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DIETARY EXPOSURE ASSESSMENT OF LEAD AND CADMIUM IN RURAL POPULATION OF ANDHRA PRADESH – INDIA - A TOTAL DIET STUDY APPROACH

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ABSTRACT

Human exposure to toxic elements and nutritional imbalances are known to result in adverse health effects. Estimation of food intakes is necessary for risk evaluation and possibly to determine adverse effects observed in humans and exposure to particular substances. Total Diet study (TDS) is an approach for exposure assessments which is useful for decision making on the regulation of nutritional or chemical products and the safety of food products. Dietary exposures of rural population of Andhra Pradesh to toxic heavy metals, lead and cadmium, were determined in the first Andhra Pradesh Total Diet Studies. Food samples were collected from 12 different procurement points from 6 districts of the state and processed as *table ready* for analyses. The intakes were estimated at mean and ninety fifth percentile consumption levels, for various physiological groups, and were compared against the toxicological reference values (PTWI, Provisional Tolerable Weekly Intakes). The concentrations of lead and cadmium in all the tested foods were below their respective maximum residue limits and also the exposures at all the physiological groups, for both the genders, were lesser than the toxicological reference values. But, in age groups 1-3 years the exposure was observed to be higher due to either high intake of a moderately contaminated or low intake of a highly contaminated food. The exposures were higher in this age group also due to higher intakes to body weight ratios. The study suggests low probability of health risk due to dietary exposure to lead and cadmium.

Key words: Dietary exposure, food consumption, total diet studies, lead, cadmium, PTWIs

INTRODUCTION

Diet is a source of nutrients as well as toxicants. Heavy metals are the major contaminants in our food supply and hence are one of the most important problems in our environment (Anastassiade and Lehotey, 2003). They have potential to accumulate in the body organs leading to several adverse health effects like the nutritional imbalances (Zaidi, et al., 2005; Jarup, 2003). Estimation of food intakes is necessary for risk evaluation and possibly to determine adverse effects observed in humans and exposure to particular substances (Leblanc et al., 2005).

Total Diet study (TDS) is an approach for exposure assessments which is useful for decision making on the regulation of nutritional or chemical products and the safety of food products. TDS is used by many countries to address the issue. TDS is used to analyze a variety of chemical compounds in foods prepared for consumption (INCHEM, 1993). Therefore, TDS yields more refined exposure data in the foods that are analyzed as they are *"table ready* "or *"as consumed"* (INCHEM, 1996). TDS also reveals which age/physiological group is at a higher exposure and what foods are contributing to the exposure, thus screening the vulnerable groups. TDS also provides evidence for the national and international authorities for policy and regulation making to alleviate the exposures through various means. As a result of the TDS estimations, the relative safety of food supply can be assessed and steps can be taken to improve food quality (INCHEM, 1993).

Lead and cadmium are among the most abundant heavy metals and are particularly toxic. They are reported to cause several cardiovascular, kidneys, nervous and bone diseases (Kawatra and Bakhetia, 2008; INCHEM, 1993). In India, intake of lead by women in sewage irrigated area was almost twice the amount compared to women from tube well irrigated area in Punjab (INCHEM, 1996). The fish and crab samples from the Gulf of Cambay, India were also reported to be contaminated by lead and cadmium due to rigorous anthropogenic activities (Kawatra and Bakhetia, 2008). Toxic metals like lead and cadmium were also detected in the vegetables (okra, spinach and beet) sold in Delhi markets. The main reason for the contamination was found out to be growing of these vegetables by the farmers, in contaminated soils (Reddy et al., 2007).

All the above studies in India were carried out for the concentrations in raw foods, where the loss due to processing was not taken care of. Therefore, a total diet study was conducted to assess the dietary exposure of lead and cadmium to various age and sex groups in the rural population of Andhra Pradesh, a South Indian state.

MATERIAL AND METHODS

Several steps were involved in designing of the study. Selection of the foods to be analyzed followed by procurement of these food samples from various representative points, transportation of the samples to the laboratory so as to process the foods and appropriate storage for the analyzing the toxic metals using a standard and validated method to determine their concentrations in various foods and their exposures to various physiological groups. The final step was to compare the exposures with the toxicological reference values and to check whether they are within the safe limits.

