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Bisphenol A (BPA) is a chemical widely used both in plastics production and in thermal papers. Besides dietary consumption, dermal absorption through handling different papers was underestimated. BPA in different paper products from Guangzhou, China, were measured in this study. BPA transferred from thermal to common papers increased with increasing contact pressure. Absorption of BPA via dermal contact will increase when hands are in sweat. Washing hands could reduce BPA dermal exposure efficiently. However, about 19-47% amounts of BPA were still on hands after different washing methods. Though the estimated daily intakes of cashier are below maximum dose recommended by U.S. Environmental Protection Agency, chronic and long-term BPA exposure through dermal absorption should be paid more attentions.

Levels of bisphenol-A in different paper products in Guangzhou, China and assessment of human exposure via dermal contact

Ruifang Fan*[a], Biyan Zeng[a], Xiaosu Liu[a], Chao Chen[a], Qinwei Zhuang[a], Yongjun Wang[a], Mingli Hu[a], Yanshan Lv[a], Junnan Li[a], Yuanxiu Zhou[a], Zhi Yuan (William) Lin[b]

[a] Key Laboratory of Ecology and Environmental Science in Guangdong Higher Education, School of Life Science, South China Normal University, Guangzhou, China 510631

[b] Department of Nanotechnology Engineering, University of Waterloo, Waterloo, Ontario N2L3G1, Canada

Bisphenol A (BPA) is a chemical widely used both in plastics production as food and beverage containers and in thermal papers as a color developer. Dietary consumption is the main route of human exposure to BPA but dermal absorption through handling different papers might be underestimated or ignored. In this study, BPA in different paper products, including different types of papers, receipts and Chinese currencies were investigated. BPA was detected in receipts (n=87) and Chinese currencies (n=46) with concentrations of 0.17-2.675×10^4 μg/g paper and 0.09-288.55 μg/g paper, respectively. Except for parchment papers (n=3), copy papers (n=3) and food contact papers (n=3), BPA was measured in all of the other paper products with the levels of 0.01-6.67 μg/g paper. BPA transfer from thermal papers to common papers increased with increasing contact pressure. Compared with that in water, the migration speed of BPA was doubled in the synthetic sweat. Washing hands could reduce BPA dermal exposure and washing hand with lotion was the most efficient way. However, about 19-47% amount of BPA was still found on hands after different washing methods. Dermal absorption via handling of receipts and papers were estimated to be 36.45 ng/day for the general population and 1.54×10^{-3}-248.73 μg/day for a cashier,

respectively. These values are below maximum doses recommended by U.S. Environmental Protection Agency and European Food Safety Authority. However, due to its uncertain adverse effects on human beings, long-term BPA exposure through dermal absorption should be paid more attention, particularly for some occupational populations.

Corresponding author: Ruifang Fan, Ph.D.

Email: 20001047@m.scnu.edu.cn

Tel: +86 -20- 85211372

Fax: +86- 20- 85215535

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Introduction

Bisphenol A (BPA) is widely used in the production of many polycarbonate plastics, epoxy resin linings for food and beverage containers, and polyacrylate dental materials. The annual worldwide production of BPA exceeded 6 million tons.[1] In addition, BPA is a preferred color developer in carbonless copy paper and thermal paper. Due to its low cost, thermal papers containing BPA are still produced in massive quantities for a wide variety of commercial applications, including different cash receipts, luggage tags, faxes, and labels.

BPA could get into human body through diet, inhalation and dermal contact and cause a variety of effects on reproduction and development in animals and humans.[2-3] Human biomonitoring studies have demonstrated a nearly ubiquitous presence of BPA in urine and other biological matrices.[4-5] Commonly, dietary consumption is thought as the main route of human exposure to BPA.[6-10] But recent studies indicated that the measured concentrations of BPA in different receipts were in a range of 0.1-20 mg/g paper [11-12] and the daily intakes from the thermal paper were estimated to

be from 6.4 ng/kg bw/day to 0.03-5.78 μg/kg bw/day. [11-12] Moreover, as people always put the receipts containing high concentration of BPA together with cash in the wallet after shopping, BPA could be transferred to cash and more widely spread during the use of BPA-contaminated cash.[13] After the thermal paper is recycled along with the other common paper for re-production, all the other paper would be contaminated by BPA.

