Assessment of the risk of exposure to cadmium and lead as a result of the consumption of coffee infusions

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Received: 8 July 2020 / Accepted: 5 August 2020 / Published online: 13 August 2020
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Abstract
The paper aimed to analyse the safety of drinking coffee by adult Poles in terms of Pb and Cd content. The degree to which Cd and Pb passed from coffee grounds into the coffee infusion was also examined. Twenty-three samples of natural coffee were examined. The content of metals was determined using the ICP method. On average, dry coffee contained ca. 0.004 μg Cd and 0.05 μg Pb per 1 g, and 95.5% Cd and 94% Pb passed into the infusion. Drinking coffee supplies these metals in the amount of less than 2% TWI (tolerable weekly intake) for Cd and BMDL (benchmark dose lower confidence limit) for Pb. In the presented studies, the values of CDI (chronic daily intake), THQ (target hazard quotient) and HI (hazard index) indicators were lower than 1, which means that the risk of developing diseases connected with chronic exposure to Cd and Pb consumed with coffee must be evaluated as very low. The content of Cd and Pb in the analysed coffee infusions was very low, so drinking coffee does not pose a risk for consumers in terms of the content of these metals. However, it must be remembered that no threshold limits for toxic metal consumption exist because these metals accumulate in the body for a long time. The studies presented here also showed a low ($r = 0.26$) but still a positive correlation between the content of Pb in coffee and the degree (%) to which Pb passed into the infusion. This problem should be thoroughly investigated.

Keywords Coffee infusions · Cadmium · Lead · Risk assessment

Introduction
Coffee, next to tea, is one of the most popular drinks in the world [1]. It is a source of antioxidants including caffeine, phenolic compounds and diterpenes. Results of studies suggest that drinking coffee can increase the level of glutathione and improve the protection of the body against DNA damage, in particular, if consumed regularly [1]. It was demonstrated that drinking coffee decreased the risk of developing breast cancer, prostate and colorectal cancer, which is attributed to the presence of antioxidants [2, 3]. It is also suggested that drinking coffee decreases the risk of developing chronic diseases such as type 2 diabetes and Parkinson’s [4, 5]. According to surveys, 95.2% of adult Poles drink coffee compared with 61% of Italians and about 40% of Spaniards [6, 7]. Statistically, in 2017 in Poland, the consumption of coffee amounted to 2.16 kg per person [8]. In Poland, the most popular type of coffee is non-instant coffee (ground and ground). This is a choice of more than 50% of consumers, preceding instant coffee and coffee mixes [6]. Most often, Poles drink 1–3 cups of coffee a day [9, 10]. However, one should not drink more than 5 cups (1 cup = 150 ml = 80 mg caffeine) a day due to its possible negative effect on the cardiovascular system (increased LDL-chol and total cholesterol levels due to diterpenoid alcohols), problems falling asleep (caffeine), pregnancy (caffeine intake of > 300 mg per day proved negative effect on the duration of pregnancy and weight at birth) and increased secretion of gastric acid and bile, which exacerbates peptic ulcer disease and hyperacidity [1, 11–13].

Apart from antioxidants and other bioactive compounds, coffee contains carbohydrates, lipids, nitrogen compounds, vitamins and minerals, including toxic elements such as cadmium (Cd) and lead (Pb) [12, 14, 15]. The presence of toxic metals in food is a global problem. Their primary source for humans is the food of plant origin [16, 17]. Although, according to available literature and own studies, the content of Cd...
and Pb in food products normally does not exceed acceptable standard levels, due to the fact that these metals are capable of accumulating in tissues and have a long half-life: 5–30 years for Cd and from 30 days (in soft tissue) to 10 years (in bones) for Pb [18], their regular supply, even in small amounts, is dangerous. These metals display mutagenic, teratogenic, carcinogenic and embryotoxic effects [19]. In 2012, EFSA reduced the tolerable intake level for Cd and Pb. The TWI (tolerable weekly intake) for Cd was determined at the level of 2.5 \( \mu \text{g kg}^{-1} \) of body weight per week [16], whereas the BMDL (benchmark dose lower confidence limit) for Pb was BMDL\(_{0.1}\)—10.5 \( \mu \text{g kg}^{-1} \) of body weight per week—and BMDL\(_{1.0}\)—4.4 \( \mu \text{g kg}^{-1} \) of body weight per week [17]. The paper aimed at analysing the safety of drinking coffee by adult Poles in terms of Pb and Cd content. The degree to which Cd and Pb passed from coffee grounds into the coffee infusion was also examined. The presented results are a part of the project aiming to estimate the intake of minerals (toxic and essential) in the Polish population.

