International Journal of Analytical Mass Spectrometry and Chromatography, 2026, 14(2), 17-32
https://www.scirp.org/journal/ijamsc
ISSN Online: 2332-1776
ISSN Print: 2332-1768

The Presence of Bisphenol A in Thermal Paper Receipts, and Its Extraction in Three Media: Water, Sanitizers, and Artificial Perspiration (Sweat)

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How to cite this paper: Sufyani, S.M., Aljohani, A.M., Alyamani, A.S., Alshammri, M.A., Theeb, M.H., Almahmoud, S.A.J. and Alhamzani, A.G. (2026) The Presence of Bisphenol A in Thermal Paper Receipts, and Its Extraction in Three Media: Water, Sanitizers, and Artificial Perspiration (Sweat). *International Journal of Analytical Mass Spectrometry and Chromatography*, **14**, 17-32.
https://doi.org/10.4236/ijamsc.2026.142002

Received: March 11, 2026
Accepted: May 11, 2026
Published: May 14, 2026

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Abstract

Bisphenol A (BPA) is a synthetic chemical commonly found in thermal paper receipts, which are widely used in various sectors such as supermarkets, gas stations, and ATMs. BPA is known to have adverse effects on human health, including endocrine disruption, reproductive toxicity, neurobehavioral disorders, and carcinogenicity. This study aims to evaluate different extraction methods to identify the optimal ratio for recovering BPA from thermal paper receipts in the Saudi Arabian market. Using liquid chromatography-tandem mass spectrometry (LC-MS/MS), we compared six extraction solutions: distilled water, distilled water/methanol (30:70), artificial acidic sweat/methanol (50:50), artificial alkaline sweat/methanol (50:50), artificial acidic sweat, and artificial alkaline sweat. Our findings indicate that the 30:70 distilled water/methanol and 50:50 artificial alkaline sweat/methanol solutions provided the highest BPA recovery, suggesting these ratios as the most effective for BPA extraction.

Keywords

Bisphenol A, Thermal Paper Receipts, LC-MS Mass, HPLC, Artificial Perspiration

1. Introduction

Thermal paper receipts are widely used in various sectors and settings, such as event tickets, retail, banking, healthcare, and education, to provide customers with a record of their transactions. However, these receipts may pose a potential health and environmental hazard, as they often contain Bisphenol A (BPA), *2,2-bis(4-hydroxyphenyl) propane*, a synthetic chemical substance. as shown in **Figure 1** [38]. There are concerns when touching these thermal papers, as Bisphenol A may leach from the paper surface and enter the human body through dermal absorption, ingestion, or inhalation [1].

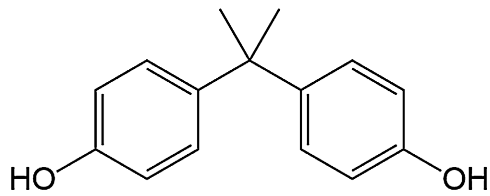

Figure 1. Bisphenol A, 2,2-bis(4-hydroxyphenyl) propane, Chemical Formula: $C_{15}H_{16}O_2$, M. Wt.: 228.29.

BPA is the most common color developer found in thermal paper, and it is easily released into the environment, which may cause dermal harms for those who are working in cashiers during their working hours [2]-[4]. BPA can be absorbed throughout the skin or enter the bloodstream of individuals touching their mouths after coming into contact with it [5]. More importantly, many individuals fail to recognize the potential risks associated with the transfer of substances from the thermal paper to their bodies. This concern is especially critical under conditions of humidity, sweating, or following the use of alcohol-based sanitizers.

There are four common chemicals (e. g., Lueco dyes, Developers, sanitizers, and stabilizers) that are used in the production of thermal paper. When they are combined, a clear and long-lasting image is created. The developers, such as Bisphenol A (BPA) and Bisphenol S (BPS), as well as sulfonylureas and zinc salts, are the essential components to produce the color [6]. When the dye is subjected to temperatures above its melting point within an acidic environment, the dye then becomes colored. When all of the aforementioned substances are mixed together under a heat source, the dye becomes dark. To ensure the chemical reaction is controlled and successful, sensitizers also have to be included, which are usually 3-methylphenoxy or 2-(benzyloxy) naphthalene, that melt around 100˚C. Sensitizers help improve the thermal reaction of the coating, facilitating dye and developer integration during melting, while stabilizers ensure smudge-free, durable prints [7].

