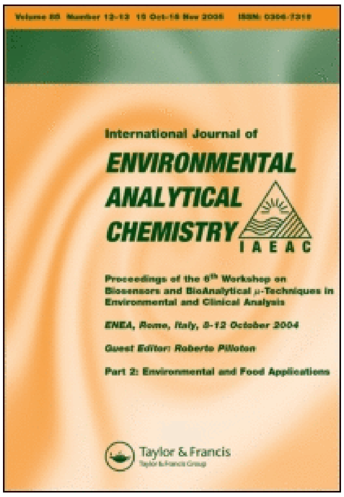

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DETERMINATION OF TRACE ELEMENTS IN INTEGRATED HUMAN DIET FOR DIETARY ASSESSMENT

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Neutron activation analysis in combination with atomic absorption spectrometry was utilized for the determination of 21 elements in integrated diet samples of the inhabitants of the Rawalpindi/Islamabad area. The study was carried out to determine prevailing concentration levels of trace elements nutrition, inadequacy, imbalances and toxicity. This data will serve as baseline values and will be helpful to monitor the degree of future contamination from foreign chemicals. The dietary intake values were also estimated and compared with the reported daily intake values. In general, the diets studied are adequate source of nutrient elements. The toxic elements intake through all the diet samples are within the safety limits.

KEY WORDS: Trace elements, essential elements, toxic elements, nutrition, food, human diet, NAA, AAS.

INTRODUCTION

Uncontrolled release of toxic chemicals from various activities of man may contaminate human food chain resources with toxic metals.[1,2] These metals ultimately find their way through foods to various human organs and body fluids where the presence of such elements even at very low levels is untolerable and toxic to the biosystem.[3] Besides, food is also a principal source for the supply of essential inorganic elements. These elements, although they constitute a small fraction of whole diet, play an important role in various metabolic processes and their deficiency or excess may disturb normal biochemical functions of the body.[4] In view of these considerations, it is necessary to measure trace elements in integrated foods to assess the adequacy and safety of human diet. Recently,[6] mixed human diet of Finland was analysed for minor and trace elements under the International Atomic Energy Agency (IAEA) intercomparison programme.[5] Currently, an IAEA co-ordinated research study[6] is underway to determine the levels of nutrients and other trace elements in total diets of USA, Canada, Sweden, Spain, Italy, Turkey, Iran, China, Thailand and Sudan. The present study was initiated to measure the prevailing concentration levels of toxic and essential elements in the integrated diets of the residents of the Rawalpindi/Islamabad area to obtain reliable information on the average daily intake of trace elements and to compare the dietary patterns of different sections of the population.

Trace elements in food articles are present in very small amount and their measurement requires reliable and sensitive analytical techniques. In recent years, a number of papers have been published on the determination of trace elements in such samples employing various analytical techniques.[7–18] Of these, neutron activation analysis (NAA) has been utilized in our studies as it requires a minimum of sample handling prior to irradiation, thus minimizing the risk of contamination. Furthermore, the technique provides maximum information under one experimental condition. However, the technique under normal mode is not suited to certain elements, e.g., Pb, Ni and Cd. Therefore, atomic absorption spectrometry (AAS) was employed for the investigation of these elements.

EXPERIMENTAL

Sampling and Sample Preparation

The basic food items daily consumed by the residents of Rawalpindi/Islamabad are wheat, rice, pulses, vegetables, fruits, meat, poultry and dairy products. Since in this region summer and winter seasons persist for 3–4 months, a large number of such food items were collected during these periods, to prepare representative diets of the population. The inhabitants of the city were grouped into three categories, A, B and C, according to their monthly income and food habits, and their weekly requirements of the edibles for both seasons are listed in Tables 1A and B. Meat, fruits and vegetables were washed with water and meat was oven-dried at 60 °C, while fruits and vegetables were freeze-dried for 48 h. The dried samples were pulverised in a grinder with PTFE-coated blades to avoid contamination by Ni and Cr. Fine powdered samples were shaken in a vibrating mill with three-dimensional motion for 72 h in pre-cleaned plastic bottles to minimize inhomogeneity. Four aliquots, each of 250 mg, of the samples were randomly selected and analysed for manganese content. The results indicate a 5–7% variation around the mean value and the samples were considered to be homogeneous. To avoid the chances of decomposition, all samples stored in the bottles were always placed in a deep-freezer when not in use. The average moisture content of food items is given in Tables 2A and 2B.

