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Review

Determination and Evaluation of Harmful Substances in Herbal Tea

Ya Li [1], Jiao-Jiao Zhang [1], Yong-Hong Chen [2], Zhi-Fei Zou [2], Tong Zhou [1], Dong-Ping Xu [1], Sha Li [3], Hua-Bin Li [1, *]

[1] *Guangdong Provincial Key Laboratory of Food, Nutrition and Health, Department of Nutrition, School of Public Health, Sun Yat-Sen University, Guangzhou 510080, China*

[2] *Guangdong Inspection and Quarantine Technology Center, Guangzhou 510623, China*

[3] *School of Chinese Medicine, The University of Hong Kong, Hong Kong, China*

* Author to whom correspondence should be addressed; E-Mail: lihuabin@mail.sysu.edu.cn; Tel.: +86-20-87332391; Fax: +86-20-87330446.

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Abstract: Herbal teas have been consumed worldwide for a long history. The health-promoting benefits of herbal teas have been widely recognized, such as antioxidant, antidiabetic, anti-carcinogenic, and antimicrobial activities. However, multiple harmful substances have been detected in herbal teas, such as pesticide residues, polycyclic aromatic hydrocarbons, pyrrolizidine alkaloids, heavy metals, and radionuclides. The presence of these harmful substances could cause potential health risks to human beings, including some acute toxic syndromes and chronic diseases, such as cancer, kidney stones, tooth wear, and allergy. This review summarized the current knowledge about determination and evaluation of harmful substances in herbal teas.

Keywords: herbal tea; infusion; harmful substances; potential risk.

1. Introduction

The term “herbal tea” usually refers to an infusion or tisane of leaves, flowers, fruit, herbs, or

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other plant material that contains no *Camellia sinensis* (Desideri et al., 2011). To be specific, herbal tea is the combination of boiling water and dried fruits, flowers or herbs. The consumption of herbal tea could date back to thousands of years ago in many countries, such as China, India, Thailand and Greece. In China particularly, the history of using herbal teas might be as long as the usage of traditional Chinese medicines (TCMs), and many TCMs are also consumed in the form of tea (Li et al., 2016). In recent years, the consumption of herbal teas has increased worldwide, probably stimulated by cultural or psychosociological factors (Monbaliu et al., 2010), and that people have become aware of possible health benefits of natural products. Diverse health-promoting functions of herbal teas have been found, such as antioxidant, antidiabetic, anti-carcinogenic, and antimicrobial activities (Giulia et al., 2014). However, as the popularity of herbal tea use increases, unfortunately, so does the frequency of cases reporting suspected adverse interactions. In recent years, the cases reporting the harmful substances in herbal teas have increased, such as pesticide residues, polycyclic aromatic hydrocarbons, pyrrolizidine alkaloids, and heavy metals. The presence of theses harmful substances could cause potential health risks to human beings, including some acute toxic syndromes and chronic diseases, such as cancer, kidney stones, tooth wear, and allergy. Therefore, like other agricultural products, the materials used for infusions must be subject to control due to the presence of the harmful substances in herbal teas (Campillo et al., 2007). This review summarized the current knowledge about determination and evaluation of harmful substances in herbal teas.

2. Determination and Evaluation of Harmful Substances in Herbal Tea

2.1. Pesticide Residues

Many types of plants are consumed throughout the world as infusions for both pleasure and therapeutic purposes. A large variety of pesticides have been applied on different types of plants aiming at reducing the losses caused by harmful weeds, insects, and diseases. As a consequence, the risk of herbal plants being contaminated by pesticides such as organochlorine pesticides (OCPs) and organophosphorus pesticides (OPPs) has increased. The acute toxic effects of pesticides could be dizziness, headache, nausea, vomiting, abdominal pain or even spasm and coma. Moreover, pesticide residues from herbal teas could be accumulated in human body for a long time, causing chronic poisoning and inducing many chronic diseases, such as cardiovascular disease, liver disease, and cancer. Herbal tea is one of the most widely consumed beverages in the world, where the daily intake in some countries may reach 500 mL per person. Therefore, herbal tea may represent an important source of human exposure to pesticides (Campillo et al., 2007).

