More than you Bargained For: BPS and BPA in Receipts

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SUMMARY

Did you know store receipts are a major contributor to your body's intake of the hormone-disrupting chemicals BPS and BPA? These chemicals are quickly and efficiently absorbed into the bloodstream through your skin.

To understand current use of these chemicals in receipt paper, Ecology Center's Healthy Stuff program tested 208 paper receipts from a wide variety of businesses. The samples included many major retailers as well as gas stations, theaters, libraries, small and independent businesses, and more.

We used our rapid screening method to detect the presence of BPA, BPS, and other chemicals known as "developers" coated on the special paper—thermal paper—typically used for printing receipts.

The negative effects of BPA on hormones, metabolism, and other bodily systems have been repeatedly demonstrated. BPS has emerged as a common and regrettable substitute, showing effects similar to BPA.

Employees who handle receipts or other thermal paper repeatedly in their jobs are at especially high risk.

Our study found:

- BPA or BPS in 93% of tested receipts
- BPS in 75% and BPA in 18%
- No coating on 2% of receipts
- Pergafast 201 (an alternative free of BPS and BPA) in receipts from Best Buy stores
- High prevalence of BPS in both retail and service sectors (85% and 68%, respectively)
- Higher prevalence of BPA in the service sector, especially restaurants, compared to retail sector (26% compared to 8%).

This study was designed to be a citizen-science study in which volunteers submitted receipts from several U.S. locations, primarily southeast Michigan. Receipts were analyzed using FTIR spectroscopy. The FTIR method was validated using GC/MS performed by a third-party lab.

BACKGROUND

Receipt paper

Businesses such as stores, restaurants, banks, airports, movie theaters, parking garages and more use thermal printed receipts and tickets (U.S. EPA, 2014). Thermal papers have a heat-sensitive layer comprised of three main components: a reactive dye, a color developer, and a sensitizer. Bisphenol A (BPA) and bisphenol S (BPS) are examples of color developers. The heat from a printer head promotes the dye to react with the developer, which produces a dark image (Minnesota PCA n.d.).

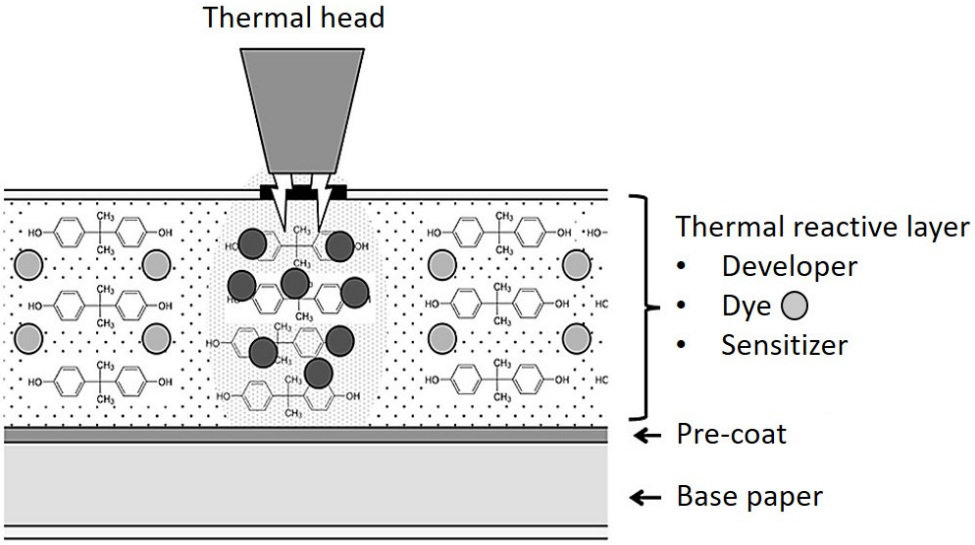

Figure 1: Diagram of thermal paper. (Hormann *et al.* 2014)

About BPA and BPS

With over 8 billion pounds produced per year, bisphenol A (BPA) is one of the most widely used chemicals worldwide. Approximately 94% of BPA is used as a base chemical in polycarbonate plastics and resin linings of food and beverage containers (Liao and Kannan, 2011a; U.S. EPA, 2014).