It was reported that BPA is an endocrine disruptor that can interfere with the hormonal system and cause various adverse effects, such as reproductive dysfunction, metabolic disorders, neurodevelopmental impairment, and increased risk of cancer [8] [9]. Studies in mice show BPA exposure can result in increased prostate weight, brain and reproductive development issues, disrupted testosterone and sperm production, and reduced semen quality with DNA damage [10]. Moreover, BPA can also contaminate the environment and affect wildlife and ecosystems, as thermal paper receipts are frequently discarded and not recycled properly [11]-

[12]. Therefore, the use of this substance in baby and drinking bottles was prohibited in the European Union in 2011. (Directive, 2011/8/EU) [13].

Large quantities of BPA has been used in industry for manufacturing polycarbonate plastic, epoxy resin, dental materials as well as paper industry [14]. The production of BPA reached 8000 tons as market size volume by 2023 [15]. Forty-six percent of production is in Asia, followed by Europe (~28%), and America (26%) [10]. Globally, BPA is a key components of the production of polycarbonate plastics used for food packaging, epoxy resins, medical devices, printing, coatings, printer inks, and flame retardants raising concerns about human exposure [16].

Thermal papers that are coated with BPA have the potential to readily transfer BPA to human skin upon contact, hence, it cannot be negligible [3]. In literature, people involved in direct handling of thermal paper are exposed to BPA at levels approximately 50 to 3366 folds higher than those not in contact with it [17]-[19]. These studies are based on a constructed layout of exposure, which may lead to conflicting observations. In another study, voluntary employees (n = 32), who are in continuous contact with thermal papers receipts for at least 2 hours, showed higher levels of BPA [20]. There is an increasing concern about BPA in receipts, in terms of its harmanes and Extraction for both human and environment, respectively. In Europe, the tolerable daily intake (TDI) levels for BPA was established to avoid health risks, therefore, risk management should keep daily human exposure below these limits [21]. Recent studies have shown that the average total amount of BPA in urine in people regularly exposed to thermal paper was 2.5 times higher than in the control group. Therefore, to avoid exposure to BPA from receipts, the European Union has set a limit of <0.02 wt% (0.2 mg/g, 200 μg/g or ng/mg) for concentrations BPA in thermal paper and this restriction is in effect, since January 2020 [22]. Some EU Member States, such as Denmark, Belgium, Sweden, and France, have implemented additional national bans on the use of BPA in food contact materials and coatings. For instance, France banned BPA from all food packaging, causing a conflict with the plastic industry [23]. The Saudi Food and Drug Authority (SFDA) has implemented regulations and standards that worn against the exceeding limits of bisphenol A in the packaging of food and beverages, emphasizing the risks associated with elevated levels [24]. Many studies have shown that there is a variation in the amounts of BPA in the thermal papers, some of which are slightly higher than the permissible percentages. Semerjian *et al.* [22] reported detection of BPA in thermal papers receipt samples from various locations in Sharjah, United Arab Emirates, with most samples exceeding the EU limit of 200 ng/mg. The estimated daily intakes (EDI) ranged from 8.22×10^{-11} to 8.12×10^{-4} $\mu g \cdot kg^{-1} \cdot bw \cdot day^{-1}$, and for the cashiers, the study showed that EDI was between 7.89×10^{-9} and 0.0681 μg/kg bw/day. Therefore, all calculated TDIs, (4 μg/kg body weight/day), are below the European Food Safety Authority's, while the possible daily intake of Health Canada established the provisional tolerance of 25 ug/kg body weight/day according to various documents [16]. The first UAE study [22] on BPA in thermal paper receipts, highlights the importance of BPA limits set by the EU's and emphasizing that policies, education, and awareness can reduce dermal

BPA exposure in the general and occupational populations.

Various extraction methods have been employed in previous studies to detect and quantify Bisphenol A (BPA) in thermal papers [25]. Traditional solvent extraction methods, such as those using methanol and acetonitrile, have been commonly applied due to their effectiveness in dissolving BPA [5] [26]. These organic solvents efficiently disrupt the thermal paper matrix, releasing the trapped BPA molecules.

Solid-liquid extraction procedures have been further optimized to enhance the efficiency of BPA recovery. Studies have explored solvents like distilled water and methanol, often at elevated temperatures or with sonication (ultrasound) to improve extraction efficiency [3] [27]. For instance, Liao and Kannan (2011) employed a methanol-based extraction method at 35˚C for one hour to determine BPA concentrations in thermal paper receipts, demonstrating significant recovery rates exceeding 80% [3]. Similarly, research by Hormann *et al.* (2014) and Biedermann *et al.* (2010) utilized combinations of water and organic solvents, such as water-methanol mixtures, to improve BPA extraction from thermal paper [5] [26]. These studies achieved reliable and reproducible results, highlighting the effectiveness of these optimized techniques.