Preparation of Standard

A multi-element comparison base standard for NAA analysis was prepared by accurately weighing out and mixing together appropriate amounts of spec-pure elements. The mixture was dissolved in aqua regia and diluted with water. The clear solution was transferred to a pre-cleaned 100 ml flask and volume was made up with doubly distilled deionized water. An aliquot of 100 μl was dried on filter paper and subsequently used as primary standard. For AAS determinations, stock solutions of Cu, Ni, Pb and Cd (1000 mg/l) were prepared by dissolving the appropriate amount of spec-pure metal oxides in purified nitric acid and diluting to the required volume with deionized distilled water. Fresh working standards for

Table 1A Average food intake for the summer season (gm/person/week)

Food commodities		*Group*[a]		
Common name	*Botanical name*	*A*	*B*	*C*
Wheat	Triticum vulgare	2400	1600	1000
Rice	Oryza sativa	150	350	400
Pulses				
Moong (Green gram)	Phaseolus mungo	100	80	35
Masoor (Split Lentils)	Lens esculenta	100	50	—
Refined Sugar	—	175	175	250
Vegetables		800	300	200
Okra	Hibiscus esculentus			
Brinjal	Solanum melongena			
Potato	Solanum tuberosum			
Onion	Allium cipa			
Tomato	Lycopersicum esculentum			
Gourd	Cucurbita pepo			
Citrulus vulgaris	—			
Fruits				
Mango	Mangifera indica			
Apple	Pyrus malus	70	140	350
Grapes	Vitis vinifera			
Meat				
Beef	—	175	400	350
Mutton	—	—	105	600
Chicken	—	—	275	550
Egg	—	28	250	450
Powder milk	—	700	1050	1550
Fats and oils	—	210	300	480
Spices	—	49	69	30

[a]A: Low income group; B: Middle income group; C: High income group.

calibration purposes were always prepared by serial dilution of the stock solutions before use.

Irradiation and Radioassay

A 5 MW swimming-pool-type research reactor (PARR-I) fueled with 90–93% enriched uranium alloy was used for the irradiation of the samples at a flux of $2 \times 10^{13}\,n \cdot cm^{-1} \cdot sec^{-1}$.

About 250 mg of integrated diet, in triplicate, and the synthetic standard were encapsulated separately in pre-cleaned polyethylene capsules and irradiated for 2 min in the pneumatic rabbit tube facility of PARR. For longer irradiations, the samples were sealed in pre-cleaned silica vials and were packed together in an aluminium container, cold welded and irradiated in the periphery of the reactor core.

Following the appropriate cooling conditions, the samples were transferred to pre-weighed polyethylene capsules and reweighed. The gamma-ray spectrometry of the samples was performed for varying times ranging from 200 sec to 16 h. The

Table 1B Average food intake for the winter season (gm/person/week)

Food commodities		*Group*[a]		
Common name	*Botanical name*	*A*	*B*	*C*
Wheat	Triticum vulgare	2400	1600	1000
Rice	Oryza sativa	150	350	400
Pulses				
Moong (green gram)	Phaseolus mungo	100	80	35
Masoor (split lentils)	Lens esculenta	100	50	—
Refined sugar	—	175	175	250
Vegetables		600	175	50
Cauliflower		600	175	50
Peas	Pisum sativum			
Turnip	Brassica rapa			
Carrot				
Radish	Raphanus compestris			
Tomatoes				
Spinach				
Methi	Fenu greek			
Fruits		70	140	350
Citrus fruits				
Apples	Pyrus malus			
Guava				
Meat				
Beef	—	175	450	400
Mutton	—	—	105	650
Chicken	—	—	325	600
Egg	—	28	350	525
Powder milk	—	700	1050	1550
Fats and oils	—	210	300	480
Spices	—	49	69	30

[a]A: Low income group; B: Middle income group; C: High income group.

counting set-up consists of ORTEC coaxial intrinsic Ge detector, Canberra spectroscopy amplifier (Model 2021) and CANBERRA series 85 MCA for pulse height analysis. The system has a resolution of 1.9 KeV for 1332.5 KeV and a peak-to-compton ratio of 40:1. The outputs of the channel content of MCA were transferred through the serial port to the main computer. The peak identification, data handling and final conversion into element content were carried out by various computer programmes developed by our group.