In vitro human skin tests showed that the dermal penetration amount of BPA was 8.6%, and a total amount of bio-available BPA was 9.3% of the dose applied after 24h incubation under realistic exposure conditions. This confirms that the systemic exposure to BPA via the skin is not negligible small.[14] Several studies conducted in viable skin models showed that the penetration amount of BPA through skin ranged between 15% and 65% and that thermal paper could be a direct source of unconjugated BPA[15] Due to the extensive use of thermal paper, the contribution of dermal contact to BPA exposure might be underestimated in our household lives.

In this study, BPA levels were reported in different types of paper products, such as supermarket receipts, paper currencies, magazines, newspapers and food wrapping papers. Additionally, potential human exposure doses of BPA from the handling of papers were estimated. The transfer of BPA from thermal papers to currencies in the wallet at room temperature was evaluated through overlapping common paper with thermal paper. The paper-palm skin transfer of BPA under different conditions was investigated by soaking thermal papers in water, synthetic sweat and the mixture of saliva and synthetic sweat, respectively. The most efficient way of hand cleaning was suggested by measuring the BPA levels in different hand washing solutions.

Materials and methods

Sample collections

A total of 220 paper products were collected from March to October in 2013. The receipts (n=87) were collected from 32 different spots, including stores, supermarkets, banks, restaurants and theatres in Tianhe District, Guangzhou, China. The Chinese

currencies (n=46) were collected in Guangzhou randomly. The different paper products (n=96) were collected mainly in Guangzhou including newspapers, auto copy paper, art papers, advertising papers, book papers, packing papers, magazines and food wrapping papers (Table 1).

Chemicals and reagents

BPA was obtained from Dr. Ehrenstorfer (Augsburg, Germany). Calibration standards of BPA were prepared at the concentrations ranged from 1.5 to 100 μg/L in methanol. Pure water was from a Milli-Q water system (Darmstadt, Germany). Sodium bicarbonate ($NaHCO_3$), potassium carbonate (K_2CO_3) and sodium chloride (NaCl) were obtained from Fisher Scientific (USA). All other reagents were of analytical grade and used without further purification.

Sample preparation

The papers were divided into two groups, including the thermal papers and non-thermal papers. The sample preparation procedure was as follows: Firstly, all paper samples were cut into small pieces, and about 0.1 g of thermal paper or 0.5 g of non-thermal paper and Chinese currencies were loaded into 50 mL glass tubes, and then ultrasonicated in 4 mL of methanol for three times (SB-80 ultrasonic instrument, Shanghai, China). The supernatants were combined, filtered and evaporated under the gentle nitrogen gas. Finally, it was reconstituted with 100 μL of methanol and stored at the freezer at -20℃until analysis.

Testing migration of BPA from thermal paper to currencies and synthetic sweat

In order to simulate the transfer of BPA from receipts to currencies, 9 new currencies of China were selected and placed in contact with 9 same thermal receipt papers with the known concentration of 24.44 mg BPA/g for 24 h, and one new currency was used as the blank sample. Different weights (i.e. 0.4 kg, 1.1 kg and 2 kg) were applied on them to simulate the different contact pressure. After 8, 16 and 24 h, the concentrations of BPA on 9 currencies were measured.

In the experiments of migration of BPA from thermal paper to the synthetic sweat, 2.000 g of thermal receipt was weighted for each, and 200 mL of water, 200 mL of synthetic sweat and 200 mL of the mixture of synthetic sweat (198 mL) with saliva (2 mL) were added to three beakers, respectively. Then, after the identical thermal papers were added into the beakers, they were incubated for 100 min at 37℃. The synthetic sweat was prepared according to the report by Liu et al.[16] One hundred milliliters of solution were taken every 10 min and BPA level in each solution was analyzed directly by high performance liquid chromatography (HPLC).

Instrumental analysis

BPA was measured on an Agilent 1100 series HPLC system (Agilent Technologies, Palo Alto, CA, USA) equipped with a vacuum degasser, a quaternary pump, an auto-sampler, and a fluorescence detector. A Chromolith performance RP-18e column (100×4.6 mm, 2 μm, Merck Germany) was used to determine BPA in different papers. Methanol and water were used as mobile phases. The gradient was initialized from 60% methanol and ramped to 100% in 6 min, and then 100% methanol was held for 4 min. The column temperature was set at 25℃ and the flow rate was at 0.6 mL/min. The excitation and emission wavelengths for the detection of BPA were set at 278 and 314 nm, respectively.