### Material and methods

#### Study material

Twenty-three samples of natural coffee were examined (Table 1). The products were purchased in August 2017 from local groceries, still within their shelf life. Before the analyses, the coffee was stored in original, tightly sealed packages at room temperature.

#### Preparation of samples for analyses

Grained coffee was ground in a laboratory grinder with plastic blades. Ground coffee was mixed by hand. Coffee infusions were prepared as follows: 6 g of ground coffee was poured with 100 ml of drinking water with a temperature of 95–100 °C; after 10 min, the solutions were drained through the Whatman drain. The resulting coffee grounds were dried in a drier at a temperature of 65 °C for 24 h. Afterwards, they

### Table 1 Characteristic of the analysed products

| Coffee form | Coffee varieties | Trademark | Size of package, g | Annotation | Origin | Made in |
|-------------|------------------|-----------|-------------------|-----------|--------|---------|
| 1 Beans     | Arabica + Robusta| A         | 1000              | Bio, Fair Trade | South America, Asia, Africa | Poland |
| 2 Beans     | No data          | B-1       | 1000              | No data     | No data | Poland |
| 3 Ground    | No data          | B-2       | 250               | No data     | No data | Poland |
| 4 Ground    | Robusta          | C         | 400               | Brazil      | Poland |
| 5 Beans     | Arabica          | D-1       | 500               | Brazil      | Holland |
| 6 Beans     | Arabica + Robusta| D-2       | 1000              | No data     | No data | Holland |
| 7 Ground    | Arabica          | D-1       | 500               | Columbia    | Holland |
| 8 Ground    | Arabica          | D-3       | 500               | Brazil      | Holland |
| 9 Ground    | Arabica          | G-1       | 250               | Bio, Fair Trade | Papua New Guinea, Peru, Mexico | Italy |
| 10 Ground   | Arabica          | G-2       | 250               | Brazil      | Italy |
| 11 Beans    | Arabica + Robusta| G-3       | 1000              | South America, Indonesia | Italy |
| 12 Ground   | Arabica + Robusta| I         | 250               | South America, Indonesia | Germany |
| 13 Ground   | Robusta          | J-1       | 500               | Vietnam     | Germany |
| 14 Ground   | Robusta          | J-2       | 250               | India       | Germany |
| 15 Ground   | Robusta          | J-2       | 100               | India       | Germany |
| 16 Ground   | Arabica          | J-2       | 500               | Brazil      | Germany |
| 17 Beans    | Arabica          | J-3       | 1000              | Fair Trade | Bolivia, Peru, Ecuador, Nicaragua | Germany |
| 18 Ground   | Arabica          | K-1       | 500               | Brazil     | Germany |
| 19 Ground   | Arabica          | K-2       | 500               | South America | Germany |
| 20 Beans    | Arabica          | K-3       | 500               | South America | Germany |
| 21 Beans    | Arabica + Robusta| K-4       | 500               | South America, Indonesia | Germany |
| 22 Ground   | Arabica          | L         | 500               | Brazil     | Germany |
| 23 Ground   | Arabica          | M         | 227               | Fair Trade | Peru, Nicaragua | England |
were pulverised in a laboratory grinder with plastic blades. The analyses covered both fresh ground coffee and coffee grounds remaining after coffee brewing.