Beyond traditional methods, innovative approaches like the use of artificial sweat solutions have been explored to simulate human exposure conditions more realistically [24]. Artificial perspiration, formulated to mimic both the acidic and alkaline pH of human sweat, has been used to evaluate BPA Extraction from thermal paper under conditions mimicking skin contact. These studies indicate that the pH and composition of artificial sweat can influence BPA extraction efficiency. For example, studies have shown that acidic sweat solutions may extract lower amounts of BPA compared to alkaline solutions, reflecting the potential impact of sweat pH on BPA Extraction from thermal paper [16] [21]. This research provides valuable insights into potential exposure risks associated with the everyday handling of thermal paper receipts.

This study aims to establish the best method for extracting bisphenol A (BPA) from thermal papers like receipts and tickets, considering the potential risks associated with BPA exposure and the insufficient information regarding its concentration in thermal papers within Saudi Arabia. The research will evaluate six extraction techniques to determine which one maximizes BPA recovery from thermal paper receipts, thereby determining the most effective and dependable method for subsequent BPA research in the region. This study will use LC-MS/MS as a highly sensitive and precise method, to separate and measure BPA and other substances in present thermal paper.

2. Experimental Section

2.1. Materials

Standard of bisphenol A (99% purity) as the reference material was purchased from LGC limited, Teddington, UK. Methanol, an HPLC-grade was from Sigma-Aldrich (Saint Louis, USA). High-purity deionized water (Sartorius 900Portable, Gottingen, Germany) was used for all experiments. Acidic and alkaline artificial perspirations (sweats) solutions were freshly prepared based on the procedure that used in *ISO 105-E04* obtained from the Textile Products Laboratory department at Saudi Standards, Metrology, and Quality Organization (SASO).

2.2. Collection and Preparation of Samples

Eight samples of different brands of unprinted Thermal paper rolls were randomly obtained from markets in Riyadh city, Saudi Arabia. The samples were assigned numerical codes ranging from 1 to 8. The names of the brand were not revealed. The samples were cut into small pieces (0.3 to 0.5 cm) using stainless scissor to prepare them for the extraction setup.

2.3. Extraction Procedure

The solid-liquid extraction procedures were carried out into six different media of solutions as follow; 1) distilled water, 2) distilled water/methanol (30:70), 3) artificial acidic sweat/methanol (50:50), 4) artificial alkaline sweat/methanol (50:50), 5) artificial acidic sweat, and 6) artificial alkaline sweat.

Based on extraction processes that are reported in literature [28]-[30]. Using water and organic solvents like methanol, we have designed the extraction procedures by the aforementioned solvents. Our method was optimized by adding artificial perspirations as another solvent extraction, and by changing the solvents' mixtures ratio. In addition to that, the sonication-assisted extraction and the temperature was performed for each solvent medium.

Accurately, one gram of the unprinted thermal paper samples was added into a 100 mL solution of each of the mentioned above solutions. Each mixture was shaken in a shaker for 60 minutes at room temperature. A sonication for 60 minutes at 50 Hz was employed for the extraction by using mixtures that contain methanol to validate the method. After extraction process, each mixture was filtrated using syringe filter (0.45 μm) membrane, and 10 μL aliquot was transferred into a vial for a direct detection via (LC MS/MS).

2.4. Liquid Chromatography-Mass Spectrometry

The liquid chromatography-tandem mass spectrometry (LC MS/MS) analysis was carried out using the Agilent 1260 Infinity II LC chromatographic system connected to an Agilent 6420 triple quadrupole mass spectrometer. 5 μL of samples were injected into a Zorbax Eclipse plus C18 column (Agilent, 2.1 × 100 mm 1.8-Micron) maintained at 30˚C. The mobile phase employed in the analysis consisted of 65% methanol and 35% deionized water at a flow rate of 0.3 mL/min with the following isocratic: 35% deionized water; 65% methanol. The mass spectrometer operated in a negative ion mode MRM of 227.1 to 211 (quantitative) and 227.1 to 133 (qualitative), with the electrospray ionization source directing the chromatographic column effluent to it. The ion source and MS settings were as follows: desolvation gas flow 650 L/hr, source temperature 350˚C, capillary voltage - 1000 V, and cone voltage-31V.