In a study, the residues of 11 pesticides (hexachlorobenzene, lindane, chlorothalonil, parathion methyl, parathion ethyl, fenitrothion, malathion, dieldrin, α- and β-endosulfan, and tetradifon) in herbal

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teas prepared with *Passiflora alata* Dryander spiked leaves were determined, using the stir bar sorptive extraction (SBSE) in combination with GC-ECD/FPD analysis. The results showed that the ranges of contents of OCPs and OPPs were from 0.05 to 1 pg/μL and from 0.15 to 3 pg/μL, respectively (Bicchi et al., 2003). In another study, organochlorine pesticide residue build-up from agricultural or storage practices in some popular brands of Indian herbal teas was analyzed. The results revealed scant presence of dichlorodiphenyltrichloroethane (DDT) or its metabolites; meanwhile, endosulfan, a highly toxic pesticide, was absent in all 8 brands of herbal teas studied. Hexachlorocyclohexane isomers were detected in 2 samples, but the levels were below the permissible limit for pesticide residue in foods (Naithani and Kakkar, 2004). Besides, the levels of pesticides in infusions of *Mentha piperita* L., *Cymbopogon citratus*, *Matricaria recutita* L., *Melissa officinalis* L., and *Pimpinella anisum* L. were measured. The results showed that for the samples *M. piperita* L., *M. recutita* L. and *M. officinalis* L., it was able to quantify three of the nine pesticides investigated: aldrin, p,p'-DDE, and p,p'-DDD, while for the *C. citratus* sample, aldrin, p,p'-DDE, and endosulfan II could be quantified. For the *P. anisum* L., only the presence of p,p'-DDD was detected (Budziak et al., 2008). In addition, two samples of camomile (*Matricaria chamomilla*) and two samples of pennyroyal (*Mentha pulegium* L.) were used as materials to test the pesticide residues. The results showed that 0.9 ng/mL of p,p'-DDE were found in an infusion prepared from a pennyroyal sample and variable amounts of seven pesticides (aldrin, bromopropylate, tetradifon, and p,p'-DDT and its metabolites) in the 0.2 – 0.8 ng/mL range were found in a camomile sample (Campillo et al**.,** 2007). Furthermore, the OCPs and OPPs in herbal infusions of *Passiflora* L. were determined by fiber introduction mass spectrometry technique. The results demonstrated the presence of OCPs and OPPs (Da Silva et al., 2007). In addition, the levels of OCPs and OPPs in herbal infusions of *Passiflora L.* were determined by GC-ECD. The results also demonstrated the presence of OCPs and OPPs (Zuin et al., 2004).

2.2. Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs), a large family of fused-ring aromatic compounds, are persistent and ubiquitous organic pollutants. The PAHs have raised considerable interest as a concern for human health, due to their carcinogenic and mutagenic capabilities (Boffetta et al., 1997). Dietary intake is the main way of exposure to PAHs, due to that their high molecular weight and lipophilic character could facilitate their bioaccumulation in human body, after the ingestion of polluted food (Phillips, 1999). PAHs have been reported in herbal infusions, and herbal tea is one of the most popular beverages in the world. Therefore, it is of importance to control the pollution of PAHs in herbal infusions.