**Chemical analyses**

The analysed material was manually mixed. Samples weighing ca. 3 g were weighed in 3 replications into previously heat sterilised china crucibles and then subjected to dry mineralisation in a muffle furnace at a temperature of 450 °C. The oxidant was hydrogen peroxide. The mineralisate was dissolved in 10 ml of 1 M HNO₃ [20, 21]. The content of cadmium and lead was determined using ICP (inductively coupled plasma mass spectrometry) in a Varian 820 MS spectrometer (Varian, Melbourne, Australia). The parameters for determination and control of correct analyses were included in Table 2. The calibration curve was drawn using the models:

Cd: standard characterised by 99.999% purity used to prepare solutions with the concentration of 0.2; 0.4; 1; 2; 4; 10 μg of Cd L⁻¹; the solutions were prepared in 1% ultra-pure nitric acid (V).

Pb: standard characterised by 99.999% purity used to prepare solutions with the concentration of 0.1; 0.2; 0.5; 1; 2; 5 μg of Pb L⁻¹; the solutions were prepared in 1% ultra-pure nitric acid (V).

Each chemical analyses was repeated 3 times. The accuracy of determination was verified using a blind test (1 M HNO₃) and two certified reference materials (CRM): INCT-TL-1 Tea leaves (containing 0.030 mg Cd and 1.78 mg Pb per 1 kg) and INCT-MPH-2 Mixed Polish herbs (containing 0.199 mg Cd and 2.16 mg Pb per 1 kg).

**Reagents and reference materials**

Hydrogen peroxide H₂O₂ (30% pure) and nitric acid HNO₃ (65% ultra-pure) were purchased from POCH S.A. (Poland). Deionised water used for dilution was made in our laboratory (Hydrolab Poland, Gdańsk). The Cd and Pb standards were purchased from Merck (Germany). Certified reference materials INCT-TL-1 and INCT-MPH-2 were obtained from the Institute of Nuclear Chemistry and Technology (Warsaw, Poland).

| Table 2 | Measurement parameters and validation data for the determination of Cd and Pb levels by ICP-MS |
|---------|------------------------------------------------------------------------------------------------|
|         | Cd                                               | Pb                                               |
| Mass monitored | 114                                             | 206; 207; 208                                     |
| Plasma gas   | Argon                                           | Argon                                           |
| Plasma gas flow, L min⁻¹ | 18                                              | 18                                              |
| Nebulizer gas flow, L min⁻¹ | 1                                               | 1                                               |
| Auxiliary gas flow, L min⁻¹ | 1.70                                             | 1.70                                            |
| Sampling depth, mm | 5                                               | 5                                               |
| RF power, kW | 1.37                                             | 1.37                                            |
| Limit of detection LOD, μg kg⁻¹ | 0.004                                             | 0.005                                           |
| Limit of quantification LOQ, μg kg⁻¹ | 0.010                                              | 0.030                                           |
| Quality control |                                                |                                                |
| Blank sample | 1 M HNO₃                                         | 1 M HNO₃                                        |
| Certified reference material (1) | INCT-TL-1 Tea leaves                           | INCT-TL-1 Tea leaves                            |
| Certified reference material (2) | INCT-MPH-2 Mixed Polish herbs                    | INCT-MPH-2 Mixed Polish herbs                    |
| Certified element concentration in CRM 1 |                                                |                                                |
| Certified, mg kg⁻¹ | 0.030                                             | 1.78                                            |
| Observed, mg kg⁻¹ | 0.029                                              | 1.76                                            |
| Recovery rate, % | 98                                                 | 99                                              |
| Certified element concentration in CRM 2 |                                                |                                                |
| Certified, mg kg⁻¹ | 0.199                                             | 2.16                                            |
| Observed, mg kg⁻¹ | 0.189                                              | 2.22                                            |
| Recovery rate, % | 95                                                 | 103                                             |
| Precision, % | 6.04                                               | 6.07                                            |
| Replicates | 3                                                  | 3                                               |
Calculations

Based on the difference in the content of Cd and Pb in coffee grounds, the degree (%) to which those metals passed into the infusion was calculated prior to after coffee brewing.

