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Nutritional Minerals and Heavy Metals in Tea Infusions and Daily Intake of Human Body

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ABSTRACT

Tea (Camellia sinensis) is one of the most popular nonalcoholic beverages in the world. During tea infusion, both essential mineral elements and toxic metals are extracted into the beverage. In oriental countries, almost a liter of tea is consumed daily by an average adult. Thus, high toxic elements in traditional teas can be of concern. Aim of the study was to determine the essential element contents and toxic heavy metal concentrations in tea products available on the market in Turkey and comparing the contents of infusion for Turkish and Ceylon black and green tea types. The associated health risk to tea drinkers were estimated with reference to Tolerable Daily Intake (TDI) Values from US EPA for adults and children. Among the essential elements in all of the black teas purchased from the market, K was present at the highest concentration followed by Mg, Ca and Al. Pb and Mn contents of several tea samples were found over the Tolerable Daily Intake levels.

Introduction

Tea (*Camellia sinensis*) has gained the world's taste in the past 2000 years as one of the most popular nonalcoholic beverage. About 18 to 20 billion cups of tea are consumed daily in the world (Karak and Bhagat, 2010). Of the tea produced worldwide, 78% is black tea, which is usually consumed in the Western countries, 20% is green tea, which is commonly consumed in Asian countries, and 2% is oolong tea which is produced (by partial fermentation) mainly in southern China (Yang and Landau, 2000). As a popular beverage, the top three tea consuming countries are Turkey, Ireland and UK (Das et al., 2017). Tea infusion is prepared by pouring boiling hot water over cured leaves of tea plant (Kottiappan et al., 2013). During tea infusion, both essential mineral elements and toxic metals are extracted into the beverage. The health benefit of tea has been well documented. However, consuming tea may provide also a significant contribution for intake and accumulation of trace metals in the human body which was not fully studied (Polechonska et al., 2015). At present, the chemical contaminants in food and drinks are becoming a global concern. As for tea, this issue has also received wide attention for the adverse effects on human health when the concentrations of some trace elements in tea infusion exceed a critical range (Lv et al., 2013). Depending on tea origin, metal accumulation can occur naturally or result from manufacturing and agronomic processes (Oliveira et al., 2018).

Presence of trace elements in tea is due to tea plants being normally grown in highly acidic soils, where trace elements are potentially more bioavailable for root uptake (Karak and Bhagat, 2010). Trace element contents of tea may have both beneficial and adverse effects on human health. The regular consumption of tea can contribute to the daily dietary requirements of some of these elements. Industrial wastes, agricultural applications, mining activities and emissions are the main pollution sources of metals in the environment. Traces of undesirable and toxic metals, i.e., Cd, Cr, Cu, Fe, Ni, Mn, Pb and Zn can easily contaminate tea plants (Szymczycha-Madeja et al., 2015). The growth media, nutrients, soil and agrochemical inputs contribute the contamination (Dambiec et al., 2013). However not all of the elements or metals are leached from tea to the infusion.

In oriental countries, almost a liter of tea is consumed daily by an average adult. Thus, high toxic elements in traditional teas can be of concern. The present study, thus, aimed at determining the essential element contents and toxic heavy metal concentrations in tea products available on the market in Turkey and comparing the contents of infusion for Turkish and Ceylon black and green tea types. The associated health risk to tea drinkers were estimated with reference to Tolerable Daily Intake (TDI) Values from US EPA for adults and children (USEPA, 1992).

Materials and methods

Nine commercial Ceylon and 11 commercial Turkish teas were analyzed for Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb and Zn concentrations in their infusions. 6 Ceylon leaf black teas (CLB), 1 Ceylon bagged black tea (CBB), 2 Ceylon leaf green tea (CLG) and 9 Turkish leaf black tea (TLB), 1Turkish bagged black tea (TBB), 1 Turkish bagged green tea (TBG) from most demanding tea trading companies were purchased from local supermarkets in Sanliurfa, Turkey.