Under the optimised conditions as shown in Table 3, the elements were measured under two irradiation and three cooling periods. Firstly, the samples were irradiated for 2 min and Cl, Mn, Na and K were determined. Secondly, samples irradiated for 24 h were cooled for 2 days and As, Br and Sb were analysed, while the rest of the elements as radioassayed after 2 weeks. The spectral interferences in the analyses of Zn and Hg were overcome without carrying out any chemical separation.[2,16] However, for the determination of Cu, a radiochemical separation procedure was adopted.[19] After complete digestion of the sample in $HNO_3 + HClO_4$, 2 ml of 0.1 M $CuSO_4$ solution was added as a carrier and for yield determination. Then 1 ml of 0.5 M thioacetamide and 1 ml of 0.5 M

Table 2A Dry weight content of summer season integrated diets

Sample	*Water content (%)*	*Diet A*		*Diet B*		*Diet C*	
		Wet wt. (g)	*Dry wt. (g)*	*Wet wt. (g)*	*Dry wt. (g)*	*Wet wt. (g)*	*Dry wt. (g)*
Cereals	7.75	2750	2537	2080	1919	1435	1324
Meat	73.0	175	47	780	211	1500	405
Eggs	73.0	28	8	250	67	450	121
Vegetables + fruits	90.0	870	87	440	44	550	55
Sugar	10.0	175	157	175	157	250	225
Powdered milk	5.0	700	665	1050	998	1550	1472
Oil & fats	2.0	210	206	300	294	480	470
Spices	3.0	49	47	69	67	30	29
Total weekly intake (g)		4957	3754	5144	3757	6245	4101
Average water content (%)		24.3		27.0		34.3	

Table 2B Dry weight content of winter season integrated diets

Sample	*Water content (%)*	*Diet A*		*Diet B*		*Diet C*	
		Wet wt. (g)	*Dry wt. (g)*	*Wet wt. (g)*	*Dry wt. (g)*	*Wet wt. (g)*	*Dry wt. (g)*
Cereals	7.75	2750	2537	2080	1919	1435	1324
Meat	73.0	175	47	880	238	1650	446
Eggs	73.0	50	13	350	95	525	142
Vegetables + fruits	85.0	670	101	315	47	400	60
Sugar	10.0	175	157	175	157	250	225
Powdered milk	5.0	700	665	1050	998	1550	1472
Oil & fats	2.0	210	206	300	294	480	470
Spices	3.0	49	47	69	67	30	29
Total weekly intake (g)		4779	3774	5219	3815	6320	4168
Average water content (%)		21.1		26.9		34.1	

NaOH solutions were added to precipitate Cu as CuS. After micropore filtration, the 511 keV peak of ^{64}Cu was measured.

ASS Determination of Cu, Ni, Pb and Cd

Samples weighing 500 mg were taken in a 100 ml flask fitted with a 30 cm long air condenser. 5 ml of ultrapure nitric acid was added to the sample and the mixture was then heated at 80 °C for 30 min. After cooling, 3.5 ml of 70% $HClO_4$ was