2.5. Standard Calibration Method

Standard stock solutions were prepared in methanol at a concentration of 100 mg·mL^{-1}. From the stock solution, standard solutions (20, 40, 80, 100, 150, 200 and 250 μg·L^{-1} were prepared by dilution. First, the calibration range was tested at seven levels, then, six levels were used. The detection limit and quantitation were calculated based on the standard deviation (SD) of standard sample (20 mg·L^{-1}) in the blank solvent (distilled water/Methanol) in 30:70 ratio.

2.6. Validation

In order to demonstrate the consistency in the results, the method employed was validated following Saudi Standards, Metrology, and Quality Organization (SASO) guidelines. The method validation was performed in accordance with the requirements of ISO/IEC 17025:2017 to ensure the reliability and accuracy of the analytical results [39]. Parameters for validation are reported in **Table 1**.

Table 1. Validation parameters and reference materials analysis.

Sample Type	Mean (ppm)	SD (ppm)	RSD%	LOD (ppm)	LOQ (ppm)	Recovery%	Accuracy%	Precision
Blank Water	0.02088	0.00005	0.24%	0.000165	0.00050	—	—	Excellent
200 ppm Standard	224.075	15.894	7.09%	—	—	106.95%	106.95%	Good

The limits of detection (LOD) and quantitation (LOQ) were calculated using the standard deviation of the true blank (Blank Water), in accordance with the methodology described in 40 CFR 136 Appendix B. The following equations were applied:

$$\text{LOD} = 3.3 \times \frac{(\text{SD blank})}{\text{Slope}}$$

$$\text{LDQ} = 10 \times \frac{(\text{SD blank})}{\text{Slope}}$$

As a result, the LOD and LOQ values are significantly lower than 20 ppm, which means that the concentrations of 20 ppm and 40 ppm fall well within the quantitative range of the method and are not near the detection limits, contrary to what appeared in the previous version. After re-evaluating the analytical data, we identified an unintentional error during data entry. The blank values were mistakenly entered in ppb instead of ppm before performing the statistical calculations (Mean, SD, RSD%, LOD, LOQ). This unit-conversion error resulted in unrealistically low blank values and consequently affected some statistical outputs. All blank values have now been recalculated using the correct unit (ppm), and the updated results are fully consistent with the raw data and the expected performance of the analytical instrument.

3. Results and Discussion

Calibration curve was tested for seven levels. It was done by preparing standard solutions from the standard Bisphenol A (99% purity), LGC limited, Teddington, UK. The calibration was performed using standard solutions prepared in the same extraction medium used for sample analysis, ensuring matrix matching and minimizing matrix effects. The validity of the calibration for the other extraction media was confirmed through spike recovery experiments, which showed acceptable recovery values within ±10%, demonstrating that the calibration is suitable for all extraction media used in this study (Table 2).

Table 2. The validity of the calibration for the other extraction media.

Replicate	With spike (10 ppm)	Without spike	Difference	Recovery (%)
1	210.416	200.282	10.134	—
2	208.741	198.875	9.866	—
3	212.184	202.132	10.052	—
Mean	210.447	200.430	10.017	100.17%

A spike recovery experiment was conducted at a fortification level of 10 ppm in the extraction medium consisting of 70% methanol and 30% water. The mean concentration of the spiked sample was 210.447, while the unspiked sample showed a mean concentration of 200.430. The difference between the two means (10.017) closely matched the nominal spike level, resulting in a calculated recovery of 100.17%. This recovery value falls well within the internationally accepted accuracy range of 80% - 120%, demonstrating that the analytical method provides reliable quantification and performs accurately within this extraction matrix.

The linearity showed a correlation coefficient of a good linearity ($R^2 = 0.998$). The calibration curve, (Figure 2) was constructed and validated using concentration levels expressed in ppm, as this unit accurately reflects the working range of the analytical method and corresponds to the expected concentration levels in real samples. Although the raw instrument signals may appear numerically similar to ppb-scale values, the calibration standards themselves were prepared and verified on a ppm basis. Consequently, all calculations of mean response, standard deviation, %RSD, recovery, accuracy, and bias were performed relative to the true ppm concentrations.

Using ppm ensures full consistency with the method's quantitative range, the LOD/LOQ values reported in the study, and the regulatory framework under which the method is intended to operate. The results in Table 3 demonstrate that the method provides excellent precision (%RSD 0.32% - 2.58%) and acceptable accuracy (97.24% - 103.12%) across the 20 - 200 ppm range. These findings confirm that expressing the calibration curve in ppm is scientifically justified and aligned with the analytical purpose of the method.