In a study, the 15+1 EU priority (considered as priority pollutants by the EU) PAHs in herbal

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infusions were analyzed, using an online-SPE-LVI-GC-MS method. The results showed that the levels of PAHs ranged from below 0.5 (LOQ) to 460 μg/kg, with a median of 4.7 μg/kg and a mean of 39 μg/kg for benzo[a]pyrene (BaP), and from below 1.0 (LOQ) to 2,700 μg/kg, with a median of 39 μg/kg and a mean of 250 μg/kg for total PAHs (Schulz et al., 2014). In another study, 10 volatile PAHs in different herbal infusions were measured by headspace sorptive extraction (HSSE) and gas chromatography-mass spectrometry. The results showed that the contents of these PAHs were between 11 and 26 ng/L (Cacho et al., 2014). Besides, another research assessed the contamination of herbal teas with PAHs. Significant differences were found in the contamination levels of particular commercial brands of herbal teas. However, results showed that similar quality profiles of PAHs were observed, with a very high level of light PAHs in the total content of these compounds (Mar et al., 2008).

2.3. Pyrrolizidine Alkaloids

Pyrrolizidine alkaloids (PAs) are secondary metabolites naturally occurring in botany widely, and are a large group of heterocyclic compounds formed as esters of a necine base (1-hydroxymethylpyrrolizidine) with mono- and di-basic acids. Consumption of PA-contaminated food or beverages may cause acute or chronic diseases by inducing hepatic sinusoidal obstruction syndrome (Wiedenfeld, 2011). Culinary herbs, traditional Chinese medicines and herbal teas have been found to be food sources of human pyrrolizidine alkaloid exposure.

In a study, 274 tea samples including rooibos, melissa, peppermint, chamomile, fennel, nettle, and mixed herbal tea or fruit tea in Berlin market were analyzed for the PA amounts. The results showed that total PA concentrations in these teas ranged from < LOD to 5,647 μg/kg. Additionally, herbal drugs were investigated to identify the source of PA in teas in this study. The results suggested that PA in these samples were most likely a contamination caused by co-harvesting of PA-producing plants. In some cases such as fennel, anise or caraway, it could not be excluded that these plants were able to produce PA themselves (Bodi et al., 2014). In another study, nine PAs and one PA N-oxide in herbal teas (camomile, fennel, linden, mint, rooibos, and verbena) were screened and measured. The results showed that, in 24 samples, PA concentrations were above the limit of quantification and the sum of the nine targeted PAs was between 0.021 and 0.954 μg per cup of tea. These data indicated that in some cases, total concentrations exceed the maximum daily intake recommended by the German Federal Institute for Risk Assessment and the UK's Committee on Toxicity (i.e. 0.007 μg/kg bw) (Mathon et al., 2014). In addition, 10 targeted PAs and 4 of their N-oxides (PANOs) in herbal products (selected herbal teas and TCMs) sourced within Ireland were detected. It was found out that a total of 50% herbal teas and 78% Chinese medicines tested positive for one or more PAs and/or PANOs

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included within this study, ranging from 10 to 1,733 and from 13 to 3,668 μg/kg, respectively (Griffin et al., 2014). Furthermore, teas prepared from comfrey leaves (*Symphytum officinale*) were analyzed for the relative quantities of two hepatotoxic PAs, symphytine and echimidine. The results found out that the concentrations of symphytine and echimidine varied considerably between teas prepared from leaves, and a much higher content of symphytine was found in the tea when steps were included to reduce N-oxides prior to analysis. The authors drew the conclusion that the concentration of PAs in such teas might be underestimated substantially if the concentration of N-oxides was not taken into consideration (Oberlies et al., 2004).

2.4. Microbial Contamination

Microbial contamination of the herbal tea is possible during processing and manufacturing, since some of these herbal teas are not pre-treated to reduce their microbial load before consumption. Medicinal plants, black tea, herbal tea and puerh tea have been investigated for fungal contamination, and several toxigenic mold species have been identified, such as *Aspergillus*, *Penicillium*, *Fusarium* and *Alternaria* species. Meanwhile, it makes the microbial contamination a more complex problem since different molds can co-occur and toxigenic fungi are able to produce more than one type of mycotoxin.