SCREENING OF STUDY FOODS

The foods which were most commonly consumed in the state of Andhra Pradesh were listed in the order of consumption. The consumption data was obtained from National Nutrition Monitoring Bureau (NNMB). NNMB has been conducting surveys in rural areas of ten Indian states since 1975 (Marshall et al., 2003). The amounts of consumption of various foods were obtained from the NNMB consumption data and among those, the 22 most commonly consumed foods were selected from various food groups along with drinking water samples. Water samples were collected to estimate the exposure through water which is drunk and also added for the cooking of various foods. All the twenty two foods and water samples were analyzed for the presence of lead and cadmium. Table.1 presents the consumption data of the key foods used for calculation of exposure to toxic metals.

SAMPLE COLLECTION

Sample collection was done from September 2008 to May 2009. Multistage random sampling was designed to collect the samples from two blocks (*mandals*) from each of the six districts of three regions of Andhra Pradesh. Each food item was collected from two markets of each block to include more variation. The final number of samples for each food was 24 (12 procurement points *x* 2 varieties).

The information about growing area of the foods, local or imported from other places, their transportation and storage conditions were obtained from the vendors through a questionnaire. The items which were not found in the select procurement points were collected from the next nearest market place. The samples procured were immediately transferred to the laboratory in the respective required condition. Different media of collection were used for different foods. Non perishable and semi perishable items like rice, red gram dhal, and potatoes were packed in sterile polyethylene zip-lock pouches and transported at ambient temperature. Perishable foods like milk and buttermilk were also packed in sterile pouches but transported under frozen condition in ice boxes and water as collected in sterile glass containers and kept in ice box. Leafy vegetables like spinach and amaranth were wrapped in sterile and wet jute mats as they became damp in vacuum zip lock packing.

PROCESSING OF FOOD SAMPLES

Individual foods were subjected to basic household cooking using de-ionized water and the foods were prepared as "*table ready*" without salt, oil and spices according to the Standard Operating Procedures (SOPs) for validating the time, temperature and processing of individual foods in the laboratory conditions. Stainless steel vessels, lids, ladles, knives and PTFE chopping boards were used for processing the food samples to avoid contamination with the test analytes. Detergents or powdered cleansers, talcum powder coated gloves were not used to avoid contamination. The chopping boards, knives and other utensils were thoroughly washed with hot water between uses to avoid cross contamination. Water used for washing was analyzed and showed no initial lead or cadmium contamination. The cooking methods for the select foods are given in Table 2. The cooked foods were cooled, weighed, homogenized and bottled in sterile 100mL PTFE wide mouthed containers. The homogenized samples were stored at -20° C until chemical analysis. Water samples were analyzed as they were collected.

ANALYSES OF THE SAMPLES

Moisture content of all the foods was determined by gravimetric method in the raw form to express the values as dry weight basis (NNMB, 2000). The estimation of lead and cadmium were done by Atomic Absorption Spectrometry (SOLAAR-Thermo, GFS 97-Graphite Furnace) using Graphite furnace by using CRM.

RESULTS

CONCENTRATIONS OF LEAD AND CADMIUM IN FOODS

Among the four priority toxic metals usually analyzed in TDS namely, lead, cadmium, arsenic and mercury, only lead and cadmium were analyzed in the present study. High risk foods for arsenic and mercury were not reported to be present in the selected most commonly consumed foods. The mean concentration of lead and cadmium in the foods is given in Table 3.

All the concentrations of lead and cadmium in all the foods were lesser than the respective MRLs (Maximum Residue Limits) given by Food Safety and Standards Authority (FSSAI) of India (AOAC, 1995). Among all the foods, sorghum was found to have the highest mean concentration (73.71µg/kg) of lead followed by rice (54.44µg/kg). The maximum lead concentration was

Table I. **Mean and 95th percentile intakes of various foods (g) in different age and physiological groups in Andhra Pradesh**