Three replicates of each sample were analyzed, and the BPA concentrations

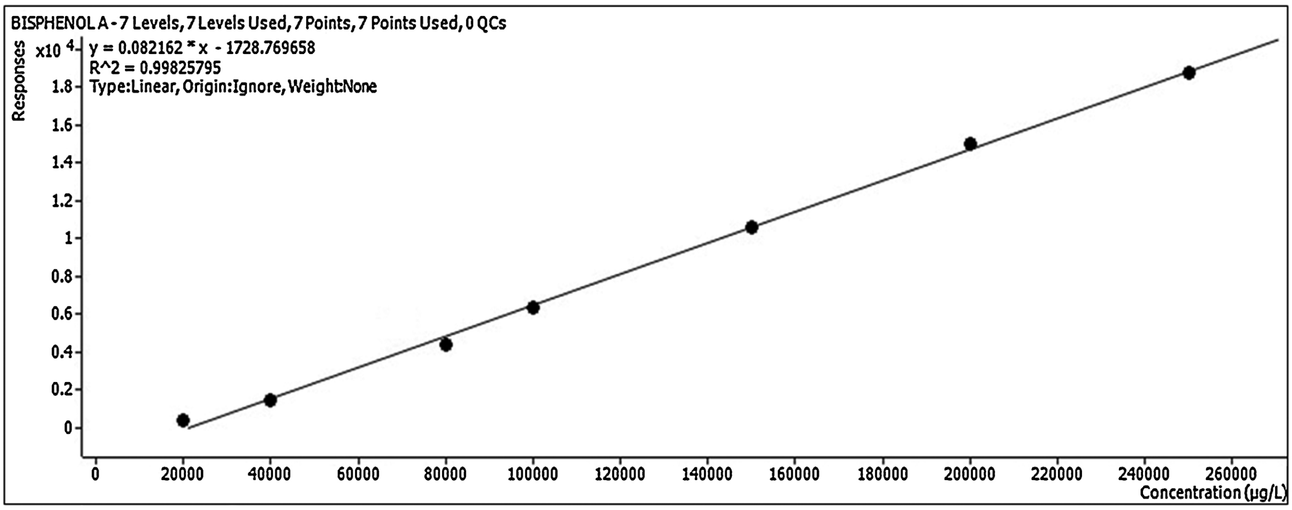

Figure 2. Calibration curve of standard BPA solutions.

Table 3. Accuracy and precision of calibration curve (ppm Basis).

True concentration (ppm)	Mean response	SD	%RSD	Recovery (%)	Accuracy (%)	Bias (%)	Precision (%)
20	20.051	63.92	0.32	100.25	100.25	+0.25	0.32
100	103.123	1326.57	1.29	103.12	103.12	+3.12	1.29
200	194.478	5014.61	2.58	97.24	97.24	−2.76	2.58

were evaluated as the mean of the three replicates. Validation parameters which characterize the analytical procedure are reported in Table 3.

The precision and accuracy for the BPA are summarized in Table 3. Samples of 20, 100, and 200 ppm of standard materials (BPA) with nine replicates were analyzed under the same conditions (30:70) distilled water and methanol.

The extraction process of BPA from unprinted thermal papers rolls was done according to previous reported methods [5] [23] [24] [26]. The concentration of BPA in the eight thermal papers samples was detected using different solutions mixtures as illustrated in Figure 3.

The BPA concentrations was found to range from 2.24 to 434.4 $mg·L^{-1}$ for the samples. The Technical Regulation for Paper and Cardboard by SASO, (SASO-2934), has reported that 200 $mg·L^{-1}$ is the allowed limit of BPA in thermal papers [31]. In the solid-liquid extraction, we have noticed that the Extraction of BPA in the different mixtures varied according to each solvent's property. Solid-liquid extraction by aqueous 70% methanol and alkaline sweat/methanol for each sample showed higher Extraction of the BPA, as extractable compound, in comparison to other solvents. This result is consistent with the reported data for BPA extraction from plastic products [32] [33] BPA, in samples number 1, 4, 5, 6, and 8, was found above the allowed limit that set by SASO, compared to other samples, (2, 3, and 7) which is detected less than the permissible limit. The average concentration of BPA in each thermal paper sample after extraction with distilled