The heavy use of BPA is concerning because the chemical interacts with estrogen and thyroid hormone receptors, causing a cascade of biological effects (Kinch *et al.* 2015). Even low doses

have been found to impact fetal development and may contribute to reproductive impairment, ADHD, autism, obesity, and type 2 diabetes (vom Saal *et al*. 2007). The most vulnerable demographics are likely developing fetuses, infants, and adolescents (Cioci, 2015), but adults are also impacted. It may be a contributing factor in premature births and early onset puberty seen over recent decades (Ehrlich *et al.* 2014; Ndaw *et al.* 2016; Qiu *et al*. 2016). In one study, a surprising spike in blood pressure was observed in human adults after drinking from beverage cans with BPA-based linings (Bae and Hong, 2014).

Public concern about BPA has led to its elimination in certain products, notably baby bottles and sippy cups, some plastic drink bottles, and some receipt paper. **Unfortunately, the most common replacement chemical in receipt paper is BPS (bisphenol S, or 4,4′-sulfonyldiphenol)--a substitute that appears to be at least as detrimental to human health as BPA.**

Evidence suggests BPS speeds up embryonic development and disrupts the reproductive system (Qiu *et al.* 2016). Low dose exposures of BPA or BPS in zebrafish embryos led to an increase in neurons growing in the hypothalamus and, as a result, hyperactive behaviors later in life (Kinch *et al.* 2015). Recent experiments with mice found that BPS exposure caused poor maternal care of offspring (Catanese and Vandenberg, 2017) and a decreased ability to lactate (LaPlante *et al*. 2017). Together, these findings support the hypothesis that BPS negatively impacts the brain and other organs.

Pathways of exposure

In thermal paper, BPA and BPS are added in their free form, not chemically bound to the paper or polymerized. Thus the molecules readily transfer to anything touching the paper, including your skin, or paper money next to the receipt in a wallet. The potential for exposure from receipts is increased compared to the much lower concentrations of BPA and BPS found in some plastic bottles and the linings of food cans (U.S. EPA, 2010).

The chemical similarity of BPA and BPS suggests similar routes of human exposure. Indeed, the skin efficiently absorbs both chemicals (Russo *et al.* 2017) and several studies have shown that even briefly handling receipt papers leads to significant BPA or BPS absorbed into the body. BPS has an even greater half-life and ability to penetrate the skin than does BPA (Usman and Ahmad, 2016). **One analysis found over 88% of BPS exposure for most humans comes from handling thermal receipts (Liao *et al.* 2012)**.

Absorption of BPA into the body increases as much as ten-fold when thermal paper is handled with moist or greasy fingers (Biedermann *et al.* 2010). Also, using hand sanitizer or hand creams causes BPA to be much more rapidly absorbed through the skin (Hormann *et al*. 2014; Biedermann *et al.* 2010).

Dietary ingestion is another important route of exposure (Ehrlich *et al.* 2014). BPA and BPS from paper receipts transfer from unwashed hands to food and are then ingested (Hormann *et al*. 2014). People also ingest BPA when consuming canned foods lined with a BPA-based epoxy resin (Thayer *et al.* 2016) or drinking from plastic containers made from BPA or BPS.

Interestingly, a recent study found that BPA absorbed through the skin (e.g., handling a receipt) remained in the bodies of adults many days longer than BPA ingested via eating (Liu *et al.* 2017).

Occupational exposure

While virtually every person tested shows BPA and BPS in their bodies, workers such as cashiers who handle paper receipts have greater amounts of these chemicals in their bodies than the general population. Calculations of daily intake due to thermal receipts are summarized in **Table 1**.