The safety of drinking coffee for adult Poles was estimated on the grounds of (1) calculation of the percentage of Cd and Pb intake in comparison with the acceptable level proposed by EFSA [16, 17], (2) calculation of parameters describing the risk of development of cancer and (3) calculation of parameters describing the risk of development of non-carcinogenic diseases. Three consumption patterns were taken into account in the calculations: 1 cup, 2 cups or 3 cups a day for 365 days in a year because such amounts of coffee in Poland are drunk by ca. 80% of coffee drinkers [9, 10].

(1) Percent of tolerable dose:

Estimated weekly intake (EWI) of Cd and Pb was calculated according to the formula [22]:

\[
EWI = \frac{MWC \times \text{metal level}}{100}
\]

where MWC is the mean weekly consumption of coffee (one, two or three cups).

Tolerable weekly intake % (TWI) was calculated according to the formula [22]:

\[
\%\text{TWI} = \frac{EWI_{Cd} \times 100}{TWI}
\]

The value adopted for TWI was 2.5 µg Cd kg\(^{-1}\) per week [16].

Benchmark dose lower confidence limit % (BMDL) was calculated according to the formula [22]:

\[
\%\text{BMDL} = \frac{EWI_{Pb} \times 100}{BMDL}
\]

The value adopted for BMDL: two values suggested by the European Food Safety Authority (EFSA) were calculated per 1 week: BMDL\(_{01}\) = 10.5 µg Pb kg\(^{-1}\) of body weight per week—and BMDL\(_{10}\) = 4.4 µg Pb kg\(^{-1}\) of body weight per week [17].

The mean body weight was assumed as 70 kg.

(2) Cancer risks parameters

Chronic daily intake (CDI) of Cd or Pb was calculated according to the formula [23, 24]:

\[
\text{CDI} = \frac{\text{EDI} \times \text{EFr} \times \text{ED}_{\text{tot}}}{\text{body weight} \times \text{AT}}
\]

where EDI is the estimated daily intake of Cd and Pb, calculated on the basis of the mean weekly consumption of coffee (one, two or three cups) and mean level of Cd and Pb; EFr is the days of exposure frequency (365 per year); \(\text{ED}_{\text{tot}}\) is the exposure duration (years)—since in Poland regular coffee drinkers are adults only, it was assumed that the time of exposure was calculated from 18 to 74 years of age (74 years—average life span in Poland), which is 56 years; AT is the period of exposure (365 per year).

CSF is a cancer slope factor which is the risk produced by a lifetime average dose of 1 mg kg\(^{-1}\) BW per day and is contaminant specific.

(3) Non-carcinogenic risks parameters

Target hazard quotient (THQ) was calculated according to the formula [23]:

\[
\text{THQ} = \text{CDI}/\text{RfD}
\]

where CDI is the chronic daily intake of Cd or Pb.

RfD (reference dose) for Cd is 1 µg kg\(^{-1}\) of body weight per day, whereas, for Pb, it is 3.5 µg kg\(^{-1}\) of body weight per day [25].

When THQ is higher than 1, it is assumed that there is a significant risk of developing negative effects on health resulting from chronic exposure to Cd and/or Pb [26].

Hazard index (HI) was calculated according to the formula [23]:

\[
\text{HI} = \text{THQ}_{\text{Cd}} + \text{THQ}_{\text{Pb}}
\]

Statistical analysis

The mean content of Cd and Pb was calculated for each sample (three weighing replications × 3 replications of chemical analysis). A statistical analysis of the results (average value, minimum and maximum value, standard deviation, median, 75 and 25 percentile) was carried out using Statistica 13.1 software. Statistically significant differences (\(P < 0.05\)) were computed by single factor analysis of variance (ANOVA), using the Duncan test. The correlation between the content of Cd and Pb in coffee and the degree (%) to which they passed into the infusion was calculated using Pearson’s method (Statistica 6.0 software).