In a study, a total of 115 commercially available herbal tea and medicinal plant samples were analyzed for the potential levels of fumonisin B-1 (FB1) and fumonisin B-2 (FB2) contamination. The minimum detectable amounts for the o-phthaldialdehyde derivatives of FB1 and FB2 were 0.025 μg/g (1 ng injected) and 0.125 μg/g (5 ng), respectively. The results showed that FB1 was detected in two samples (0.160 and 1.487 μg/g), and FB2 was detected in none of the samples (Omurtag and Yazicioglu, 2004). In another study, the raw tea and herbal infusion materials as well as for their drinkable products were analyzed by developing a multimycotoxin UPLC-MS/MS method. The limits of detection for the different mycotoxins varied between 2.1 μg/kg and 121 μg/kg for raw materials and between 0.4 μg/L and 46 μg/L for drinkable products. Among the 91 different tea and herbal infusion samples investigated, only in one sample, *Ceylon melange*, 76 μg/kg fumonisin B-1 was detected. No mycotoxins were detected in the drinkable products (Monbaliu et al., 2010). Furthermore, 22 conventional herbal teas available on the Swiss market were investigated for black *Aspergilli* contamination. The results showed that in total, 12 of 22 samples were found to be contaminated with black *Aspergilli* which were able to produce mycotoxins, indicating that black *Aspergilli* were widespread fungal contaminants of herbal teas (Storari et al., 2012). There were other studies focused on detecting the microbial populations in herbal teas. In a study, the types and levels of microbial populations in common medicinal and aromatic plants, as well as in their respective commercial herbal

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tea mixtures were examined. The presence of several kinds of microbes was detected. Among them, aerobic mesophilic bacteria, spore-formers and moulds had the highest plate counts, while yeast genera *Saccharomyces* and *Candida* were detected most often, as well as mould species of genera *Penicillium*, *Aspergillus*, *Cladosporium*, *Atternaria*, *Mucor*, *Fusarium*, *Rhizopus*, *Absidia*, and *Trichoderma*. Sulphite-reducing clostridia were also found. The results indicated that the processing of medicinal and aromatic plants seemed to increase the microbial populations, and some herbal teas seemed to be more prone to such contamination than others (Halt and Klapec, 2005). Interestingly, another study investigated the effect of steam pasteurization (at > 99 ^{o}C for 2.5 min), on the microbial load of *Lippia multiflora* herbal tea leaves. Several species of bacteria were identified, and most of the bacteria identified belonged to the genus *Bacillus*. One species each from the genera *Pantoea* and *Kocuria* was also identified, but only the *Bacillus* species survived the steam pasteurization treatment. These results indicated that the steam treatment should complement good agricultural and hygienic practices rather than replace them, as some bacteria could survive this treatment (Arthur et al., 2011). In another study, the presence of *Cronobacter sakazaki* in herbal teas was investigated. *C. sakazakii* is an emerging food-borne pathogen that has raised increasing interest in food industry, especially in the production of powder infant formula. The results showed that *C. sakazakii* was isolated from 48 (32%) samples dried herbal teas, and was not isolated only from 2 (4%) of the 48 tested samples of prepared tea. Moreover, in 46 (96%) of the samples *C. sakazakii* remained viable after 2 h, 12 h and 24 h. These results indicated that better control and improve testing as well as new facts about *C. sakazakii* were necessary (Stojanovic et al., 2011). Moreover, a study investigated pathogen growth in intentionally contaminated brewed tea over time, and found that some herbal teas used in clinical settings could cause a possible risk of patients developing a nosocomial infection when used in patient care (Wilson et al., 2004).

2.5. Heavy Metals

Iron, copper, zinc, and manganese are essential metals since they play a critical part in biological systems, whereas cadmium, arsenic, and lead are nonessential metals as they are toxic even in traces (Unak et al., 2007). As herbal tea products are normally produced in dried leaf form in tea bags or as an instant tea, they could be easily contaminated with heavy metals from the environment (soil, water, or air) during growth and the manufacturing processes when the ready-made products are produced (Chan, 2003). As heavy metals could cause a hazard to human health, limits in therapeutically or otherwise consumed plants are regulated for some of them.