Table 3 Nuclear data on optimum conditions employed for the analysis

Isotope used	*Half-life*	*γ-ray used kev*	*Irradiation time*	*Cooling time*	*Counting time*
^{38}Cl	37.3 m	2167.5, (1642.4)	2 m	30 m	2 m
^{56}Mn	2.58 h	846.6	2 m	2 h	10 m
^{24}Na	15.0 h	1368.5	2 m	2 h	10 m
^{42}K	12.4 h	1524.7	2 m	2 h	10 m
^{64}Cu	12.7 h	511.0	2 h	2 h	30 m
^{82}Br	35.4 h	554.3, (776.5)	24 h	2 d	30 m
^{76}As	26.3 h	559.1	24 h	2 d	2 h
^{122}Sb	2.7 d	564.1	24 h	2 d	2 h
^{203}Hg	46.6 d	279.2	24 h	2 w	16 h
^{75}Se	120.0 d	264.5, (135.9)	24 h	2 w	16 h
^{59}Fe	44.6 d	1099.3, (1291.6)	24 h	2 w	16 h
^{65}Zn	243.8 d	1115.5	24 h	2 w	16 h
^{51}Cr	27.8 d	320.1	24 h	2 w	16 h
^{60}Co	5.26 y	1173.2, (1332.5)	24 h	2 w	16 h
^{86}Rb	18.6 d	1078.8	24 h	2 w	16 h
^{46}Sc	83.9 d	889.3, (1120.5)	24 h	2 w	16 h
^{134}Cs	2.04 y	795.8, (801.9)	24 h	2 w	16 h

added and, then, the mixture was heated at 250 °C with occasional shaking till white fumes evolved. The clear solution obtained was cooled and transferred into a 25 ml measuring flask and the volume was made up with water. A blank was prepared under similar conditions. The reliability of this wet ashing procedure has already been established.[8]

AAS was carried out using a Hitachi Model Z-8000 spectrometer with a Zeeman-effect background correction mode and equipped with a graphite furnace and auto-sampler. Argon was used as an inert purging gas; the flow was interrupted during the atomisation step. Signal evaluation was based on integrated absorbance values. The conditions for the instrumental determinations were optimised and listed in Table 4. The measurements of Cu and Ni were carried out with an air-acetylene flame and that of Pb and Cd with a electrothermal atomisation technique.

Results and Discussion

The summer and winter season integrated diets of the three categories, A, B and C were analysed for 21 elements. The precision and accuracy of the procedures were checked by analysing bovine liver (USA, NBS SRM-1577a); the results are presented in Table 5A. The precision is expressed in terms of the relative variation coefficient, $V_c = s/X.100$, where X is the arithmetic mean and s is the standard deviation. The relative variation of the measured value X from the certified values X_c is considered to indicate the accuracy. The statistical treatment of data, as shown in Table 5B, indicates that most of the elements were analysed with an overall (median) precision and accuracy of 8.4% and 5.0%, respectively.

Table 4 Experimental AAS conditions

Analytical conditions	*Cu*	*Ni*	*Pb*	*Cd*
Lamp current (mA)	7.5	12.5	7.5	7.5
Wavelength (nm)	324.8	232.0	283.3	228.8
Slit width (nm)	1.3	0.2	1.3	1.3
Burner height (mm)	7.5	7.5	—	—
Oxidant gas press. (kg/cm^2)	1.6	1.6	—	—
Fuel gas press. (kg/cm^2)	0.3	0.3	—	—
Carrier gas flow (ml/min)	—	—	100	100
Sample volume (μl)	—	—	10	10
Heating programme:				
Drying: temp. (°C)	—	—	80–120	80–120
time (sec.)			30	30
Ashing: temp. (°C)	—	—	400	300
time (sec.)			30	30
Atomiz: temp. (°C)	—	—	2100	1700
time (sec.)			7	7
Cleaning: temp. (°C)	—	—	3000	2600
time (sec.)			3	3

Summer Diets

The concentrations of 21 elements, as measured in the summer diets of inhabitants of the Rawalpindi/Islamabad area, are presented in Table 6A. In general, the elemental distribution pattern of most of the elements—viz. Cd, Mn, Co, Zn, Cr, Cl, Na, K, Rb, Cs, Sc and Eu—in all three categories of the diets is similar. The elemental content of As, Sb, Ni, and Se in diet A is slightly higher than in diets B and C, whereas Hg, Pb, Br, Cu and Fe in diet C are higher than in diets A and B.