Sample Preparations and Element Analysis

Tea infusions were prepared by adding 100 mL of boiling distilled water to 2.00 g of tea leaves (traditional beverage method applied by tea drinkers). The tea infusion was mixed using a glass rod, covered by watch glasses to extract the components of tea leaves and allowed to brew for 10 minutes. The infusion was filtered through filter paper (Whatman 42, 125 mm) into test tube, cooled and analysed immediately for Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Mn Na, Ni, Pb and Zn in an inductively coupled plasma (ICP) mass spectrometer (Perkin Elmer Optima 5300 DV model). All of the tests were conducted in duplicate. Concentrations of Cd and Cr in all tea infusions and Ni and Pb in some infusions were below the detection limit of 0.05 mg/L Hg in all tea infusions was lower than detection limit of 0.01 mg/L (USEPA, 1992).

Tolerable Daily Intake (TDI) and Daily Adequate Intake (AI) Values

In this study, tolerable daily intake of several elements from tea infusion for adult and children was assessed. Tolerable daily intake of metals from ingestion in Table 1 was estimated following USEPA (1992) and (WORLDBANK, 2018). Adequate intake of nutritional minerals for adults and children was presented in Table 2.

$$ATDI \text{ or } CTDI = TDI \times BW \quad (1)$$

Where, ATDI (mg/day) and CTDI (mg/day) is adult and children tolerable daily intake, respectively. TDI is the tolerable daily intake (mg/kg/d) and BW is body weight (kg). For children and adults, default body weight was 20 kg and 70 kg, respectively.

Statistical Analysis

The data was subjected to the statistical analysis of variance (ANOVA) and Duncan multiple range test to assess difference between means and homogeneous subsets using the SPSS 17. statistical software (SPSS Inc., USA). Statistical significance for differences was determined at 5% probability level.

Table 1 Tolerable daily intake of metals (mg/day)

Heavy metals	TDI* oral (mg/kg-d)	ATDI** (mg/day)	CTDI*** (mg/day)
Al	1.0000	70.0000	20.0000
Cd	0.0005	0.0350	0.0100
Cr	0.0030	0.2100	0.0600
Cu	0.0400	2.8000	0.8000
Fe	0.7000	49.0000	14.0000
Pb (for drinking water)	-	0.05 mg/L	0.05 mg/L
Hg	-	-	-
Ni	0.0200	1.4000	0.4000
Mn	0.1400	9.8000	2.8000
Zn	0.3000	21.0000	6.0000

*TDI: Tolerable Daily Intake, **ATDI: Tolerable Daily Intake for adults, ***CTDI: Tolerable Daily Intake for children

Table 2 Adequate intake of nutritional minerals (mg/day)

Nutritional minerals	(AI_A)*	(AI_C)**
Ca	1200	800
Mg	308	120
K	4700	3800
Na	2013	1500
Cu	2.25	1.5
Fe	9	10
Ni	0.175	-
Mn	5.3	1.5
Zn	8	5

*Adequate intake for adults (AI_A) (mg/day), **Adequate intake for children (AI_C) (mg/day)

Results and Discussion

Element concentrations in tea infusions examined in the present study were summarized in Table 3a and 3b. Concentrations of Cd, Cr, and Hg in all tea infusions were below the detection limits. Ni was found average of 0.10 mg/L in all of the studied 11 Turkish teas; but only in 3 of the nine studied Ceylon teas as average of 0.06 mg/L. Pb was found as 0.054 mg/L in only 1Turkish leaf black tea and as 0.052 mg/L in 1 Ceylon bagged black tea sample. Their Pb contents are higher than the acceptable level in drinking water. Pb concentrations in other 18 tea infusions were below the detection limit. Pb is more bioavailable to tea plants growing in highly acidic soils (Han et al., 2006a, b). Leaching of Pb from tea leaves during soaking in boiling water is an important issue. There is a risk of exceeding the World Health Organization (WHO) limit set for Pb in drinking water (0.05 mg/L) by tea infusions (WHO, 2003; Brzezicha-Cirocka et al., 2016).