Efficiency of hand cleaning methods

One volunteer cashier was recruited. His hands were cleaned carefully with the methanol-soaked cotton balls prior to experiments. Three routine cleaning ways were simulated: (1) only rinsed hands with tap water for 10s; (2) rinsed hands with tap water and rubbed hands for 10s; (3) rubbed hands with lotion and then rinsed hands with tap water for 10s. Firstly, after the volunteer simulated the cashier to handle the thermal receipts for 1h, the methanol-soaked cotton balls were used to wipe the palms' and the fingers' area 3 times. The total amount of BPA on palms and fingers ($\sum$BPA) was the summation of the three times' measurements in the cotton balls.

Then the first simulation and cleaning way were carried out. When hands were dry, the second simulation experiment continued. The procedure was the same as the first one. To avoid the variation to the most degree, the volunteer was required to handle the same thermal paper receipt for 1 h with the same handling frequency and contact stress. Although only one volunteer did the experiment of the cleaning efficiency, it was replicated three times and the results were the average data.

After the cottons balls were extracted by sonication for 30 min in 10 mL of methanol, the extracts were dried under the gentle nitrogen gas and then reconstituted with 100 μL of methanol, stored at the freezer at -20℃ until analysis. The amount of BPA measured in the three cotton balls ($\sum BPA_{(after\ washing)}$ was divided by the $\sum BPA$ and the ratio was defined as the clean efficiency (Shown in the Eq1)).

$$\text{Clean efficiency (\%)} = \frac{\sum BPA_{(after\ washing)}}{\sum BPA} \times 100 \qquad \text{Eq (1)}$$

All cotton balls in this experiment were pre-cleaned with acetonitrile and methanol in advance, to confirm that the BPA residual amount in these cottons was lower than the method detection limit. Every simulation experiment was performed three times and the final results were the mean ratios.

Quality assurance and quality control (QA/QC)

To avoid the contamination of BPA from plastics, glass and metal containers were used as much as possible in the study. All the calibration curves were linear and R^2 values were above 0.99. The detection limit (LOD) of BPA was 0.65 μg/L, which was defined as 3 times the signal-noise (S/N) ratio. When the concentrations of BPA in paper samples were above the highest limit of the calibration curve, the final solution was diluted with methanol for re-analysis. Three levels of BPA (500, 10 and 1 μg/mL) were spiked into the paper samples to control sample quality, and the recoveries were between 75-108% with RSDs less than 20%. The intra-day variation (n=6) and inter-day variation (n=6) was 100±19% and 100±5%, respectively. Twelve samples were set as a batch. In each batch, a method blank, a solvent blank

and three levels of QC samples were analyzed. Two solvent blanks were run following the analysis of the highest levels of calibration standards and QC samples to examine and avoid the potential carry-overs. To monitor the potential instrumental variation, every 10 sample in a batch was inserted with one standard (10 μg/mL). If neither of deviations exceeded 10%, the instrumental performance (resolution and sensitivity) was considered to be acceptable for the analysis of a batch of samples.

Estimated daily intakes of BPA exposure via dermal contact

For different populations, because the frequency of handling paper currencies and thermal receipts vary, the estimated daily intakes of BPA (EDI, unit: ng/day) are significantly different. Equation 2 was used to estimate the BPA exposure.[17-18]

$$EDI = k \times C \times HF \times HT \times AF / 10^9 \qquad \text{(Eq. 2)}$$

Where k is the paper-to-skin transfer coefficient of BPA (calculated as 21522.4 ng/s); C is the concentration of BPA in the different types of papers (μg/g); HF is the handling frequency (times/ day); HT is the handling time of paper; and AF is the absorption fraction of BPA by skin, which is 27%.

For general people, questionnaires were taken to learn the handling time and handing frequency of different paper products in their household lives, including reading books, newspapers, magazines and brochures, opening the packing of goods, sending or receiving mails and paying money. The average times or frequencies were listed in Table 2.

Three cashiers in one store (32 stores in total) were selected randomly to investigate for their daily work hours and the numbers of customers they served to determine the HD and HF. The averages of HD and HF were used to calculate the estimated daily intakes of BPA for the cashiers.