Table 1. Estimated daily intakes of BPA and BPS by the general population and by the occupationally exposed. Units are nanograms per kilogram of body weight per day.

	Estimated Daily Intake (ng/kg bw/day) from paper receipts for a 70-kg person		
Chemical		**General Population**	**Workers Handling Receipts**
BPA and BPS (Rocha *et al.* 2015), Brazil	*Median*	20	1,014
	Maximum	29	1,429
BPA (Fan *et al.* 2015), China	*Median*	521	1,753
	Maximum	not reported	3,280
BPA (Lu *et al.* 2013), China	*Mean*	10	577
	Maximum	57	4,957
BPS (Liao *et al.* 2012), China	*Median*	4	312
	Maximum	11	821
BPA and BPS (Thayer *et al.* 2016), U.S.	Cashier workers had much higher BPA and BPS in their urine after a work shift.		

How much BPA and BPS is too much?

There is no scientific consensus on acceptable BPA or BPS intake.

Estimated tolerable intakes defined by certain government bodies for BPA are listed in **Table 2**. No agency has estimated a tolerable intake for BPS.

The European Union classifies BPA as toxic to reproductive organs and requires the chemical to be labeled as such. The European Commission has issued a ban on BPA in thermal paper to take effect in 2020. It has also asked the European Chemicals Agency (ECHA) to study BPS.

Table 2. Estimated tolerable intakes defined by selected government bodies for BPA listed from newest to oldest. Units are nanograms per kilogram body weight per day.

Government Body	**BPA limit from all sources, ng/kg-bw/day**	**BPS Limit**
European Food Safety Authority, EFSA (2015)	4,000	Not defined
U.S. Food and Drug Administration (2008)	50,000	Not defined
European Commission Scientific Committee on Food (2002)	10,000	Not defined

Comparing the estimated exposures listed in Table 1 to the estimated tolerable intakes in Table 2, it is clear that employees may exceed at least the most recent European limit for BPA just from handling receipts. In a real-world scenario, workers are exposed additional sources of BPA--and BPS--throughout the day.

Employees in myriad sectors are exposed: retail stores, libraries, parking lots, transportation, hospitals and clinics, entertainment, technicians handling medical test readouts, banking, restaurants, and more.

Some scientists who study hormonally active chemicals view the thresholds in Table 2 with skepticism, concerned they are too high. Researchers at the University of Calgary's departments of Medical Genetics and Biological Sciences explained in a 2015 paper (Kinch *et al.* 2015):

"[Government agencies] rely on linear dose-response relationships and so begin compound testing at high doses, then lowering the dose to the level at which no physiological effect is observed. However, many endocrine-disrupting compounds follow alternative U-shaped dose–response curves, whereby exposure to mid-range concentrations activates physiological

defense mechanisms against the compound, but at low-range concentrations, the compound mimics endogenous hormones."

The evidence for effects on the hormone system at very low doses is growing, but this research is still at an early stage. It is possible that current thresholds are too high to adequately protect human health.

METHODS

Sample Collection

Paper receipts were collected using a citizen science approach from consumers in southeast Michigan from January to April 2017. Consumers were instructed to fold receipts with printed side in and place in a paper envelope. The collected receipts were printed in 2016 and 2017 and originated from eight U.S. states with the majority from southeast Michigan. While not exhaustive of all possible businesses and entities that use thermal paper, the receipts in this study represent a wide range of retailers and service providers. The breakdown of business types is shown in **Figure 2**.