Age Groups / Foods	2-4 yrs		4-6 yrs		7-9 yrs		10-12 yrs		13-15 yrs		16-17 yrs		Sedentary Worker		Pregnant Women	
	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th
Cereals	172	345	243	455	279	540	347	565 (B) 589 (G)	440	745 (B) 543 (G)	510	836(B) 644 (G)	426	689(M) 600 (F)	401	659
Pulses	12	37	18	55	22	75	22	75 (B) 71(G)	23	68 (B) 70(G)	37	123 (B) 95 (G)	32	92 (M) 86 (F)	14	97
Spinach and Amaranth	1	5	3	25	4	27	6	45 (B) 29 (G)	9	68(B) 28(G)	7	39 (B) 40 (G)	7	40 (M) 32 (F)	14	93
Tomato and Brinjal	11	47	19	88	22	99	27	116 (B) 114 (G)	30	101 (B) 114 (G)	48	159(B) 119 (G)	41	161(M) 142 (F)	47	125
Potato	12	50	17	69	21	78	24	76 (B) 88 (G)	30	97(B) 61(G)	44	182 (B) 91 (G)	39	146(M) 111 (F)	33	161
Fruits	33	166	34	194	39	207	47	186 (B) 235(G)	38	161 (B) 254 (G)	45	186 (B) 175 (G)	44	173(M) 205 (F)	58	260
Milk and Buttermilk	81	298	77	255	78	356	82	364 (B) 274 (G)	71	210 (B) 263 (G)	106	284 (B) 308 (G)	139	388(M) 392 (F)	141	652
Fish	2	14	2	8	2	6	1	1 (B) 7 (G)	6	48 (B) 5 (G)	5	40 (B) 14 (G)	6	48(M) 42(F)	6	85
Other flesh foods	4	38	7	44	9	44	12	90 (B) 66 (G)	16	89 (B) 75 (G)	23	137 (B) 51 (G)	14	89 (M) 86 (F)	31	265
Sugar	8	26	8	25	6	19	7	20 (B) 21 (G)	6	21 (B) 24 (G)	9	30 (B) 19 (G)	10	28 (M) 34 (F)	9	42
Spices	5	16	8	19	11	24	14	39 (B) 31 (G)	16	35 (B) 36 (G)	19	42 (B) 46 (G)	17	40 (M) 39 (F)	18	58
Cooking Oil	7	19	9	22	12	27	13	30 (B) 31(G)	14	29 (B) 34 (G)	23	57 (B) 36 (G)	20	52 (M) 43 (F)	14	34

yrs, years; B, boys; G, girls; M, male; F, Female; 95^{th}, 95^{th} percentile intake level.

Table 2- Methods adopted for processing of the foods

S. No	Food	Method of Preparation
1.	Rice, raw, milled	Boiled in distilled water, cooled and homogenized
2.	Sorghum	Made into a dough, rolled and roasted on pan, cooled and homogenized
3.	Red gram dhal	Boiled in distilled water, cooled and homogenized
4.	Tomato	Washed with distilled water, chopped and boiled in water, cooled and homogenized
5.	Brinjal (Aubergine)	Washed with distilled water, sliced and boiled in water, cooled and homogenized
6.	Potato	Washed with distilled water, boiled in distilled water and peeled off the skin, cooled and homogenized
7.	Onion	Peeled off, washed with distilled water, cut into cubes and boiled, cooled and homogenized
8.	Amaranth	Washed with distilled water dried overnight, chopped and boiled, cooled and homogenized
9.	Spinach	Washed with distilled water dried overnight, chopped and boiled, cooled and homogenized
10.	Mango	Washed with distilled water, peeled, sliced and homogenized
11.	Banana	Peeled and homogenized
12.	Buffalo milk	Boiled and analyzed
13.	Butter milk	Analyzed as it was
14.	Fish	Scraped off the fins, washed with distilled water, boiled in distilled water, spines removed and homogenized
15.	Other flesh foods (Fowl and Goat meat)	Washed in distilled water, boiled in distilled water, cooled and homogenized
16.	Eggs (hen)	Boiled with shell, removed the shell, cooled and homogenized
17.	Groundnut oil	Analyzed as it was
18.	Red chili powder	Analyzed as it was
19.	Sugar	Ground into a powder form and stored
20.	Tamarind	Deseeded, boiled, strained to a pulp, cooled and stored
21.	Water	Analyzed as it was