Statistical analysis

The SPSS program, version 10, was used for statistical analysis. The skewness normality was applied to check the distribution normality of BPA concentrations. For

descriptive analysis (geometric mean, median, SD, range, 95th percentile), the results are presented as μg BPA/g paper (μg /g) or mg BPA/g paper (mg/g). For the target compounds with concentrations below the detection limits (LLODs), LLODs were directly used for statistical analysis rather than zero.

Results

Except for the parchment papers (n=3, which was classified into the art papers), the auto-copy papers (n=3) and the food contact papers, BPA could be detected and determined in all the other papers. The geometric mean, range, median, 95th percentile and detection frequency of different types of the papers were listed in Table 1. The paper receipts were grouped into thermal-paper and non-thermal paper. The concentrations of the thermal paper receipts had the highest BPA concentrations (in a range of 0.16-26.75 mg/g) among all of the paper products. The non-thermal paper receipts had the lower concentrations ranged from 0.17-4.76 μg/g BPA, which were similar to the other non-thermal paper products. The non-thermal paper products, such as the newspapers and the book papers, had the concentrations of BPA (μg/g) from LLOD to 11.61, which were thousand times lower than the thermal paper receipts. As for the currencies, the concentrations of BPA (μg/g) ranged from 0.09 to 288.55, covering 5 orders of magnitudes. The currencies were significantly lower than those in the thermal paper receipts (T-test, $p<0.05$), but slightly higher than those in the non-thermal paper products.

The simulation tests showed that BPA transferred from thermal paper receipts to currencies increased as the pressure applied to the thermal papers and currencies increased (Shown in Fig. 1). The solubility experiments of BPA-containing thermal paper showed that BPA was quickly dissolved into these solutions and reached a constant concentration in half an hour. The BPA migration amount in the synthetic sweat solution (about 160 μg/L) was almost double than that in the water (about 80μg/L), however it was similar to that in the mixture of sweat and saliva (Shown in Fig 2).

The cleaning efficiency experiments showed that the concentrations of BPA left on the palms decreased quickly after different cleaning ways. Three simulation experiments showed that the initial BPA levels on hands after handling thermal paper were 143, 150 and 160 μg/L respectively, when the volunteer handled the paper with the same frequency and contact stress. Hence the mean value of 151μg/L was used as the initial concentrations of BPA on hands. After hands were rinsed with water for 10s, with water and rubbing hands for 10s, and with tap water and lotion, respectively, the residues of BPA on hands were 85.54, 55.19 and 28.05μg/L. Hence the cleaning efficiencies were 43.31%, 61.51% and 81.34%, respectively (Shown in Fig. 3).

The people's life habits and the average frequency of HF and HT were investigated to estimate the daily BPA intakes (Shown in Table 2). The mean values for daily intakes of BPA for general population, through the handling of different types of papers and currencies, were summarized in Table 2. The total absorption of BPA (ng/day) via dermal contact was calculated as 36.45 for the general population. As for the occupational population, such as cashier, the EDIs ranged from 4.3 ng/day to 229.6 μg/day with the average concentration of 122.7 μg/day and with the median concentration of 148.5 μg/day (Shown in Table 3), which were 3366 times higher than that for the general population. Here, HF was assumed as 320 per day (the contact frequency was 40 times per hour and the work time was 8 hours per day according to the investigation) and HT was assumed as 5s per time.

Discussion

Exposure source of non-thermal paper and currencies

The results of Table 1 indicated that concentrations of BPA in the thermal paper were 3 or 6 orders of magnitude higher than those in the non-thermal paper products, which was in accordance with the previous reports.[11, 12, 18] Though BPA was not added into common paper products, it could be detected and determined in most of the paper products. Thermal paper might be the BPA source of non-thermal paper.[11,18] Non thermal paper products could be contaminated by BPA from large quantities of the thermal paper receipts in the paper recycling process.[18] Moreover,

Fig 2 also suggests that currencies could be polluted by BPA when a receipt is placed near the currency in a cash register or wallet or whenever one handles a receipt before handling money. Hence in our daily life, awareness should be kept to classify different types of paper garbage. Moreover, thermal paper receipts should be discarded after shopping, instead of being kept in the wallet. Hormann' study already found that French fries were easily contaminated by BPA transferred from people's hands after they held thermal receipt paper immediately. And the combination of dermal and oral BPA absorption had led to a rapid increase in the concentration of unconjugated BPA to, 7 ng/mL in serum and, 20mg total BPA/g creatinine in urine within 90 min. [19]

Though the food wrapping papers collected were limited, as they were collected randomly, it is a good and satisfactory fact that BPA was not detected in these samples. Based on the previous study, food contaminated by BPA was main exposure source.[20] Hence, the food wrapping papers should be from the wood pulps, not the recycle papers. In addition, good habits should be developed before eating food to avoid the BPA contamination from hands.