Among the macroelements in all of the black teas purchased from the market, K was present at the highest concentration with the average value of 315.98 mg/L followed by Mg, Ca and Al with the average values of 16.41, 9.23 and 8.70 mg/L, respectively. Such high concentrations might be explained, as Kumar et al. (2005) suggested, by the specific incorporation of K within a binding ligand of the tea leaves. They reported that K concentration in tea is higher than Mg, while the Mg content is higher than Na one (Brzezicha-Cirocka et al., 2016). It appears that Mg is also quite easily extracted as a component of chlorophyll. Other alkaline earth element, i.e., Ca is strongly trapped inside plant cells and for that reason extraction efficiencies for these elements are relatively lower (Matsuura et al., 2001). The high content of Al in tea leaves may be explained by the fact that tea is one of the few Al accumulating plants (Lanhai et al., 2015). The increase in Al content in black tea can also be connected to the frying of leaves aimed to change the composition and stop the fermentation process that is performed using pans made of Al-Cu alloys (Fung et al., 2003). The high Mn concentrations such as average of 6.85 and 3.46 mg/L in Turkish and Ceylon black tea samples, respectively; suggest that this plant can be considered as also accumulator for Mn (Dambiec et al., 2013). The contribution of tea from drinking three cups daily to total exposure only in the case of Al and Mn is substantial (Polechonska et al., 2015).

In present study, average K, Mg and Zn concentrations of Ceylon teas (358, 22 and 0.37 mg/L respectively) were found higher than Turkish teas ($P<0.05$) (287, 13 and 0.24 mg/L, respectively). However, Al, Ca, Fe, Mn and Na concentrations in Turkish tea infusions were higher than Ceylon ($P<0.05$). In addition there is no statistically differences between Cu and Ni concentrations in Turkish and Ceylon teas ($P>0.05$). The Ceylon and Turkish tea infusions differed a little in respect of element concentration sequences, which were as follows: K > Mg > Ca > Al > Mn > Na > Zn > Fe > Cu > Ni for Ceylon tea samples and K > Mg > Ca > Al > Mn > Na > Zn > Fe > Ni > Cu for Turkish tea infusions. The differences in results concerning elements' contents are thought to depend on tea sample origins and conditions of their cultivations.

Table 3a. Mineral and heavy metal concentrations in infusions of teas purchased from local supermarkets in Sanliurfa, Turkey (mg/L)*