In a study, a total of 14 diverse herbal teas, including yarrow, basil, St. John's wort, peppermint, horsetail, nettle, thyme, corn silk, hibiscus, marshmallow, chamomile, rosehip, heather and wild mint,

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were examined for heavy metal amount. The results showed that in the three samples (yarrow and two St. John's wort samples), cadmium concentration was higher than the maximum level for dried herbs, recommended by WHO (Mihaljev et al., 2015). Besides, the contents of Cd, Cr, Cu, Fe, Pb, Mn, Ni and Zn in several commercial herbal mixtures (Pyrosan, Septosan and Urosan) were measured. The results showed that the levels of Mn, Zn and Cd were characteristic for Pyrosan infusions, while Cr, Fe and Cd were specific to Septosan, and Mn, Zn and Fe to Urosan (Suchacz and Wesolowski, 2014). In another study, 14 medicinal plants from Serbia were analyzed for the levels of Fe, Mn, Cu, Zn, Mo, Co, Ni, Se, Sn and Al. The results showed that contents of the elements in the examined samples were in the range: Mn (23.86-453.71 mg/kg), Fe (61.87-673.0 mg/kg), Cu (6.68-24.46 mg/kg), Zn (16.11-113.81 mg/kg), Mo (0.576-4.265 mg/kg), Co (0.039-0.532 mg/kg), Se (0.036-0.146 mg/kg), Ni (0.738-6.034 mg/kg), Al (154.0-3015.0 mg/kg) and Sn (2.68-10.22 mg/kg), which were safe for human consumption (Mihaljev et al**.,** 2014). Furthermore, the amounts of some heavy metals (Al, Ba, Cr, Cu, Fe, Mn, Ni, Sr and Zn) in 18 herbal tea samples were determined (Altintig et al., 2014). The ranges of the levels of the investigated heavy metals were: Al (268.0 ± 0.6 to 2164.0 ± 0.6 μg/g), Ba (3.0 ± 0.1 to 101.0 ± 0.6 μg/g), Cr (2.0 ± 0.1 to 8.0 ± 0.1 μg/g), Cu (5.0 ± 0.2 to 64.0 ± 0.8 μg/g), Fe (18.0 ± 0.1 to 1471.0 ± 0.3 μg/g), Mn (121.0 ± 0.4 to 657.0 ± 0.7 μg/g), Ni (2.0 ± 0.1 to 17.0 ± 0.3 μg/g), Sr (6.0 ± 0.2 to 82.0 ± 0.2 μg/g), and Zn (15.0 ± 0.1 to 103.0 ± 0.4 μg/g). In another study, herbal teas (*Mentha piperitae folium* and mixture *Marticaria chamomilla flos* with *Lavandula officinalis flos*) were compared considering the total contents of microelements (Al, Ba, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Sr, Ti, and V). The results showed that the daily intake of all elements from the analyzed herbal tea infusion did not exceed the maximum permissible levels and did not constitute health risk (Szymczycha-Madeja et al., 2013). In addition, eight different types of herbal flowers and their infusions from China were assessed for potential health risk caused by arsenic and heavy metals. The results showed that in general, the concentration of iron was higher than those of seven other metals in the investigated herbal flowers and their infusions, and the dietary intakes of the eight metals determined from daily consumption 4.5 g of the investigated herbal flowers for a normal adult should pose no potential risk to human health (Zhu et al., 2013).