The dietary intake of essential and toxic elements calculated on the basis of Tables 1A, 2A and 6A are given in Table 7A along with the reported daily intake values.[3,4,23] The data indicate that the intake levels of Cd, Sb, Cl, Cr, Co, K, and Na are almost similar for all three income groups. However, the daily intake of Hg, Pb, Br, Fe, Cu, and Mn in diet sample C are higher than in A and B, while the As, Ni, and Se intake by the low income group is higher than in the other groups.

Winter Diets

The elements determined in the summer diets were also analysed in the winter diets, they are shown in Table 6B. The study indicates that the concentrations of As, Cd, Se and Na are higher in diet A as compared to diets B and C, whereas the levels of Hg, Sb, Fe, Cr, and Co are higher in diet C than in the others. The distribution pattern of Cd and Br in B and C, and of K in A and B are similar. The concentrations of Pb, Ni, Cu, Zn, Cl and Rb are highest in the diet of the middle-income group. The concentration of the remaining elements do not vary significantly between the diet groups.

The daily intake of essential and toxic elements was also estimated for winter

Table 5A Analysis of bovine liver SRM-1577a (NBS, USA)[a]

Elements	Our Values		Certified values	Deviation (%)
	X	s%		
As	49	8.1	47±6	+4.1
Pb[a]	146	13.7	139	+4.8
Cd[a]	417	8.6	440	−5.5
Ni[a]	300	18.6	—	—
Se	0.75	9.3	0.71±0.07	+5.3
Hg[a]	6	33.0	4±2	+33.0
Sb[a]	4	25.0	3	+25.0
Cl	2768	7.0	2800±100	−1.1
Br	9.4	5.3	9.0	+4.2
Fe	197	5.5	194±20	+1.5
Cu	165	4.2	158	+4.2
Cr[a]	630	12.6	650	−3.2
Zn	132	9.8	123±8	+6.8
Mn	10.3	5.8	9.9±0.8	+3.9
Co[a]	229	11.3	210±50	+8.3
Na	2490	2.7	2430±130	+2.4
K	9849	1.0	9960±70	−1.1
Rb	12.1	1.6	12.5±0.1	−3.3
Sc[a]	0.9	11.0	0.7	+22.0
Cs[a]	16	6.2	19	−18.7

[a]Concentration expressed in ppm unless indicated by asterisk (ppb).

Table 5B Overall precision and accuracy of the method

Parameter	Precision (Vc,%)	Accuracy (Δ,%)
Range, R	1.0–33.0	1.1–33.0
Arithmetic Mean, X	10.1	9.98
Geometric Mean, Xg	7.5	5.51
Median, $\tilde{X}$	8.4	5.03

diet samples using the data in Tables 1B, 2B, and 6B. They are tabulated in Table 7B along with the reported daily intake values.[3,4,23] Table 7B indicates that levels of intake for As and Cd by group A people are higher as compared to the higher income groups B and C. The intake of Hg, Sb, by group C is slightly higher than in groups A and B. The Pb and Ni intake by the middle income group is higher than the rest. However, the intake of the toxic elements studied, except for Cd, is well below the reported safe limits for all groups. The data in Table 7B indicates that the diets of the middle and upper income groups are relatively rich in Fe and Cr. The supply of Zn, Mn and Cl is similar in all diets. The comparison of the data with reported daily intake values reveals that the high income group diet is more than adequate for Co, Fe and Cr supply. The other essential elements are well balanced in terms of nutritional requirements.

The comparison of the present data with those from other countries in Table 8 shows that our Se intake values are similar to those of Australia[20] and China[21]

Table 6A Trace element concentration in summer season integrated diets (in $\mu g/g$ on dry weight basis)