TI	Al	Ca	Cd	Cr	Cu	Fe	Hg	Pb
CLB1	3.895 ± 0.033^{b}	5.406 ± 0.013^{a}	BDL	BDL	0.051 ± 0.007^{a}	0.124 ± 0.001^{c}	BDL	BDL^{a}
CLB2	4.153 ± 0.042^{c}	7.950 ± 0.049^{c}	BDL	BDL	0.056 ± 0.027^{a}	0.047 ± 0.031^{a}	BDL	BDL^{a}
CLB3	4.635 ± 0.057^{e}	8.363 ± 0.037^{d}	BDL	BDL	0.066 ± 0.031^{abc}	0.050 ± 0.001^{a}	BDL	BDL^{a}
CLB4	3.554 ± 0.074^{a}	8.531 ± 0.030^{e}	BDL	BDL	0.052 ± 0.011^{a}	0.045 ± 0.002^{a}	BDL	BDL^{a}
CLB5	4.842 ± 0.048^{f}	8.272 ± 0.037^{d}	BDL	BDL	0.062 ± 0.018^{ab}	0.062 ± 0.003^{a}	BDL	BDL^{a}
CLB6	4.447 ± 0.059^{d}	9.046 ± 0.048^{g}	BDL	BDL	0.056 ± 0.017^{a}	0.157 ± 0.011^{d}	BDL	BDL^{a}
CLG1	6.137 ± 0.078^{g}	12.695 ± 0.035^{r}	BDL	BDL	0.089 ± 0.014^{abcd}	0.120 ± 0.004^{c}	BDL	BDL^{a}
CLG2	6.356 ± 0.068^{h}	16.190 ± 0.016^{s}	BDL	BDL	0.130 ± 0.028^{de}	0.209 ± 0.021^{f}	BDL	BDL^{a}
CBB1	6.278 ± 0.057^{h}	12.09 ± 0.102^{n}	BDL	BDL	0.117 ± 0.014^{cde}	0.100 ± 0.004^{b}	BDL	0.052 ± 0.000^{b}
TLB1	9.479 ± 0.085^{j}	7.531 ± 0.028^{b}	BDL	BDL	0.069 ± 0.028^{abc}	0.056 ± 0.001^{a}	BDL	BDL^{a}
TLB2	9.210 ± 0.042^{i}	9.259 ± 0.040^{h}	BDL	BDL	0.084 ± 0.020^{abcd}	0.393 ± 0.011^{h}	BDL	BDL^{a}
TLB3	9.134 ± 0.048^{i}	9.269 ± 0.057^{h}	BDL	BDL	0.080 ± 0.014^{abcd}	0.056 ± 0.006^{a}	BDL	BDL^{a}
TLB4	14.520 ± 0.030^{s}	10.395 ± 0.014^{kl}	BDL	BDL	$0.075\pm0.018a^{bc}$	0.183 ± 0.004^{e}	BDL	BDL
TLB5	9.707 ± 0.040^{k}	10.35 ± 0.049^{k}	BDL	BDL	0.153 ± 0.033^{e}	0.236 ± 0.011^{g}	BDL	0.054 ± 0.000^{c}
TLB6	10.740 ± 0.028^{k}	8.907 ± 0.047^{f}	BDL	BDL	0.072 ± 0.020^{abc}	0.185 ± 0.007^{e}	BDL	BDL^{a}
TLB7	11.550 ± 0.035^{n}	10.127 ± 0.031^{j}	BDL	BDL	0.072 ± 0.014^{abc}	0.098 ± 0.003^{b}	BDL	BDL^{a}
TLB8	12.110 ± 0.027^{p}	9.555 ± 0.057^{i}	BDL	BDL	0.054 ± 0.011^{a}	0.058a±0.007	BDL	BDL^{a}
TLB9	13.765 ± 0.033^{r}	11.410 ± 0.040^{m}	BDL	BDL	0.058 ± 0.008^{a}	0.181 ± 0.010^{e}	BDL	BDL^{a}
TBB1	15.820 ± 0.088^{t}	10.475 ± 0.028^{l}	BDL	BDL	0.090 ± 0.014^{abcd}	0.111 ± 0.007^{bc}	BDL	BDL^{a}
TBG1	10.870 ± 0.043^{m}	12.555 ± 0.047^{p}	BDL	BDL	0.114 ± 0.024^{bcde}	0.512 ± 0.008^{i}	BDL	BDL^{a}
MTBT	11.603 ± 0.046^{B}	9.728 ± 0.039^{B}	BDL	BDL	0.080±0.018	0.155 ± 0.004^{B}	BDL	BDL
MCBT	4.543 ± 0.031^{A}	8.522 ± 0.045^{A}	BDL	BDL	0.065±0.005	0.083 ± 0.002^{A}	BDL	BDL
MGT	7.788 ± 0.063^{a}	13.813 ± 0.033^{b}	BDL	BDL	0.111±0.022	0.280 ± 0.006^{b}	BDL	BDL
MABT	8.696 ± 0.040^{b}	9.231 ± 0.042^{a}	BDL	BDL	0.074±0.013	0.126 ± 0.001^{a}	BDL	BDL