In another study, the overall content of lead in several herbal drugs was determined, as well as the content of lead which was released from tested drugs during the preparation of tea drinks. The results showed that the lowest overall content of lead was detected in chamomile and ranged from 0.73 to 0.77 μg/g, while the highest content of lead was determined in the samples of the frangula bark, and yielded approximately 3 μg/g. Meanwhile, it was also found that the content of lead released from the herbal drug into the tea drink was three to five times lower than those of the overall content of this metal (Kalicanin and Velimirovic, 2013). In addition, 25 herbal teas widely consumed in Serbia were investigated for 9 elements (Fe, Cu, Mn, Zn, As, Cd, Sn, Hg, and Pb). The contents of toxic elements

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(As, Cd, and Pb) were below the maximum permissible levels, except for one brand of peppermint tea in which the level of Cd was 8.61 mg/kg, much higher than the allowed 0.3 mg/kg (Razic and Kuntic, 2013). In another study, a multi-element analysis was conducted in mentha herbal teas (*Mentha piperita*, *Mentha pulegium* and *Mentha* species). The results showed that the level of Pb (0.65 ± 0.71 mg/kg) was below legal limits. The maximum permissible limit for Cd, 0.3 mg/kg, set by the WHO for medicinal plants, was exceeded by 19.44% of the samples (Rubio et al.**,** 2012). What's more, contents of 8 heavy metals (Zn, Ni, Fe, Cd, Cr, Pb Cu, and Mn) were evaluated in infusions prepared by 13 different herbal compositions. The results showed that the concentrations of heavy metals in infusions decreased in the following descending order: Mn > Fe > Zn > Cu > Ni > Cr > Pb > Cd. However, the concentrations of the tested elements did not exceed the allowable limits (Bogdan and Marek, 2012). Similar investigation was done in various children's herbal tea types for the concentrations of heavy metals. The results showed that lead concentrations were in the range of 0.340-1.564 mg/kg, and the concentrations of mercury were very low in all samples (0.002-0.004 mg/kg), which were both safe to human body (Miroslav et al.**,** 2008). Additionally, three types of popular herbal tea products, *Gynostemma pentaphyllum*, *Camellia sinensis*, and *Morus alba*, were analyzed for 19 kinds of elements. It was found that the level of Cd was high in *M. alba* infusion. However, the daily intake of all elements from these herbal tea infusions (three cups/day) is still within the average daily intake (Nookabkaew et al., 2006).

2.6. Radionuclides

Radionuclides enter the human body through inhalation and ingestion of natural or artificial radionuclides, and food has been considered to be the main pathway. Studies have found that the presence of radionuclides in beverages could constitute a pathway for their migration to the human. Since the consumption of herbal infusions is widespread nowadays, great importance should be attached to the control of radionuclide concentration in such plants.

In a study, the activity concentrations of K-40 and Cs-137 in herbal tea were determined, using the gamma spectroscopy method. The results showed that the activity concentrations of K-40 and Cs-137 were in the range of 130-1160 and 0.7-124 Bq/kg, respectively, indicating that the investigated herbal teas originating from Maljen, Zlatibor and Tara mountains were radiologically safe for human consumption (Mitrovic et al., 2014). In another study, several kinds of herbal teas were analyzed to determine natural and artificial radioactivity (Desideri et al., 2011). ^{210}Po was determined by alpha spectrometry, while ^{228}Ac, ^{214}Pb, ^{214}Bi, ^{210}Pb, ^{40}K and ^{137}Cs were determined by gamma spectrometry. The results showed that ^{228}AC ranged between 0.6 and 9.0 Bq/kg$_{dry}$, ^{210}Po between 1.90 and 36.1 Bq/kg$_{dry}$, ^{214}pb and ^{214}Bi between 0.7 and 4.9 Bq/kg$_{dry}$, ^{210}Pb between <10.0 and 58.9 Bq/kg$_{dry}$, ^{40}K