Characterization of BPA transfer dynamics and the efficient cleaning ways

Although BPA is more readily dissolved in sweat than in water, the results in the study are not the direct proof that the absorption of BPA via dermal contact will be increased. However, it is possible to deduce that when hands are in sweat, more BPA could be dissolved in it and then the probability of BPA absorbed via dermal could increase significantly (Shown in Fig 2). The synthetic sweat solution contained basic $NaHCO_3$, and BPA has two hydroxyl groups, which make them react with basic group quickly. These might be the reasons why BPA is easily dissolved into it. So when our palms are sweating, the potential exposure to BPA through the dermal contact would increase significantly when handling the BPA-containing papers. Studies on the female rhesus monkeys postulated that the impact of non-oral routes of human exposure to BPA has been greatly underestimated.[21] As thermal receipts are applied in our everyday household lives, the frequency of skin absorption via handling the

thermal receipts will go up in modern society, especially when hands are wet or sweating. Study conducted by Biedermann et al also indicated that BPA penetration through skin depends on various conditions. When holding a receipt made of thermal printing paper for 5 s, roughly 1 μg BPA (0.2-6 μg) was transferred to the forefinger and the middle finger if the skin was rather dry and about ten times more if these fingers were wet or very greasy.[22] For the cashiers in Guangzhou who handle thermal paper receipts and currencies about 320 times everyday, the potential health risk from exposure to BPA via dermal contact should increase significantly to 64-1920 μg/day.

The amounts of BPA transferred from the thermal paper to the fingers and palms were an important step to ensure the relevance and reliability of this experiment. It was influenced by the frequency of touch and the power of contact. In our initial experiments, three volunteers were recruited to estimate the cleaning efficiencies. They were requested to simulate the cashier to handle the same thermal paper for 10 min with the same frequencies and touch powers. Then the amounts of BPA were determined to assess the variations of BPA transfer from the thermal papers to the fingers and palms. However, the results showed that the amounts varied significantly (Data not shown here).

It suggested that it was difficult to control the same amounts of BPA transferred for different persons. Hence, we selected one volunteer to simulate the whole procedure and replicated for 3 times in three days because we found that after several trainings he could controlled his touch power and touch frequencies to ensure that CV of the amount of BPA transfer was below 15%. And the pre-experiments also showed that the simulation time could influence the amount of BPA because the skin might be saturated. One hour was finally determined because the variation of BPA amount could be ignored.

The results showed that washing hands after handling thermal paper could effectively reduce the residues of BPA left on palms and fingers (Fig 3). Washing hands with lotions were the most efficient way among the three different cleaning ways. However, a large amount of BPA remained on hands after tap water rinsing. Even with hands cleaning with lotion, there was still at least 18.66% BPAs left on

palms. Hence routine cleaning ways is not enough for the removal of BPA completely from hands. For the occupational populations, such as cashier, to keep palm dry and clean hands with methanol after work or wear gloves is an efficient way to reduce the potential exposure risk to BPA.