TI: Tea infusions, MTBT: Mean of Turkish black teas, MCBT: Mean of Ceylon black teas, MGT: Mean of Green teas, MABT: Mean of all black teas, *Different letters indicate statistical differences within the tea samples ($P<0.05$) , BDL: Below detection limits, CLB: Ceylon leaf black tea (6), CBB: Ceylon bagged black tea (1), CLG: Ceylon leaf green tea (2), TLB: Turkish leaf black tea (9), TBB: Turkish bagged black tea (1), TBG: Turkish bagged green tea (1)

Table 3b Mineral and heavy metal concentrations in infusions of teas purchased from local supermarkets in Sanliurfa, Turkey (mg/L)*

TI	K	Mg	Mn	Na	Ni	Zn
CLB1	370.300±0.057[r]	19.120±0.028[m]	3.179±0.025[b]	1.947±0.086[c]	BDL[a]	0.267±0.044[def]
CLB2	376.250±0.055[y]	21.565±0.035[s]	3.613±0.028[d]	2.421±0.048[g]	BDL[a]	0.324±0.025[hi]
CLB3	375.550±0.005[v]	21.485±0.001[r]	3.771±0.002[e]	4.158±0.003[m]	BDL[a]	0.334±0.042[ij]
CLB4	374.900±0.006[t]	19.160±0.002[n]	3.204±0.001[c]	1.617±0.004[a]	BDL[a]	0.308±0.028[fghi]
CLB5	374.700±0.023[s]	24.175±0.013[v]	3.767±0.006[e]	2.289±0.009[f]	BDL[a]	0.317±0.031[ghi]
CLB6	323.550±0.028[p]	21.410±0.018[p]	4.210±0.031[f]	2.211±0.007[e]	BDL[a]	0.573±0.025l
CLG1	190.600±0.045[b]	9.180±0.056[b]	5.833±0.006[k]	1.857±0.003[b]	BDL[a]	0.277±0.002[defg]
CLG2	183.750±0.067[a]	9.156±0.021[a]	5.607±0.014[i]	4.360±0.003[n]	0.057±0.002[b]	0.248±0.003[bcde]
CBB1	309.650±0.078[n]	23.370±0.015[t]	2.502±0.007[a]	4.615±0.004[p]	0.062±0.001[b]	0.472±0.002[k]
TLB1	257.850±0.063[d]	10.795±0.005[d]	5.376±0.009[g]	31.810±0.078[t]	0.083±0.002[cd]	0.251±0.003[bcde]
TLB2	278.200±0.034[g]	10.870±0.006[e]	5.899±0.008[l]	3.084±0.010[j]	0.097±0.001[cdefg]	0.265±0.004[cde]
TLB3	277.500±0.017[f]	10.810±0.012[d]	5.669±0.006[j]	2.021±0.002[d]	0.089±0.003[cde]	0.223±0.005[abc]
TLB4	297.050±0.035[j]	15.245±0.019[k]	8.820±0.042[t]	10.560±0.008[s]	0.113±0.005[g]	0.243±0.002[bcd]
TLB5	276.700±0.021[e]	10.240±0.007[c]	5.519±0.004[h]	3.200±0.013[k]	0.079±0.007[c]	0.244±0.003[bcd]
TLB6	286.300±0.076[h]	13.700±0.026[g]	7.375±0.009[p]	2.917±0.031[i]	0.108±0.004[fg]	0.214±0.001[ab]
TLB7	302.150±0.045[l]	14.610±0.014[j]	8.050±0.011[s]	3.353±0.004[l]	0.101±0.001[defg]	0.217±0.002[ab]
TLB8	298.600±0.037[k]	13.545±0.012[f]	6.844±0.025[n]	2.772±0.018[h]	0.097±0.002[cdefg]	0.188±0.003[a]
TLB9	293.550±0.073[i]	14.430±0.011[i]	7.489±0.005[r]	2.914±0.003[i]	0.105±0.003[efg]	0.219±0.006[ab]
TBB1	298.850±0.081[l]	14.370±0.007[h]	7.482±0.003[r]	2.797±0.006[h]	0.103±0.001[efg]	0.290±0.002[efgh]
TBG1	237.300±0.009[c]	18.265±0.012[l]	6.018±0.003[m]	4.958±0.001[r]	0.094±0.002[cdef]	0.366±0.007[j]
MTBT	286.675±0.016[A]	12.862±0.006[A]	6.852±0.011[B]	6.543±0.007[B]	0.097±0.032	0.235±0.023[A]
MCBT	357.843±0.027[B]	21.469±0.009[B]	3.464±0.008[A]	2.751±0.019[A]	0.056±0.015	0.370±0.028[B]
MGT	203.883±0.076[a]	12.200±0.011[a]	5.819±0.216	3.725±0.003[a]	0.075±0.010	0.297±0.004
MABT	315.979±0.05[b]	16.406±0.041[b]	5.457±0.128	4.981±0.010[b]	0.090±0.002	0.291±0.011