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between 463 and 936 Bq/kg_{dry}, and ^{137}CS between <0.3 and 2.6 Bq/kg_{dry}. In addition, 18 different samples of medicinal herbal infusions from Serbian market were analyzed for the natural and artificial radioactivity levels. The activity concentrations of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs were found to be in a range of 0.6-8.2, 1.7-15.1, 126-1243.7, and 0.3-8.8 Bq/kg, respectively (Milutin et al., 2011). Similarly, another study investigated some medicinal plants available as herbal teas in Romania for the radioactive contamination level. Six plants, *Tilia cordata*, *Matricaria chamomilla*, *Calendula officinalis*, *Ocimum basilicaum*, *Achillea millefolium* and *Hypericum perforatum*, were selected as experimental materials. The maximum levels of natural radionuclides were ranked as follows: Po-210 and U-238 in *Ocimum basilicum* and *Achillea millefolium* (8 mBq/kg and 40 mBq/kg, respectively), Pb-210 in *Matricaria chamomilla*, *Achillea millefolium* and *Hypericum perforatum* (30 mBq/kg) and Th-232 in *Achillea millefolium* and *Hypericum perforatum* (60 mBq/kg). Among them, *Achillea millefolium* showed the strongest potential to accumulate natural Pb-210, Po-210, Th-232 and U-238 radionuclides (Elisabeta et al., 2014). Besides, samples of *Peperomia pellucida* were measured for the concentrations of U-238, Th-232, Th-230, Ra-226, Ra-228 and Pb-210. The results showed that the radionuclide activity concentrations ranged from 4.3 to 38 Bq/kg, 1.7-124 Bq/kg, 2.1-38 Bq/kg, 8.5-37 Bq/kg, 3.2-46 Bq/kg, and 39-93 Bq/kg, respectively. In another study, 3 brands of *Ilex paraguariensis*, a mate tea, were analyzed for the K-40 and Cs-137 activities. The results showed that the average value for the K-40 activity were 1216 ± 8, 1047 ± 14 and 666 ± 13 Bq/kg, respectively. The Cs-137 activity was lower than the limit of detection (Scheibel and Roberto, 2007).

2.7. Other Harmful Substances

Except for the harmful substances contained in herbal teas mentioned above, there are still other categories of harmful substance that could directly or indirectly cause potential health risks to human health.

Fluorine is an essential element for human with a narrow margin between the requirement and toxicity, thus it is justifiable to control the concentrations of this element in its rich food source, i.e., teas to evaluate exposure of some groups of people and possible hazards on human health. In a study, the fluoride contents of 14 herbal and 7 fruit infusions were tested. It was found that herbal and fruit infusions were characterized by low values of fluoride (0.02-0.04 mg/L) after 5 min of brewing and increasing brewing time to 10 min caused only slight increases in some infusions. The researchers suggested that although fruit and herbal infusions are safer to consume, their fluoride contents are too low for caries prevention (Emekli-Alturfan et al., 2009). In another study, the fluoride contents in infusions of commercially available teas, herbal teas and instant tea were determined. It was found that, herbal tea infusions showed the lowest content of fluoride, ranging from 0.02 to 0.09 mg/L

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(Malinowska et al., 2008).

In addition, oxalate is widely distributed in plants. In general, ordinary people consuming food containing oxalic acid is not harmful; however, patients with gallstones are often suggested not to excessively consume food with high level of oxalate, since oxalate is able to bind to a significant proportion of calcium and form kidney or bladder stones. In a study, the contents of soluble oxalates (SO) in water infusions of herbal teas made by different extraction procedures were determined. The results showed that the water infusions prepared from whole herbal tea leaves with the use of EWPM (microwave radiation supported extraction at 80 ^{o}C) procedure were characterized by the highest SO content, for example: peppermint tea, 18.11 mg/g; sage tea, 12.23 mg/g; and nettle tea, 11.76 mg/g (Beata and Grzegorz, 2010).