Elements	*Diet A*	*Diet B*	*Diet C*
Hg[a]	1.1 ±0.05	1.5 ±0.05	2.9 ±0.03
Cd[a]	130 ±8	127 ±10	113 ±8
Pb[a]	109 ±30	140 ±20	150 ±30
As	0.26±0.01	0.18±0.01	0.20±0.01
Sb[a]	1.8 ±0.06	1.5 ±0.07	1.4 ±0.07
Ni[a]	325 ±30	280 ±20	246 ±20
Se	0.16±0.04	0.12±0.01	0.12±0.01
Cl	2820 ±162	2765 ±148	2689 ±168
Br	3.2 ±0.2	3.0 ±0.2	4.1 ±0.2
Fe	15.2 ±1.4	18.4 ±1.8	24.3 ±1.0
Cu	1.9 ±0.2	2.7 ±0.3	2.8 ±0.3
Zn	22.1 ±2.8	26.4 ±3.0	21.3 ±2.9
Mn	10.2 ±0.7	10.8 ±0.5	11.0 ±0.7
Cr	0.41±0.03	0.38±0.05	0.36±0.03
Co[a]	24 ±2	29 ±2	27 ±2
Na	1897 ±60	1923 ±64	2014 ±87
K	4439 ±350	4126 ±260	4244 ±340
Rb	2.0 ±0.1	2.8 ±0.2	2.8 ±0.1
Cs[a]	26 ±1	24 ±2	26 ±2
Sc[a]	17 ±0.2	18 ±0.3	17 ±0.5
Eu[a]	22 ±0.2	18 ±0.2	19 ±0.1

[a]Concentration expressed in ppb (ng/g).

Table 6B Trace element concentration in winter season integrated diets (in $\mu lg/g$ on dry weight basis)

Elements	*Diet A*	*Diet B*	*Diet C*
Hg[a]	2.3 ±0.1	3.0 ±0.2	4.1 ±0.2
Cd[a]	175 ±12	116 ±10	126 ±10
Pb[a]	153 ±11	438 ±25	243 ±15
As	0.41±0.01	0.29±0.02	0.19±0.01
Sb[a]	2 ±0.1	2.5 ±0.1	4 ±0.2
Ni[a]	260 ±20	342 ±25	210 ±20
Se	0.2 ±0.04	0.18±0.03	0.14±0.03
Cl	2464 ±194	2916 ±196	2670 ±210
Br	6.72 ±0.5	8.25±0.6	8.15±0.6
Fe	18.9 ±1.6	31.5 ±2.1	37.7 ±1.9
Cu	2.90±0.04	8.50±0.22	2.96±0.10
Zn	20.4 ±2.1	24.9 ±1.4	22.6 ±1.0
Mn	11.2 ±0.6	10.7 ±0.7	9.9 ±0.5
Cr	0.28 ±0.02	0.44±0.03	0.67±0.03
Co[a]	8.9 ±0.1	13.8 ±0.2	16.1 ±0.2
Na	2445 ±56	1811 ±33	968 ±53
K	4864 ±215	4828 ±264	3479 ±198
Rb	2.74±0.23	3.33±0.31	1.94±0.16
Sc[a]	36 ±2	37 ±3	36 ±3
Cs[a]	44 ±4	43 ±4	45 ±5
Eu[a]	26 ±2	21 ±2	20 ±1

[a]Concentration expressed in ppb (ng/g).

Table 7A Estimated dietary intake from summer season integrated diets (in mg/day except otherwise specified)

Elements	*Diet A*	*Diet B*	*Diet C*	*Reported values*[3,4,23]
Hg[a]	0.59	0.80	1.70	40
Cd[a]	70	68	66	50–150
Pb[a]	59	75	88	100–300
As[a]	139	97	117	400
Sb[a]	0.96	0.80	0.82	—
Ni[a]	174	150	144	300–500
Se[a]	86	64	70	50–200
Cl	1512	1484	1575	275–5100
Br	1.7	1.6	2.4	1
Fe	8.2	9.9	14.2	8–18
Cu	1.0	1.4	1.6	2–5
Zn	11.8	14.2	12.5	8–15
Mn	5.5	5.8	6.4	0.5–5
Cr[a]	220	203	211	10–200
Co[a]	12.9	15.5	15.8	2 as Vit.B_{12}
Na	1017	1032	1180	115–3300
K	2380	2214	2486	350–5625

[a]Intake expressed in μg/day/person.