Results

Content of Cd and Pb in coffee

Dry coffee prior to brewing contained from 1.204 to 10.33 µg Cd per 1 kg (Tables 3 and 4). The mean content of Cd in the analysed samples was 3.784 µg (± 2.464) per 1 kg. Coffee
grounds contained from < LOQ to 0.698 μg per kg; in 35% of samples, the level of Cd was lower than determinable with the applied method (LOQ = 0.01 μg kg⁻¹). About 79 to 100% (on average 95.5%) of Cd present in the output material passed into the infusion; the infusion contained, on average, 3.613 μg kg⁻¹ (range 1.2–10.33 μg). A very low positive correlation \( r = 0.15 \) was identified between the content of Cd in coffee and the degree (%) to which Cd passed into the infusion (Fig. 1a). On average, dry coffee prior to brewing contained ca. 49.6 μg kg⁻¹ Pb (range 21.22–80.06 μg kg⁻¹), whereas coffee grounds < LOQ — 10.2 μg kg⁻¹. In 17% of coffee ground samples, the level of Pb was lower than determinable using the analytical method applied (LOQ = 0.03 μg kg⁻¹). From nearly 79 to 100% (on average 94%) of Pb passed into the infusion, the infusion contained, on average, 46.86 μg kg⁻¹ (range 16.66–80.06 μg). A low positive correlation \( r = 0.26 \) was identified between the content of Pb in coffee and the degree (%) to which Pb passed into the infusion (Fig. 1b).

**Coffee drinking safety**

Data concerning the estimated safety of drinking coffee infusions, taking into account three consumption patterns (1, 2 or 3 cups of coffee a day), is presented in Table 5.

**Pattern 1: 1 cup of coffee a day**

The estimated weekly intake (EWI) of Cd with coffee infusion is 0.156 μg, which accounts for about 0.09% TWI. The value of CDICd and THQCd indicators is identical and it amounts to 0.022. The estimated weekly intake of Pb is 1.968 μg, which corresponds to ca. 0.27% BMDL₀₁ and ca. 0.64% BMDL₁₀. The value of CDIPb = 0.281, whereas that of THQpb = 0.08. The HI risk factor (Cd + Pb) is 0.103.

**Pattern 2: 2 cups of coffee a day**

EWI of Cd with coffee is 0.312 μg, which accounts for 0.18% of TWI. The value of CDICd and THQCd indicators is 0.045 each. EWI of Pb is ca. 0.312 μg, which accounts for 0.18% of TWI. The value of CDIPb = 0.281, whereas that of THQpb = 0.08. The HI risk factor (Cd + Pb) is 0.103.

**Pattern 3: 3 cups of coffee a day**

EWI of Cd with coffee is 0.468 μg, which accounts for 0.27% TWI. The value of CDICd and THQCd indicators is 0.066 each. EWI of Pb is 0.312 μg, which accounts for 0.18% of TWI. The value of CDIPb = 0.281, whereas that of THQpb = 0.08. The HI risk factor (Cd + Pb) is 0.103.

