7**	0.0	**0.5**	-0.4	0.4	**0.5**	**0.6**	0.1	0.3	0.3	1.0

4. CONCLUSION

The present investigation is primarily focused on the baseline evaluation of various trace metals including essential and non-essential metals in chicken samples collected from the various locations around the Tummalapalle uranium mining site. The obtained trace metal concentrations in the present study in chicken samples were found to be acceptable and are within the permissible bounds of human consumption in respect of nutritional and toxic levels as compared with the literature data reported from various regions of the globe. According to interrelation study of trace metals, the elements Cr, Mn and Ni have a common source of ancestry.

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