Table 3- Mean concentration (µg/kg) of lead and cadmium in cooked foods

Foods	n	Lead Mean (SD)	Cadmium Mean (SD)
Rice	24	55.4 (45.80)	0.2 (0.49)
Sorghum	21	73.7 (81.13)	0.06 (0.20)
Red gram dhal	24	1.4 (5.29)	0.05 (0.17)
Tomato	24	1.1 (2.01)	0.6 (0.97)
Brinjal (Aubergine)	24	0.5 (1.32)	0.5 (1.00)
Spinach	20	27.7 (53.30)	4.1 (5.96)
Amaranth	22	27.2 (24.41)	10.1 (13.89)
Onion	24	4.4 (5.70)	0.2 (0.33)
Potato	24	3.9 (6.31)	2.5 (3.45)
Milk	24	11.2 (15.23)	0.01 (0.04)
Buttermilk	22	17.4 (25.89)	0.03 (0.11)
Banana	24	13.8 (14.44)	BDL
Eggs (Hen's)	24	1.5 (4.71)	BDL
Goat meat	22	0.2 (0.79)	0.01 (0.06)
Fowl meat	24	0.3 (1.22)	3.3 (14.15)
Fish (Catla catla)	09	5.5 (14.59)	BDL
Cane sugar	24	40.5 (68.24)	0.1 (0.27)
Groundnut oil	24	8.4 (22.76)	BDL

Tamarind	24	30.1 (44.54)	BDL
Red chili powder	23	10.4 (24.21)	4.7 (12.16)
Water	24	0.2 (0.55)	0.1 (0.36)

µg/Kg: micrograms per kilogram of fresh weight; n, number of samples tested; BDL- Below Detection Limit

detected in one sample of cane sugar (290.3 µg/kg) procured from *Gangadhara* mandal (block) of Kareemnagar district, followed by a sample of sorghum (264 µg/kg) from *Banaganapalli* mandal of Kurnool district. Lead concentrations in more than 80% samples of red gram dhal, eggs, chicken, mutton, groundnut oil, red chili powder and water were below detectable levels, while, more than 70% of the samples of rice, sorghum, amaranth and banana were detected with lead. All the mango samples except one were detected with lead, the concentration ranging from 0.1-26.8 µg/kg.

The highest mean concentration of cadmium was detected in amaranth (10µg/kg) followed by red chilies (4.6 µg/kg). Cadmium was detected in more than 80% of spinach, amaranth, and potato samples. The chicken samples (69.4µg/kg) and red chilies (58.8µg/kg) procured from East Godavari and Dakkili, respectively, showed highest concentrations of cadmium.

DIETARY EXPOSURE ASSESSMENT

Dietary exposure to a specific contaminant is dependent on the quantity of food consumed, which varies with age and the concentration of the contaminant in that food and in water used to cook that food at household levels. Dietary intakes were calculated by multiplying the concentration of the metal in unit amount of a food by the amount eaten by the age group subjects. This concentration was then added up with the concentration of metals in the water (if any) needed to cooked that amount of food. Exposures were calculated per kg body weight for a week and compared against the reference toxicological values (PTWIs).

The age and physiological groups considered exposure assessment were 1-3 years, 4-6 years, 7-9 years, 10-12 years (boys and girls), 13-15 years (boys and girls), 16-17 years (boys and girls), sedentary worker (Male and female) and pregnant women (PW). The exposure estimates were calculated both at mean (pooled for both the genders) and at *"upper bound"* i.e. at 95th percentile (both genders) intakes levels.

Dietary intakes of both the metals were below their respective provisional tolerable weekly intakes (PTWIs) Tables 4 and 5. The exposures did not exceed the PTWIs for both the metals all the age and physiological groups at both mean and 95th percentile intakes. However, the exposures to lead at mean intake levels were highest in 1-3years (30.81% of PTWI) and lowest in sedentary worker (14.86% of PTWI) and at 95th percentile intake levels, they were found to be highest in 1-3yrs (76.44% of PTWI) and lowest in 16-17 years(girls) and sedentary workers (female).

The exposures for cadmium also were highest in 4-6years (0.99% of PTWI) but lowest in sedentary workers (0.65% of PTWI) at mean intake levels, while the exposures at 95th percentile intake levels ranged from a lowest of 0.25% of PTWI (13-15 years girls) to a highest of 0.57% of PTWI (4-6 years). Overall, exposures to cadmium were much lesser than exposures to lead mainly due to less concentration of cadmium than lead in foods.