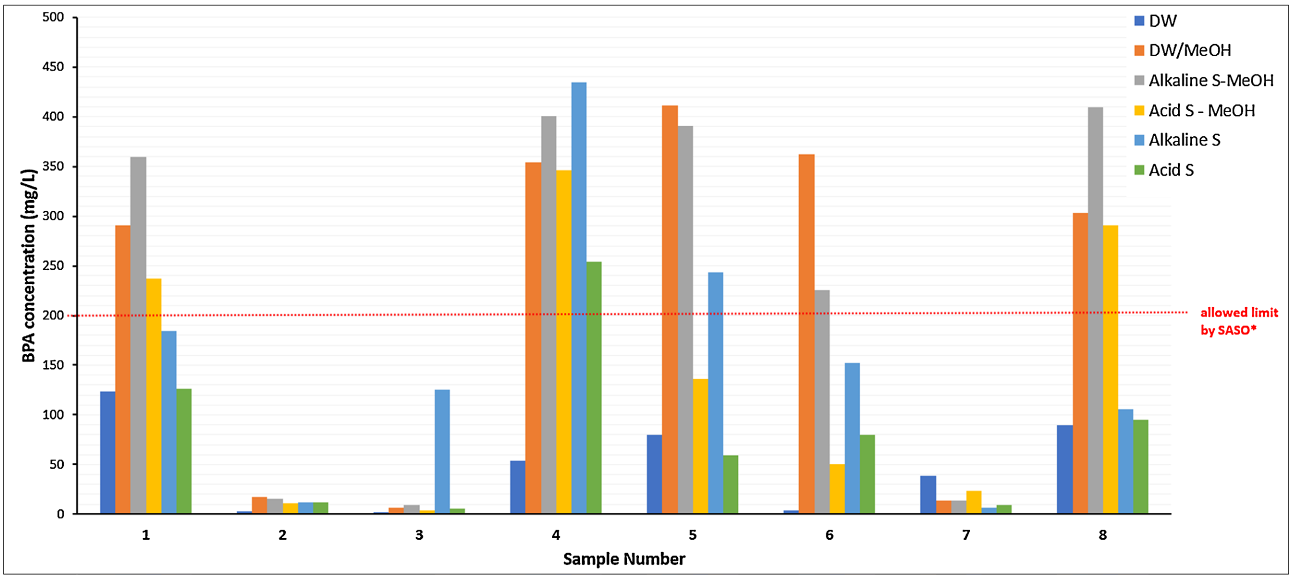

Figure 3. Concentration of BPA in the eight-samples of thermal papers.

water, distilled water/methanol, alkaline sweat/methanol, acidic sweat/methanol, alkaline sweat, and acidic sweat are 220.15, 11.7, 25.56, 307.1, 220.1, 145.6, 17.7, and 215.7 mg·L^{-1}, respectively as illustrated in Figure 3.

For samples that subjected to extraction with solution containing methanol have showed significant higher extraction of BPA, which is consistent with reported data in literature [34] [35]. Interestingly, the extraction of the BPA when using both basic sweat and acidic sweat without methanol is higher than that of distilled water. This is an alert since many people deal with receipts and tickets made of thermal papers, they may be exposed to the substance, especially in hot climates such as that of Riyadh region.

When comparing the Extraction of BPA into alkaline and acidic artificial sweats, the results showed almost similar concentration of the BPA for most of the thermal paper samples, with a slight increase noted for the samples that were treated with the alkaline artificial sweat, (Figure 4). These results are attributed to the chemical composition and pH values for the artificial sweats [36]. Still it falls into the risk for people health through dermal exposure. More investigations need to be carried out about transdermal exposure in terms of temperatures and humidity. Based on this Detection, samples 2, 3, and 7 showed the lowest concentration of BPA even after heating for a period of time. This is an interesting observation, it reveals that the BPA embedded in these thermal papers, is difficult to extract unlike in other thermal papers and hence may be safer to use in humid and hot climates.

2.4. Statistical Analysis

The descriptive statistics for BPA concentration in different media extractions are shown in the Table 4. The descriptive statistics reveal that each media of extraction was tested with 8 samples, and there is notable variation in the mean BPA