### Table 3: Content of Cd and Pb in dry ground coffee (before brewing), dregs and infusions (n = 23), μg kg⁻¹

|                | Dry coffee | Dregs | Infusions | Leaching percentages of Cd and Pb |
|----------------|------------|-------|-----------|----------------------------------|
| **Cd**         |            |       |           |                                  |
| 1              | 5.041E      | 73.37E | 0.600F    | 4.443D                           |
| 2              | 10.33I      | 74.37F | < LOQA    | 6.280H                           |
| 3              | 1.204A      | 34.84B | < LOQA    | 5.134G                           |
| 4              | 3.991D      | 38.04B | < LOQA    | 2.143C                           |
| 5              | 8.883H      | 43.47C | < LOQA    | 1.087B                           |
| 6              | 3.289C      | 80.06G | 0.702G    | < LOQA                           |
| 7              | 1.502A      | 44.21C | < LOQA    | 1.120B                           |
| 8              | 2.106B      | 33.87B | < LOQA    | 1.060B                           |
| 9              | 3.413C      | 58.13C | < LOQA    | 3.100C                           |
| 10             | 2.204B      | 61.35E | 0.122B    | 1.223B                           |
| 11             | 1.273A      | 55.41D | < LOQA    | 3.206F                           |
| 12             | 2.106B      | 61.35E | < LOQA    | 4.581F                           |
| 13             | 3.122C      | 54.36D | 0.189C    | 1.250B                           |
| 14             | 7.703F      | 33.35B | 0.133B    | < LOQA                           |
| 15             | 6.111F      | 44.36C | < LOQA    | 3.561D                           |
| 16             | 1.489A      | 55.36D | 0.100B    | 2.105D                           |
| 17             | 2.110B      | 21.36A | 1.122B    | 3.210D                           |
| 18             | 3.311C      | 65.12E | 0.191C    | 3.220D                           |
| 19             | 4.089D      | 21.22A | 0.210F    | 5.458E                           |
| 20             | 2.210B      | 35.48F | < LOQA    | < LOQA                           |
| 21             | 3.401C      | 48.22C | 0.103B    | 2.010F                           |
| 22             | 5.824F      | 63.22E | 0.223C    | 2.011C                           |
| 23             | 4.350D      | 38.95B | 0.484E    | 4.123F                           |

Average values for 3 replications

A, B Means with different superscripts in the same column differs significantly at \( P < 0.05 \) by Duncan’s test; LOQ Cd = 0.010 μg kg⁻¹; LOQ Pb = 0.030 μg kg⁻¹
3.94, which corresponds to 0.54% BMDL₁₀ and nearly 1.3% BMDL₁₀. The value of CDIₚb = 0.56, whereas THQₚb = 0.16. The HI risk factor equals 0.205.

**Pattern 3: 3 cups of coffee a day** EWI of Cd with infusion is less than 0.5 μg, which accounts for about 0.27% TWI. The values of CDIₖd and THQₖd indicators are 0.067 each. EWI of Pb was equal to 5.715 μg, which corresponds to about 0.78% BMDL₁₀ and about 1.86% BMDL₁₀. The value of CDIₚb = 816, whereas THQₚb = 233. The HI risk factor equals 0.3.

**Discussion**

In the presented studies of this author, dry coffee contained on average nearly 3.8 μg Cd and ca. 50 μg Pb per 1 kg of the natural product, which accounts for ca. 0.004 μg Cd and 0.003 μg Pb per 1 kg of the natural product.
Table 5  Safety of coffee for consumption

| Pattern 1: drinking 1 cup of coffee a day | Cd  | Pb  |
|-----------------------------------------|-----|-----|
| EWI, μg | 0.156 | 1.964 |
| % TWI | 0.089 | |
| % BMDL<sub>01</sub> | 0.268 | |
| % BMDL<sub>10</sub> | 0.726 | |
| CD<sub>2</sub> | 0.222 | 0.281 |
| THQ<sup>3</sup> | 0.222 | 0.080 |
| HI<sup>4</sup> | 0.103 | |

| Pattern 2: drinking 2 cups of coffee a day | Cd  | Pb  |
|-----------------------------------------|-----|-----|
| EWI, μg | 0.312 | 3.936 |
| % TWI | 0.178 | |
| % BMDL<sub>01</sub> | 0.541 | |
| % BMDL<sub>10</sub> | 1.278 | |
| CD<sub>2</sub> | 0.045 | 0.562 |
| THQ<sup>3</sup> | 0.045 | 0.161 |
| HI<sup>4</sup> | 0.205 | |

| Pattern 3: drinking 3 cups of coffee a day | Cd  | Pb  |
|-----------------------------------------|-----|-----|
| EWI, μg | 0.468 | 5.715 |
| % TWI | 0.267 | |
| % BMDL<sub>01</sub> | 0.777 | |
| % BMDL<sub>10</sub> | 1.856 | |
| CD<sub>2</sub> | 0.067 | 0.816 |
| THQ<sup>3</sup> | 0.067 | 0.233 |
| HI<sup>4</sup> | 0.300 | |