TI: Tea infusions, MTBT: Mean of Turkish black teas, MCBT: Mean of Ceylon black teas, MGT: Mean of Green teas, MABT: Mean of all black teas, *Different letters indicate statistical differences within the tea samples (P<0.05), BDL: Below detection limits, CLB: Ceylon leaf black tea (6), CBB: Ceylon bagged black tea (1), CLG: Ceylon leaf green tea (2), TLB: Turkish leaf black tea (9), TBB: Turkish bagged black tea (1), TBG: Turkish bagged green tea (1)

Average Al, K, Mg, and Na contents of green teas with the values of 7.79, 203.88, 12.20 and 3.73 mg/L, respectively were found lower than (P<0.05) all of the studied black tea infusions. However, average Ca and Fe contents of green teas with the values 13.81 and 0.28 mg/L were found higher than (P<0.05) all of the studied black tea infusions. Green tea character mainly depends on leaf compositions at the time of harvesting than on compounds formed during technological processing. Moreover, the elemental composition of green tea is strongly associated with its geographical origin, genetic differences, soil composition and agricultural or climatic conditions (Khizar et al., 2015).

Tolerable and Adequate Daily Intake Values of Nutritional Elements from Tea Infusions

The regular consumption of tea may contribute to the daily requirements of some elements. Some metals found in tea (e.g., Fe, Mn, Zn) are components of important enzymes or participants in a number of physiological processes so they are considered essential for the proper functioning of the human body. However, some of the other elements are undesirable or toxic to human health, such as Cr, Cd, Ni, and Pb (Polechonska et al., 2015). Considering an average consumption of five cups or ten glasses (1000 ml) per person per day, the percentage of the average daily intake of elements from Turkish black tea (TBT), Ceylon black tea (CBT) and green tea (GT) was determined and depicted in Table 4. The values of calculated daily intake of Mn from five cups of tea per person provide 100 % of the adequate daily intake for adults and children, whereas for CBT the calculated dose is 65.35% of the adequate daily intake for adults. Tolerable daily intake levels of metals from tea infusions for adult or children were not exceeded except for Mn and Pb (Table 5). For children, Tolerable Daily Intake of Mn from all tea types exceeded CTDI level of 2.8 mg/day. Tea is a rich source of the Mn and it is an essential element for a number of key enzymes including liver pyruvate carboxylase, arginase and, most notably, mitochondrial or Mn-dependent superoxide dismutase (Hope et al., 2006). However excess manganese can result in interference with the absorption of iron and may result in ADHD-like (Attention Hyperactivity Deficit Disorder) symptoms in children exposed in utero (Schwalfenberg et al., 2013).

Tolerable Daily Intake of Pb from TBT and CBT also exceeded both of the ATDI and CTDI levels of 0.05 mg/L for adult and children. Pb was below the detection limit in green tea samples. Pb causes permanent damage to key enzymes and many systems of the body including the circulatory, renal, and central nervous ones (Santos et al. 2013). Therefore, it is important to monitor the concentration of these metals, especially in view of permissible limits for growth and good health (Brzezicha-Cirocka et al., 2016).