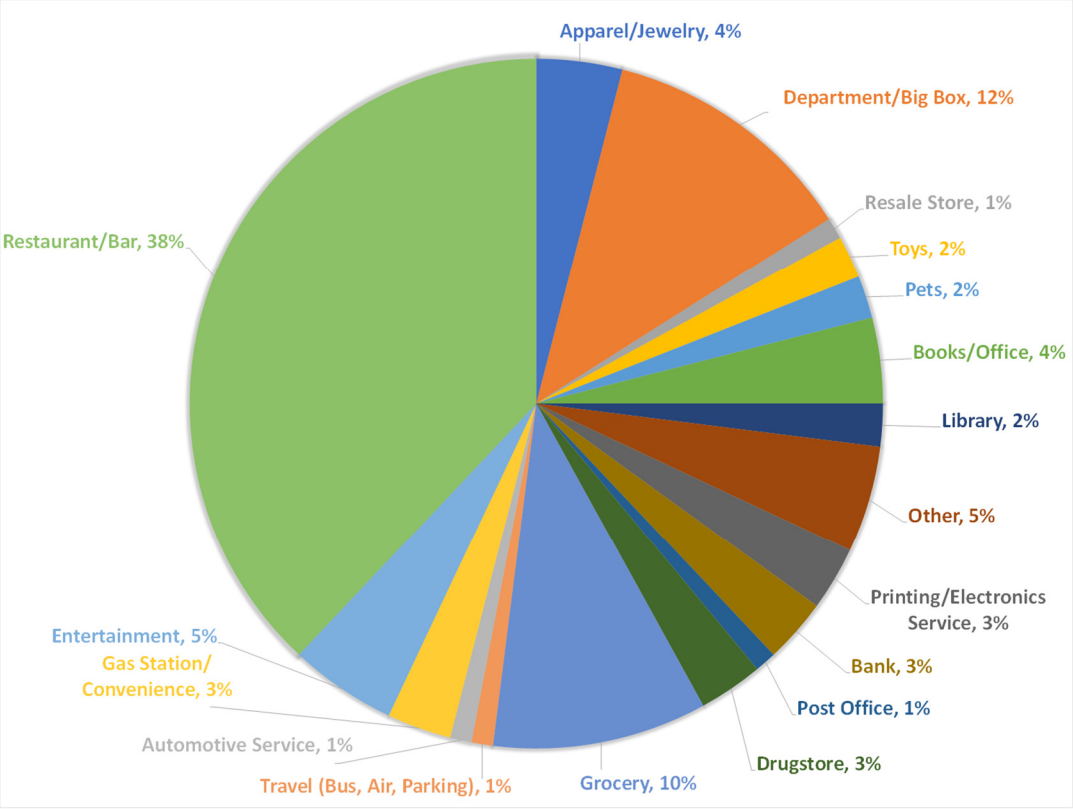

Figure 2: Percentage of receipts collected from each business category

Among the 208 receipts, we received 41 replicate receipts from 39 unique businesses locations. (For example, we received three receipts from a local favorite, Zingerman's Delicatessen, on 422 Detroit Street in Ann Arbor, MI.) Our analysis determined most of these replicate receipts contained the same developer chemical. To avoid skewing statistics, we removed redundant receipts from the data set. This resulted in 167 samples. Only two (TCAUP Media and The Raven's Club) had disparate results, namely one receipt from the same business location had BPS and the other had BPA, and these results were preserved in the data set.

Receipts collected from *different locations of the same store* were preserved in the data set.

Instrumental Analysis

Receipts were wiped with a dry Kimwipe to remove dust from the surface. Developer chemicals are abundant on thermal receipt paper, so this dry wiping did not affect our ability to detect BPA, BPS or other developer compounds.

Next, a Thermo Scientific Nicolet iS5 Fourier Transform Infrared (FTIR) spectrometer was used in attenuated total reflection (ATR) mode with a diamond crystal. Each receipt was placed with the printed side on the ATR sample stage and a spectrum was obtained from 4000-450 cm^{-1}. For some receipts, a spectrum was also obtained from the back side to verify the absence of thermal coating chemicals on that side.

To avoid cross-contamination, the ATR stage was thoroughly cleaned with isopropyl alcohol after each spectrum was obtained.

The resulting infrared spectra were analyzed visually and compared against a library of known spectra to detect the presence of developer chemicals on the printed side of each receipt. FTIR is a widely used tool for determining the chemical identity of compounds.