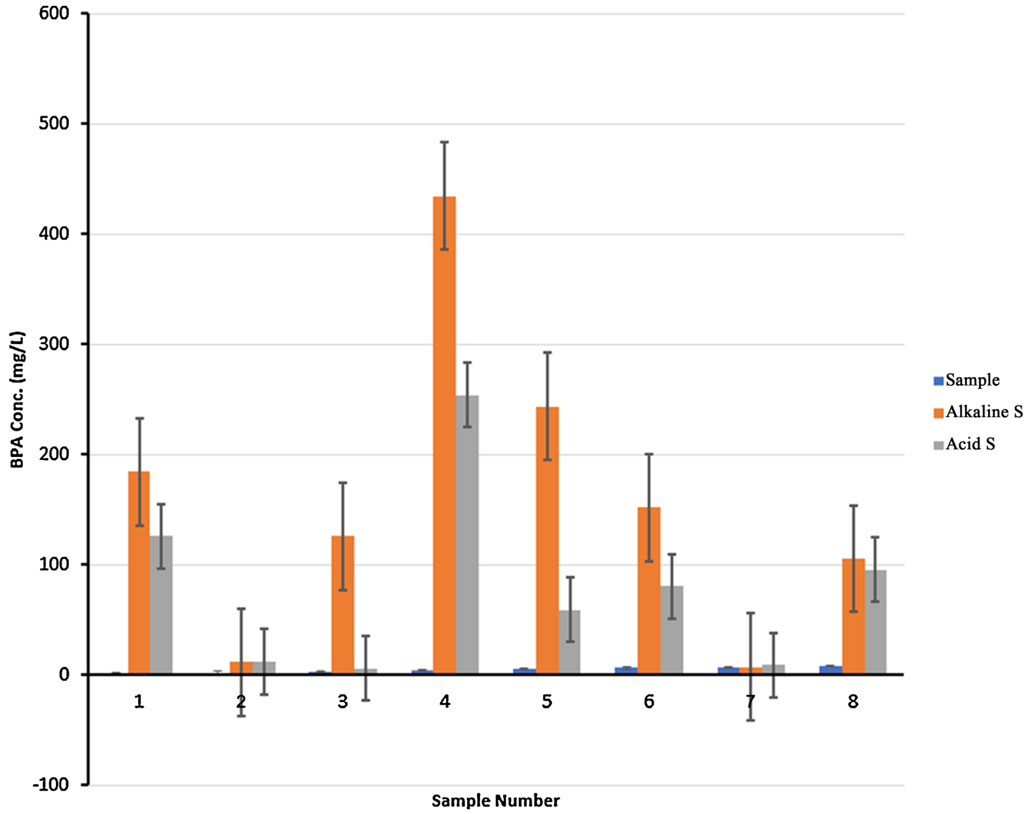

Figure 4. Concentration of BPA in the alkaline sweat and acid sweat.

Table 4. Descriptive statistics for different concentration methods of BPA (mg/L).

Method of Extraction	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Min	Max
				Lower Bound	Upper Bound		
(Method1) D. W.	8	49.21	45.59	11.09	87.33	2.25	123.35
(Method2) DW/MeOH	8	220.02	175.64	73.18	366.87	6.84	411.52
(Method3) Alkaline sweat: MeOH)	8	228.03	187.22	71.51	384.55	9.42	409.86
(Method4) Acidic sweat: MeOH)	8	137.23	137.06	22.65	251.82	3.52	345.94
(Method5) Alkaline sweat	8	157.98	137.59	42.95	273.01	6.82	434.42
(Method6) Acidic sweat	8	80.09	82.96	10.73	149.45	5.69	253.79
Total	**48**	**145.43**	**145.66**	**103.13**	**187.72**	**2.25**	**434.42**

concentration across the methods. Extraction with DW/MeOH mixture and Alkaline sweat/MeOH mixtures recorded the highest mean concentrations, while extraction with using distilled water and acidic sweat had the lowest. Method 3 also exhibited the highest variability in BPA concentrations, as indicated by its standard deviation, whereas Method 1 had the least variability. The 95% confidence intervals for the mean BPA concentrations provide a range within which the true mean is likely to fall, with Method 2, for example, ranging from 73.18 to 366.87 mg/L.

One-way analysis of variance (ANOVA) was employed to statistically analyze the BPA concentrations in thermal papers samples. ANOVA facilitates comparing the average contents between the different extraction methods. Data were considered statistically significant at $p < 0.05$. Table 5 shows the one-way ANOVA for different concentration of BPA obtained by the extraction methods.

The ANOVA analysis aimed to determine whether there are statistically significant differences in BPA concentration across the six methods of extraction. The resulting p-value is 0.069, which is slightly above the conventional significance threshold of 0.05. This indicates that the differences in BPA concentrations between the extraction methods are not statistically significant, but the result is close to the significance level, suggesting a potential trend worth further investigation.

Post-Hoc Test

Table 6 shows the multiple comparison analysis reveals for different concentration of the BPA in mg/L. The LSD (Least Significant Difference) multiple

Table 5. One-way ANOVA for different concentration methods of BPA (mg/L).