Table 4- Dietary exposures (µg/Kg bw/day) at mean intake levels

Age group	Lead			Cadmium		
	Exposure µg/Kgbw/d	Exposure µg/Kgbw/wk	%PTWI	Exposure µg/Kgbw/d	Exposure µg/Kgbw/wk	%PTWI
1-3yrs	1.10	7.70	30.81	0.01	0.07	0.97
4-6yrs	0.95	6.62	26.50	0.01	0.07	0.99
7-9years	0.76	5.34	21.37	0.01	0.06	0.87
10-12yrs	0.70	4.89	19.56	0.01	0.06	0.84
13-15yrs	0.63	4.38	17.51	0.01	0.05	0.78
16-17yrs	0.63	4.42	17.69	0.01	0.05	0.77
Sedentary Worker	0.53	3.72	14.86	0.01	0.05	0.65
Pregnant Women	0.59	4.15	16.60	0.01	0.06	0.91

µg/Kg bw/day, micrograms per kilogram body weight; PTWI, Provisional Tolerable Weekly Intake; yrs, years

Table 5- Dietary exposures (µg/Kg bw/day) at 95th percentile intake levels

Age groups	Lead			Cadmium		
	Exposure µg/Kgbw/d	Exposure µg/Kgbw/wk	%PTWI	Exposure µg/Kgbw/d	Exposure µg/Kgbw/wk	%PTWI
1-3years	2.730	19.11	76.44	0.029	0.20	0.42
4-6yrs	2.110	14.77	59.08	0.030	0.21	0.57
7-9y	1.920	13.44	53.76	0.031	0.22	0.45
10-12y B	1.560	10.92	43.68	0.032	0.22	0.45
10-12G	1.490	10.43	41.72	0.026	0.18	0.37
13-15y B	1.290	9.03	36.12	0.031	0.22	0.45
13-15y G	1.080	7.56	30.24	0.017	0.12	0.25
16-17yB	1.260	8.82	35.28	0.024	0.17	0.35
16-17G	1.016	7.11	28.45	0.019	0.13	0.27
SW M	1.040	7.28	29.12	0.022	0.15	0.31
SW F	1.020	7.14	28.56	0.019	0.13	0.27
PW	1.170	8.19	32.76	0.033	0.23	0.47

µg/Kg bw/d, micrograms per kilogram body weight per day; µg/Kg bw/wk, micrograms per kilogram body weight per week; PTWI, Provisional Tolerable Weekly Intake; yrs, years

DISCUSSION

The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) are in the forefront of the development of risk-based approaches for the management of public health hazards in food (FSI, 2011).Total diet studies are recommended internationally as the most effective method for national exposure assessments (WHO, 2012). Such studies are very much needed in the developing countries where a persistent presence of some contaminants is encountered, even after imposed bans. This further affects a great number of people as usually these countries inhabit a large population.

FDA total diet studies have analyzed many macro and trace elements namely, arsenic, cadmium, calcium, copper, iron, lead, magnesium, mercury, nickel, phosphorus, potassium, selenium, sodium and zinc (GEMS/Food, 2010). However, lead and cadmium are considered to be the most toxic and abundant of all the existing heavy metals and excessive content of these meals in foods have associations with the etiology of several disease as CVDs and kidney and nervous system diseases.

The Total Diet Study in Andhra Pradesh (APTDS) is first of its kind to have been conducted in India where, a total of 503 food and water samples were analyzed for lead and cadmium. The source of lead in foods could be due to presence of lead in water and soil or use of lead based solders as in canned foods. Lead in foods may also be derived from the environment in which the food is grown (air pollution from nearby industrial sources) or from preparation of foods with lead-contaminated water and/or utensils. The major route of exposure to cadmium for the non-smoking population is via food, due to contamination of soil and water. Cadmium is also absorbed from water and soil. There are no regulatory limits, i.e. tolerances for toxic elements in foods. FDA has established Provisional Daily Tolerable Intakes (PDTI) for lead for some risk groups (FDA, 2001). When consumption of a contaminated food has exceeded PTDI, regulatory action may be taken on an ad-hoc basis. The total diet surveys indicate the average lead intakes from food have decreased more than 95% since the 1970.