Many epidemiological studies showed a high prevalence of tooth wear, even in young patients. One factor that may be contributing to this problem is the consumption of herbal teas. There was a study designed to determine whether an herbal tea were capable of eroding dental enamel. Three groups of 21 teeth were exposed to a conventional black tea Typhoo (R) (Group A), a herbal tea Twinings (R) Blackcurrant, Ginsing and Vanilla (Group B) and water (control). The results showed that the herbal tea resulted in tooth surface loss, five times more severe than the black tea (Brunton and Hussain, 2001). In another study, the erosive potential of a variety of herbal teas was assessed by measuring their pH, neutralisable acidity as well as their ability to erode enamel. Orange juice was selected as the positive control. The results showed that the amount of enamel removed following 1 h immersion in the herbal teas ranged from 0.00 to 9.6 μm, whereas the orange juice removed 3.3 μm of enamel. It could be concluded that many of the herbal teas were more erosive than orange juice (Phelan and Rees, 2003).

Several other unexpected and unpleasant substances have also been found in herbal teas in different studies. A study investigated the concentrations of morphine in several herbal teas and in urine of volunteers after enzymatic hydrolysis. Two Papaveris fructus containing herbal teas were administered to five male volunteers and urine samples were taken quantitatively during the first 12 h after the administration. The results showed that the morphine concentrations in the herbal teas were 10.4 and 31.5 μg/mL, respectively. The maximum morphine concentrations in the urine were 4.3 and 7.4 μg/mL, respectively (Van Thuyne et al., 2003). In addition, caffeine acts as a weak psychostimulant and is known to cause sleeping troubles. Therefore, the existence of caffeine in sleep-aid herbal teas was somewhat surprising and unpleasant. In a study, caffeine content was determined in 11 linden-based samples. The results showed that the concentrations were between traces and 110 mg/kg in the herbal material, while those in the corresponding prepared sleep-inducing hot beverages ranged from traces to 226 μg per cup (Caroline et al., 2014). Apart from caffeine and morphine, estragole, a volatile phenylpropanoid contained in a variety of edible herbs, has been demonstrated to

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be genotoxic and carcinogenic, and banned as flavoring substance to foodstuffs. A study confirmed the existence of estragole in infusions of commercial fennel seed teas, and the concentration was found to be within 50-250 μg/mL (Giulia et al., 2014). In another study, fourteen emerging contaminants in different herbal infusions (chamomile, linden-blossom and pennyroyal) were tested. Among them, estrone was detected in several herbal infusions (Beatriz et al., 2015).

Researchers have also found some unpleasant effects caused by herbal teas. There was a study investigated the contact allergy to herbal teas derived from the *Asteraceac* plant family in patients allergic to sesquiterpene lactones (SLs). The results showed that in 18 of 20 patients with SL allergy, there were positive test reactions to the *Asteraceae* teas, mainly to those based on German chamomile, dandelion and wormwood (Lundh et al., 2006). In another study, it was found that three generations of a same family presented acute and moderately severe atropine intoxications after drinking an infusion prepared with *Pulmonaria officinalis* (lungwort) (Baca-Garcia et al., 2007). Besides, another study investigated that whether drinking herbal tea could cause acute drug toxicity to a kidney transplant recipient. The results showed that some ingredients within the herbal tea had inhibitory effect on cytochrome CYP3A4 *in vitro* studies, indicating that transplant recipients should be alert that there might be potent interaction between the immunosuppressive drugs and herbs resulting in adverse effect on allograft function (Kwan et al., 2014).

3. Conclusions

As a natural health product, herbal teas have showed numerous healthy-promoting benefits. However, the harmful substances in herbal teas, which could raise potential risks to human health, should not be ignored. In recent years, increasing cases have reported the harmful substances in herbal teas, such as pesticide residues, polycyclic aromatic hydrocarbons, pyrrolizidine alkaloids, and heavy metals. The presence of these harmful substances could bring some acute toxic syndromes, or indirectly cause some chronic diseases to human beings, such as cancer, kidney stones, tooth wear, and allergy. Therefore, the materials used in herbal teas should be subject to control so that the potential healthy risks caused by consuming herbal teas could be decreased.

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