	Sum of Squares	*df*	Mean Square	F	Sig.
Between Groups	209,107.10	5	41,821.42	2.22	0.07
Within Groups	788,089.87	42	18,764.04		
Total	997,196.97	47			

Table 6. Multiple comparisons using LSD for different concentrations of BPA (mg/L) [37].

(I) Method	(J) Method	Mean Difference (I-J)	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Method1 D. W.	Method 2	−170.81	0.01	−309.03	−32.59
	Method 3	−178.81	0.01	−317.04	−40.59
	Method 4	−88.02	0.20	−226.24	50.19
	Method 5	−108.76	0.12	−246.98	29.45
	Method 6	−30.88	0.65	−169.10	107.33
Method2 DW/MeOH	Method 3	−8.00	0.90	−146.22	130.21
	Method 4	82.78	0.23	−55.43	221.00
	Method 5	62.04	0.37	−76.17	200.26
	Method 6	139.92	0.04	1.70	278.14
Method3 Alkaline sweat/MeOH	Method 4	90.79	0.19	−47.42	229.01
	Method 5	70.05	0.31	−68.16	208.27
	Method 6	147.93	0.03	9.71	286.15
Method4 Acidic sweat/MeOH	Method 5	−20.74	0.76	−158.96	117.47
	Method 6	57.13	0.40	−81.08	195.35
Method5	Method 6	77.88	0.26	−60.33	216.10

comparison analysis reveals several important findings regarding the BPA concentration significant differences across the methods of extraction media:

- Method 1 vs. Method 2 and Method 3: There are significant differences in BPA concentrations between Method 1 and both Method 2 and Method 3, with p-values of 0.017 and 0.012, respectively. The mean BPA concentrations for Method 2 and Method 3 are significantly higher than those for Method 1, as indicated by the negative mean differences.
- Method 2 vs. Method 6: There is also a significant difference between Method 2 and Method 6, with a p-value of 0.047, where Method 2 has a higher mean BPA concentration.
- Method 3 vs. Method 6: There is also a significant difference between Method 3 and Method 6, with a p-value of 0.037, where Method 3 has a higher mean BPA concentration.

4. Conclusion

In this study, eight samples of thermal paper rolls, from Saudi Arabia markets, were randomly collected and analyzed for determining the concentrations of Bisphenol A (BPA) in thermal paper receipts. The method involved solid-liquid extraction and analysis via liquid chromatography-tandem mass spectrometry (LC-MS/MS). The results of our study provide important insights into the presence and variability of BPA in thermal paper receipts and its potential implications for human health and the environment. The method of analysis was validated and statistically analyzed, and it showed good linearity, trueness, and precision. Regardless of the extraction method. For BPA in thermal paper receipts set by the Saudi Standards, Metrology and Quality Organization (SASO) and the European Union (EU) BPA concentrations vary depending on the amount and type of BPA present in the paper coating, as well as the brand and source of thermal paper receipts. It is important to conduct further studies on a wide range of samples from different sources and applications of thermal paper, such as restaurants, banks, hospitals, schools, etc. This would help assess the prevalence and diversity of BPA in thermal paper receipts and estimate exposure and risks for different segments of the population, especially those most vulnerable to the effects of BPA. The results of this study will help raise awareness of the prevalence of BPA in thermal paper receipts in the Saudi Arabian market and aid in developing policies and strategies to mitigate the potential health and environmental risks associated with this synthetic chemical. Based on our analysis, we found that BPA concentrations in thermal paper receipts varied depending on the brand and source of the receipts. The levels of BPA detected in some samples exceeded the regulatory limits and guidelines set by the Saudi Standards, Metrology and Quality Organization (SASO) and the European Union (EU). This suggests that there may be a potential health risk associated with the use of thermal paper receipts in Saudi Arabia. Further research is needed to expand the scope of this study and investigate a wider range of thermal paper receipt samples from different sources and applications, such as restaurants, banks, hospitals, schools, etc. This would help provide a more comprehensive understanding of the prevalence and diversity of BPA in thermal paper receipts in Saudi Arabia and allow for a more accurate estimation of exposure and risks.

Acknowledgements

The authors thank manager and supervisors at the Chemical and Petroleum Materials Laboratory at SASO for their support and engorgement, and the instruments laboratory staff for experimental assistance on varying parts of the current study. The authors also extend their appreciation and thanks to the Department of Chemical technology at Riyadh College of Technology and the Department of Chemistry at Imam Mohammad Ibn Saud Islamic University (IMSIU) for their academic support of this study.

Author Contributions:

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Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical reasons.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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