Risk assessment of BPA exposure via dermal absorption for different populations

Humans contact different types of papers everyday in household life. Because the BPA concentrations of common papers were low, the EDI for general population was 36.45 ng/day, which was much lower than the recommended concentration (50μg $(kg/bw)^{-1}day^{-1}$) given by the United States Environmental Protection Agency (EPA) and European Food safety Authority.[17] Hazard assessments in 2009 by major regulatory and advisory bodies have shown that the overall no-observed-adverse-effect level (NOAEL) for BPA from robust data is 5 mg/kg body weight/day[23] and the European Food Safety Authority (EFSA) recently proposed to decrease the tolerable daily intake (TDI) to 5 μg/kg/day[24]. The EDI for a cashier in this study was as high as 229.6 μg/day, which was similar to the report by Lu,[11] but it was still lower than 50 μg $(kg/bw)^{-1}day^{-1}$ or 5μg $(kg/bw)^{-1}day^{-1}$) (assumed a weight of 60 kg for an adult). In conclusions, dermal exposure to BPA contributes marginally to the total exposure for the general population, and that for the cashiers it could be of concern. However, a disputed issue is whether the low-level and long-term exposure to BPA is safe for people, especially for those pregnant women and for the toddlers.[25-26] Mounting evidences have suggested that the low dose of BPA exposure plays an important role in the prevalence of metabolic syndrome.[25-27] Hence, it is important and crucial to avoid BPA exposure in our household life and for those special and occupational populations. The sensitivity analysis study in the previous report showed that HT and HF were the variables that contributed mostly to the total variance of BPA exposure both for general and occupational population groups, [11] which suggested that people could avoid handling thermal papers to reduce the BPA exposure and the potential risks induced by BPA.

Conclusion

In conclusions, BPA could be detected and determined in most of the paper products in Guangzhou, China. Their concentrations ranged from LLOD to more than 200 mg BPA/g paper. Thermal papers might be the main source of BPA to common papers, which are polluted in the paper recycling reproduction process. When hands are wet or sweating, the risks of BPA adsorption through dermal increased significantly. The EDIs of BPA via dermal contact were much lower than the value of biological safety given by U.S EPA and European Food Safety Authority, both for the general and occupational population. However, due to the ubiquitous presence of BPA in our household life, the low-level and long-term exposure to BPA should be taken into closer account, particularly for occupational and special populations.

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Table 1: Concentrations of BPA in the different paper products from Guangzhou, China

BPA concentration in receipts (mg/g paper)						
Type of receipts	n	GM	Range	Median	95th percentile	Detection frequency (%)
thermal paper	56	13.94×10^{3}	0.16×10^{3}-26.75×10^{3}	16.60×10^{3}	25.04×10^{3}	100
non-thermal paper	31	0.80	0.17-4.76	0.69	3.06	100
BPA concentration in currencies (μg/g paper)						
	n	GM	Range	Median	95th percentile	Detection frequency (%)
currency paper	46	3.17	0.09-288.55	2.34	34.61	100
BPA concentration in different paper products (μg/g paper)						
Types of paper	n	GM	Range	Median	95th percentile	Detection frequency (%)
newspaper	15	6.54	2.12-11.61	7.63	11.37	100
auto copy paper	12	4.85	LLOD -6.39	4.85	6.29	75
art paper	12	2.95	LLOD -6.67	3.64	6.64	75
advertising paper	6	0.94	0.71-1.15	1.00	1.13	100
book paper	21	0.350	0.01-1.78	0.61	1.73	100
packing paper	9	0.65	0.21-1.42	0.75	1.40	100
magazine paper	18	0.16	0.06-1.35	0.12	1.26	100
food wrapping paper	3	LLOD	LLOD	LLOD	LLOD	0%

n: number of the samples; GM: geometric mean;

Table 2: EDIs of BPA in the household life through skin absorption by handling different papers for the general population[17]

Type of paper	action	HF（times/day）	HT（s/time）	EDI (ng/day)
book	reading	40	2	0.16
magazine	reading	5	30	0.14
newspaper	reading	15	60	34.20
packing paper	opening	5	30	0.57
envelope	Sending or receiving	1	60	0.27
brochure	reading	2	30	0.33
currencies	Paying	10	2	0.37
Thermal paper receipt	Paying	1	5	0.41
Total				36.45

HT: handling time; HF: handling frequency; EDI: estimated daily intakes

Table 3: The estimated daily intakes of BPA for cashiers from receipts from different supermarket spots (unit: μg BAP/day).

Store number	Number of Sample	Mean	SD	Range
1	10	21.3×10^{-3}	8.6×10^{-3}	13.5×10^{-3}-44.3×10^{-3}
2	15	218.3	13.4	196.4-239.7
3	9	176.6	35.6	153.9-229.6
4	9	6.9×10^{-3}	4.6×10^{-3}	2.6×10^{-3}-17.0×10^{-3}
5	7	8.4×10^{-3}	11.9×10^{-3}	1.7×10^{-3}-35.1×10^{-3}
6	7	3.7×10^{-3}	1.5×10^{-3}	2.5×10^{-3}-5.9×10^{-3}
7	6	151.8	3.9	148.1-155.5
8	5	7.2	5.4	1.5-14.5
9	5	126.5	3.4	122.7-129.2
10	5	114.8	5.2	109.7-122.0
11	5	147.8	1.5	145.9-149.4
12	4	185.7	36.0	164.0-227.2

Note: All of the receipts were collected from 32 different spots. The receipts from different spots which belong to the same supermarket or store were combined.