Our spectral library included BPA and BPS. We visually examined the BPA and BPS spectra to identify bands unique to each chemical to avoid misidentification.

The developer chemical known as Pergafast 201 was not in the library. We determined the presence of this chemical by noting spectral similarities with related compounds (with sulfonate and sulfonamide groups in particular) that were in the library and comparing those findings to the molecular structures of developer chemicals, including Pergafast 201, known to be used in thermal receipts (U.S. EPA 2014). Our determination of Pergafast 201 should be verified in future work using gas chromatography/mass spectrometry.

Receipts with no coating--in other words, that were not thermal paper--showed the characteristic spectrum of plain paper.

Collected infrared spectra that did not match the unique bands of plain paper, BPA, BPS, or the chemical we identified as Pergafast 201 were marked "inconclusive."

Figure 3. Receipt undergoing ATR-FTIR testing.

Method Validation

Four thermal paper samples from our study were tested by a third-party lab, TÜV Rheinland, using gas chromatography–mass spectrometry (GC/MS) for BPA and BPS. TÜV Rheinland of North America is accredited as a Nationally Recognized Testing Laboratory (NRTL) by OSHA, the Occupational Safety and Health Administration, in the United States.

According to our FTIR analysis, one of these samples contained significant BPA, one contained significant BPS, one contained an undetermined developer, and one was uncoated. The GC/MS analysis corroborated the FTIR results for all four samples. Details are in the Results section.

RESULTS AND DISCUSSION

FTIR analysis

A table of the results can be downloaded at https://www.ecocenter.org/healthy-stuff/pages/receipt-paper-study-2018/findings

Based on the FTIR spectra of the surfaces of 167 receipts from 148 businesses, we sorted results into the following categories: BPA, BPS, Pergafast 201, uncoated, and inconclusive. **Table 3** and **Table 4** sort results by business category and sector, respectively.

Of the 167 receipts, BPS was the most prevalent (75% of receipts) followed by BPA (18%), inconclusive, (3%), no coating (2%), and Pergafast 201 (1%). Pergafast 201 was detected only in the two receipts collected from two Best Buy stores.

We compared receipts from the retail sector (apparel/jewelry, books/office, department/big box, drugstore, gas station/convenience, grocery, pets, resale, toy stores) versus the service sector (automotive, bank, entertainment, library, post office, printing and electronics, restaurants/bars, salon, travel). BPS was the most common developer chemical in both sectors (85% of retail and 68% of service sector receipts). Table 4 shows that BPA was more prevalent among the service sector receipts (26% of service sector receipts versus 8% of retail receipts). Many of the service sector receipts were restaurants.

Four receipts were uncoated; in other words, they appear to be regular paper, not thermal paper. These receipts were from three business: Brooks Lumber, Village Hardware, and two different Culver's restaurant locations.

Other chemicals detected

In addition to BPA, BPS, and Pergafast 201, we identified the chemical diphenyl sulfone in many of the BPS-containing receipts. Diphenyl sulfone is used as a sensitizer in thermal paper and was recently quantified in receipts from Germany (Eckart 2017).

Many receipts also contained characteristic infrared bands of calcium carbonate, a common filler in plastics and coatings.

Table 3: Developer chemicals detected by FTIR in paper receipts sorted by business category.

Business Category	Number of Samples	BPA	BPS	Pergafast 201	Inconclusive	No Coating
Apparel/Jewelry	7	1	6	0	0	0
Automotive Service	2	0	1	0	1	0
Bank	5	0	5	0	0	0
Books/Office	6	0	6	0	0	0
Department/Big Box	20	0	17	2	1	0
Drugstore	5	0	5	0	0	0
Entertainment	8	2	6	0	0	0
Gas Station/ Convenience	5	3	2	0	0	0
Grocery	16	3	13	0	0	0
Library	3	3	0	0	0	0
Other	8	0	6	0	0	2
Pets	4	0	4	0	0	0
Post Office	2	0	2	0	0	0
Printing/ Electronics Service	5	1	4	0	0	0
Resale Store	2	0	2	0	0	0
Restaurant/Bar	62	16	43	0	1	2
Salon	2	1	1	0	0	0
Toys	3	0	3	0	0	0
Travel (Bus, Air, Parking)	2	0	0	0	2	0
TOTAL	167	30	126	2	5	4

Table 4: Receipt results by sector.