<sup>1</sup> EWI, estimated weekly intake calculated on the basis of the mean weekly consumption of coffee infusions and mean level of Cd and Pb
<sup>2</sup> Chronic daily intake calculated on the basis of the mean weekly consumption of coffee, mean level of Cd and Pb and exposure duration
<sup>3</sup> Target hazard quotient calculated on the basis of the chronic daily intake of Cd or Pb
<sup>4</sup> Hazard index is the sum of THQ for Cd and Pb

0.05 μg Pb per 1 g. As 95.5% Cd and 94% Pb passed into the infusion, the infusion contained on average 0.0037 μg Cd and ca. 0.047 μg Pb per 1 g. Considering the consumption of coffee infusion (1, 2 or 3 cups a day), an adult Pole consumes less than 0.5 μg Cd and nearly 6 μg Pb per day. Based on the content of coffee grains, the grains of coffee from Brazil contained 0.006 μg Cd g<sup>−1</sup> and 0.12 μg Pb g<sup>−1</sup>. According to other authors, the content of Cd and Pb in the ground coffee was lower than LOD, which means that the risk of developing diseases connected with chronic exposure to Cd and Pb consumed with coffee must be evaluated as very low. Coffee drinking safety is also confirmed by the degree of coverage of the tolerable intake level of Cd and Pb recommended by EFSA [16, 17]. According to the studies of the present author, drinking 3 cups of coffee a day contributes to supplying these metals in the amount of less than 0.3% TWI (Cd) and less than 2% BMDL.
(Pb). According to Šemen et al. [34], drinking 2 cups of coffee a day contributes to Cd intake amounting to 0.01–0.06% PTWI and Pb intake amounting to 0.03–0.38% PTWI, depending on the type of coffee and content of toxic metals. Suseela et al. [31] found that drinking instant coffee contributes to intake of Cd amounting to 1.1% and that of Pb amounting to 0.7% of the acceptable limit in India. Pigozzi et al. [15] recount that 1 cup (50 ml) of Brazilian ground coffee infusion contains maximum 2.835 μg Pb, which accounts for 0.21 to 4.54% of the acceptable limit (that is 25 μg kg⁻¹ of body weight), while the content of Cd in those coffees was lower than LOD.

To sum up, the content of Cd and Pb in the analysed coffee infusions was very low. However, it must be remembered that no threshold limits for toxic metal consumption exist because these metals accumulate in the body for a long time; in the case of Cd and Pb, it is even 30 years [18], whereas their largest amounts accumulate in organs in charge of detoxicating processes (liver and kidneys) and in the brain [19, 36], leading to their damage and dysfunction. Nędzarek et al. [14] mention the level of Pb in coffee; despite it was low in their studies, those authors suggest that the content of Pb in coffee should be monitored regularly because it is higher than the content of Cd and can accumulate in tissues. Studies involving rats showed that during complex exposure (Cd + Pb), Pb accumulates in the organs to a higher degree than Cd (0.6% vs 0.48% in adults and 0.5% vs 0.7% in a younger population) [19, 36]. Lead is absorbed to a higher extent by the gastrointestinal tract than Cd after oral intake (10–50%, 1–8%) [37, 38]. In the presented study of this authors, an alarming signal is CDIₚb close to 1. It must be taken into account that some authors found that the Pb level was higher than acceptable in 75% of the analysed samples [15, 30]. The studies presented here also showed a low (r = 0.26) but still, a positive correlation between the content of Pb in coffee and the degree (%) to which Pb passed into the infusion. This problem should be thoroughly investigated.

**Conclusions**

The content of Cd and Pb in the analysed coffee infusions was very low, so drinking coffee does not pose a risk for consumers in terms of the content of these metals. However, it must be remembered that no threshold limits for toxic metal consumption exist because these metals accumulate in the body for a long time; in the case of Cd and Pb, it is even 30 years.

**Compliance with ethical standards**

Conflict of interest  The authors declare that they have no conflicts of interest.

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