Among the 8 physiological groups, children of 1-3 years and 4-6 years were at highest exposures both for lead and cadmium, respectively, at both the levels of food consumption. These high exposures to 1-3 years and 4-6 years old may be attributed to consumption of rice, milk and sorghum. The per day exposures were higher for 4-6 year olds but when calculated per kg body weight, exposures were higher for 1-3 years old due to higher food intake to body weight ratio.

CONCENTRATIONS OF LEAD IN FOODS AND DIETARY EXPOSURE

Lead was detected in all the analyzed food and water samples, though at higher levels in cereals (sorghum and rice), milk, red gram dhal, red chili powder and sugar unlike fruits and green vegetables as in Egyptian population (Carrington et al., 1992) and in cereals, non alcoholic beverages, and sugars in French foods (Dabeka and Mckenzie, 1992). However, the levels were not analyzed in beverages other than water in the present study. Lead concentration was lesser in fish and other flesh foods, tomatoes, mangoes, and potatoes. Higher contamination of rice with lead and its high consumption among the population of Andhra Pradesh contributed to the overall high exposure to lead due to rice. The case was similar for milk and buttermilk. However, exposures due to red gram dhal, amaranth, red chilies were more due to high concentrations than amounts of consumptions.

The exposures were highest for children of age 1-3 years and lowest for sedentary workers at mean consumption levels. These values are lesser than the highest for UK population (0.47µg/kgbw/day) where the highest exposure was in the age group of 1-4yrs similar to our study but the lowest exposure levels were observed in people >65yrs (Radwan and Salama, 2006). In the first French Total Diet Study (Dabeka and Mckenzie, 1992) the lead levels were 18µg for adults and 13µg for children with cereals, vegetables, fruits and water contributing the most.

CONCENTRATIONS OF CADMIUM IN FOODS AND DIETARY EXPOSURE

Cadmium levels in foods like eggs, fish, bananas, groundnut oil and tamarind were below detection limits (BDL). Green leafy vegetables (amaranth) showed highest mean cadmium levels (10 µg /kg) as compared to other foods that were analyzed. Green leafy vegetables were followed by red chilies which showed levels of (4.6 µg /kg). Similar results were reported in Egyptian Total Diet Study (Carrington et al., 1992**,** whereas, in UK (Radwan and Salama, 2006), highest concentration was found in offal (0.084µg/kg), followed by nuts (0.065µg/kg) and in France TDS, it was highest in offal and shellfish baskets (Dabeka and Mckenzie, 1992). It was found in French TDS that the average daily intake of cadmium in adults aged above 15 years was 2.7 µg and 2µg for children aged 3-15 years, with leafy vegetables and starchy foods contributing the most.

In Andhra Pradesh TDS, more than 80% of spinach, amaranth, and potato samples were found to be detected with cadmium. The reasons for high levels of cadmium in some of the chicken samples need further investigation.

The highest exposure to cadmium at mean consumption levels was observed in the children of age 1-3 years (0.14% PTWI) similar to the UK population, where highest exposure is seen in age group 1-4 yrs and lowest in people aged above 65 years. A Canadian study showed that the average daily intake is higher than Andhra Pradesh population, being 0.21µg of cadmium/Kg bw/day (Ysart et al., 1999). Rice was the highest contributor for cadmium in the diet in our study. The exposures to cadmium were high due to rice, amaranth, potato and red chili. The high exposures due to rice was more because of high amounts of consumption rather than high contamination while exposures due to amaranth, red chili and potatoes were more due to high contamination. The trend was similar in all the physiological groups.

Cereals were the maximum contributor for toxic metal exposure among all the food groups. Earlier, studies in India have shown the high concentrations of lead (5ppm) and cadmium (0.2ppm) in spinach samples from Delhi (Reddy et al., 2007) and Bangalore (Rawn et al., 2004). The high levels reported in the study could be attributed to the highly contaminated water grown in polluted water. A study conducted in the suburban areas of Varanasi (Reddy et al., 2007; Lokeshwari and Chandrappa, 2003) showed that cadmium and lead, in spinach, exceeded the safe limits, cadmium being high in summer season and lead being high in both summer and winter seasons.

To conclude, the results of this study revealed that estimates of daily dietary exposures to lead and cadmium investigated are lower than violative levels in all age groups. Certain age groups showed higher levels of intakes of lead although well within violative levels. At upper bound food consumption levels in certain physiological groups the exposure to lead was higher suggesting the need to monitor the levels in the foods.

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