The calculated daily intakes of the studied elements showed that the tea infusions could contribute toward daily intake of metals. Some important ones of these values provide 55.63%, 32% and 43% of adult adequate daily intake for Ni from TBT, CBT and GT, respectively. Adequate daily Mg intake for children from TBT, CBT and GT was %10.72, %17.89 and %10,17; whereas daily Zn intake for children was %4.70, %7.41 and %5.93, respectively. Adequate daily intakes of K and Cu from TBT, CBT and GT for children were %7.54, %9.42, %5.37 and %5.36, %4.36, %7.39, respectively. For all other studied elements, adults and children adequate daily intake values were presented in Table 4. Concisely, tea contains trace elements that are essential to human health. Especially, manganese, zinc and iron play an important role in human metabolism and interest in these elements is increasing together with reports relating trace element status and oxidative diseases (Cabrera et al., 2003). However, different opinions are also there about the safety of tea drinking by taking into consideration of such non-essential or trace elements accumulation in human body. Thus, more focus should be placed on monitoring heavy metal contents in tea infusion and studying their health risk to tea consumers.

Table 4 Adequate Daily Intake of essential elements from tea infusions (%)

Nutritional minerals	Percentage of adequate daily intake for adults			Percentage of adequate daily intake for children		
	from TBT*	from CBT**	from GT***	from TBT	from CBT	from GT
Ca	0.81	0.71	1.15	1.22	1.07	1.73
Cu	3.58	2.91	4.93	5.36	4.36	7.39
Fe	1.73	0.92	3.11	1.55	0.83	2.80
K	6.10	7.61	4.34	7.54	9.42	5.37
Mg	4.18	6.97	3.96	10.72	17.89	10.17
Mn	100.00	65.35	100.00	100.00	100.00	100.00
Na	0.33	0.14	0.19	0.44	0.18	0.25
Ni	55.63	32.00	43.00	-	-	-
Zn	2.94	4.63	3.71	4.70	7.41	5.93

*TBT: Turkish black tea, **CBT: Ceylon black tea, ***GT: Green tea

Table 5 Tolerable Daily Intake of toxic metals from tea infusions (mg/day)

Toxic metals	ATDI*	CTDI**	Daily intake from TBT[1]	Daily intake from CBT[2]	Daily intake from GT[3]
Mn	9.800	2.800	6.852	3.464	5.819
Pb	0.050	0.050	0.054	0.052	BDL[4]

*ATDI: Tolerable Daily Intake for adults, **CTDI: Tolerable Daily Intake for children, [1]TBT: Turkish black tea, [2]CBT: Ceylon black tea, [3]GT: Green tea, [4]BDL: Below detection limits

Conclusions

Among the macroelements in all of the black teas purchased from the market, K was present at the highest concentration with the average value of 315.98 mg/L followed by Mg, Ca and Al with the average values of 16.41, 9.23 and 8.70 mg/L, respectively. Among the toxic heavy metals, concentrations of Cd, Cr and Hg in all tea infusions were found below the detection limits. Ni and Pb were determined in several black tea infusions. Tolerable Daily Intake of Pb from TBT and CBT exceeded both of the ATDI and CTDI levels of 0.05 mg/L for adult and children. Pb was below the detection limit in green tea samples. The values of calculated daily intake of Mn from five cups of tea per person provide 100 % of the adequate daily intake for adults and children, whereas for CBT the calculated dose is 65.35% of the adequate daily intake for adults. Tolerable daily intake levels of metals from tea infusions for adult or children were not exceeded except for Mn and Pb. For children, Tolerable Daily Intake of Mn from all tea types exceeded CTDI level of 2.8 mg/day. Tea contains trace elements that are essential to human health. However such non-essential or trace elements accumulation in human body is an important issue to be emphasized.

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