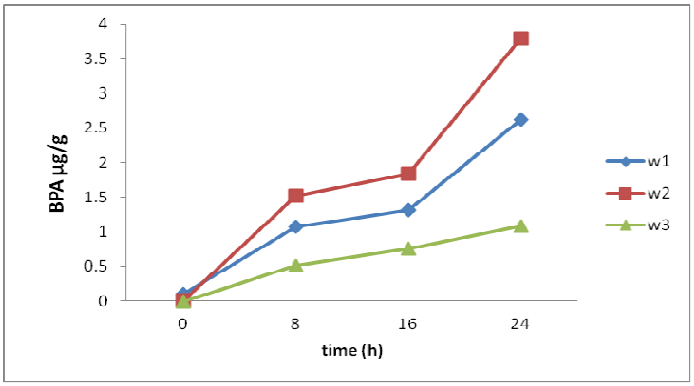

Fig 1: BPA transfer from thermal receipt papers to currencies over time for different applied pressure (w1 (0.4 kg), w2 (1.1 kg), w3 (2 kg).

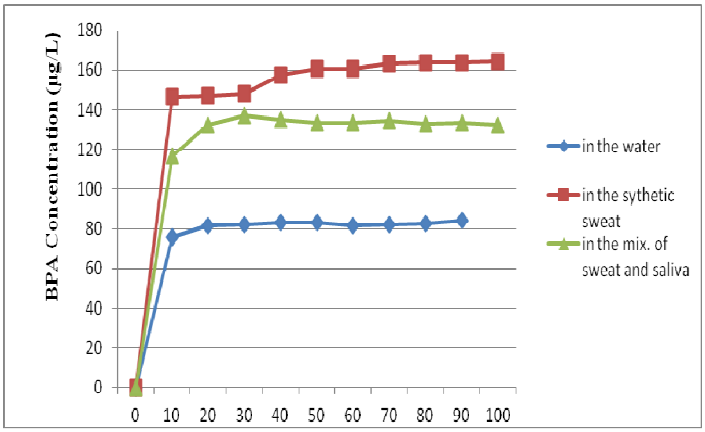

Fig 2: Dynamics of the BPA migration from thermal paper to water, synthetic sweat, and mixture of sweat and saliva at 37℃.

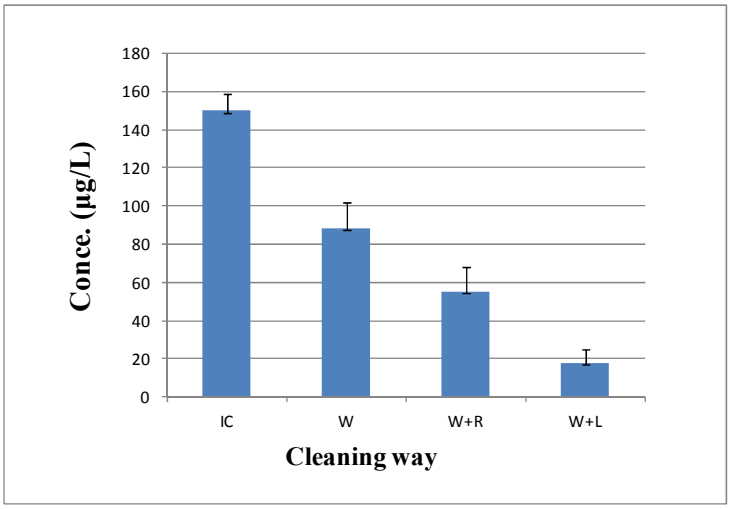

Fig. 3 The residues of BPA levels on hands after different cleaning ways (Unit: μg/L) IC: the initial concentration of BPA after handling thermal paper. W: hands were rinsed with water for 10s; W+R: hands were rinsed with water and rubbing hands for

10s; W+L: hands were rinsed with tap water and lotion.