Table 7B Estimated dietary intake for winter season integrated diets (in mg/day/person except otherwise specified)

Element	*Diet A*	*Diet B*	*Diet C*	*Reported values*[3,4,23]
Hg[a]	1.2	1.6	2.4	40
Cd[a]	94	63	75	50–150
Pb[a]	82	239	145	100–300
As[a]	221	158	113	400
Sb[a]	1.1	1.4	2.4	—
Ni[a]	140	186	125	300–500
Se[a]	108	98	83	50–200
Cl	1328	1589	1590	275–5100
Br	3.6	4.5	4.8	1
Fe	10.2	17.2	22.4	8–18
Cu	1.6	4.6	1.8	2–5
Zn	11.0	13.6	13.5	8–15
Mn	6.0	5.8	5.9	0.5–5
Cr[a]	151	240	399	2 as Vit. B_{12}
Co[a]	4.8	7.5	9.6	140–1710
Na	1318	987	576	115–3300
K	2600	2631	2071	350–5625

[a]Intake expressed in μg/day/person.

Table 8 Intercomparison of estimated intake of trace elements (intake expressed in μg/day unless otherwise specified)

ELEMENT	Pakistan: Islamabad/Rawalpindi, Summer, Diet A	Summer, Diet B	Summer, Diet C	Winter, Diet A	Winter, Diet B	Winter, Diet C	Median	China (21): Beijing	Shanghai	Xian	Wuhan	Median	Australia (20)
As	139	97	117	221	158	113	128	42.6	52.2	46.2	63.2	49.2	—
Cr	220	203	211	151	240	399	216	166.3	167.0	184.0	142.1	166.7	—
Cu[a]	1.0	1.4	1.6	1.6	4.6	1.8	1.6	1.7	1.2	1.8	1.6	1.6	—
Se	86	64	70	108	98	83	85	106.8	91.5	119.2	76.9	99.2	85.2
Zn[a]	11.8	14.2	12.5	11.0	13.6	13.5	13.0	7.94	6.03	8.73	7.88	7.91	—
Br[a]	1.7	1.6	2.4	3.6	4.5	4.8	3.0	1.14	0.52	1.13	0.53	0.83	—
Pb	59	75	88	82	239	145	85	67.1	89.9	133.4	73.7	81.8	—

[a]Intake in mg/day.

Table 9 Intercomparison of trace elements in the diet samples (in ppm unless otherwise specified)

Elements	*Integrated diet (Pakistani)*	*Mixed human diet*[5] *(Finnish)*
Hg[a]	2.9	4.79
Cd[a]	128.0	31.84
Pb[a]	152.0	150.0
As	0.28	0.0898
Sb[a]	1.9	11.92
Ni[a]	270.0	260.0
Se	0.15	0.10899
Br	5.41	7.54
Fe	21.6	33.51
Cu	2.9	2.85
Zn	22.4	27.58
Mn	10.7	11.84
Cr	0.41	0.14
Co[a]	20.0	43.61

[a]Concentration expressed in ppb (ng/g).

and are within the adequate range suggested by the US Food and Nutrition Board.[22] The dietary intake values for other elements, Cr, Cu and Pb, are similar and those of As, Zn and Br are higher than the Chinese values.

The comparison of the elemental distribution (median values) in our diet samples with that of Finland[5] in Table 9 indicates that the values of Hg, Sb, Br, Fe, Zn, Mn and Co are lower and those of Cd, As, Se and Cr are higher than the mixed human diet (IAEA, H-9) of the Finnish population. The content of Pb, Ni and Cu is similar in both diets.

CONCLUSION

The concentrations of 21 trace elements were determined in integrated diets by means of NAA and AAS. The accuracy of the measurements was checked by analysing standard reference material which showed good agreement with the certified values. The NAA and AAS techniques agree within 10% for the determination of Cu. The measurement of these elements in the diets provides information regarding the baseline levels which should be helpful in monitoring any contamination from foreign sources.

None of the diet samples analysed was contaminated with trace toxic metals to an extent that may cause any adverse effects on human health. The integrated diet samples contain fairly adequate amounts of the essential trace elements in all the three (income) categories of diets. The estimated daily intake of Fe and Cr through the diet sample of the high-income group is slightly higher than the suggested upper limit for their intake.

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