Sector	Number of Samples	BPA	BPS	Pergafast	Inconclusive	No Coating
Retail	73	6 (8%)	62 (85%)	2 (3%)	1 (1%)	2 (3%)
Service	94	24 (26%)	64 (68%)	0 (0%)	4 (4%)	2 (2%)
Total	167	30 (18%)	126 (75%)	2 (1%)	5 (3%)	4 (2%)

Gas chromatography/mass spectrometry (GC/MS) analysis

Four paper receipts were analyzed by GC/MS. Three were tested for both BPA and BPS and one, a sample of EKG paper, was tested only for BPA. **Table 5** lists the results. The first two "Measurement" columns give BPA and BPS in units of parts per million (ppm), which is the same as ug/g. The next two columns give the results based on surface area of the paper: micrograms per square centimeter.

GC/MS analysis corroborated our FTIR results. The sample we had identified by FTIR as containing BPS (Von Maur) was found to have a BPS concentration three orders of magnitude higher than the other samples: 71,000 ppm BPS at Von Maur store compared to 27 and 73 ppm in the other receipts.

Similarly, the sample we had identified by FTIR as containing BPA (EKG paper) was found to have a BPA concentration two orders of magnitude higher than the other samples: 14,500 ppm BPA in the EKG paper compared to 24 and 95 ppm in the others.

Our FTIR analysis determined that the Culver's receipt was uncoated and the Delta receipt was coated with an inconclusive developer, neither BPA nor BPS. The GC/MS analysis accordingly found low levels of BPA and BPS in these receipts, much too low to be used as a developer in the thermal coating.

We posit that the relatively low levels of BPA (3, 24, and 95 ppm) and BPS (27 and 73 ppm) found by GC/MS in receipts not expected to contain these developers reflect the ease with which developers in thermal paper are transferred from one surface to another (Liao and Kannon, 2011b). The receipts were collected as convenience samples from consumers, who typically handled them with bare hands that may have touched other receipts and in some cases temporarily carried them in a bag or pocket. Consumers then placed the receipts in paper envelopes with printed sides folded in.

Trace amounts of BPA and BPS could also come from recycled paper used to manufacture the thermal paper (Liao and Kannon, 2011b).

Table 5. Gas chromatography/mass spectrometry (GC/MS) results for four paper receipt samples

		Measurement by GC/MS (detection limit 1 ppm)			
Name	**Our FTIR Result**	**BPA, ppm**	**BPS, ppm**	**BPA, ug/cm^2**	**BPS, ug/cm^2**
Culver's Receipt	Not coated	3	27	0.02	0.16
Von Maur Receipt	BPS	95	**71,000**	0.42	311
Delta Receipt	Inconclusive	24	73	0.18	0.56
EKG paper*	BPA	**14,500**	not tested	78.6	not tested

* The EKG paper sample was not part of the citizen receipt collection and is not technically a receipt so, while we used it to validate our BPA FTIR determination, we have not included it in Tables 3 and 4.

Comparison with previous studies on BPA and BPS in receipt paper

Table 6 compiles our GC/MS results from six prior studies by other researchers. Our quantification of BPA in an EKG paper sample--14,500 ppm--is similar to the upper range of results from receipts from multiple other countries.

The concentration of BPS we measured in a Von Maur store receipt is higher than that in receipts from recently published studies. We found 71,000 ppm BPS, whereas receipts from Italy and Japan had up to 3,600 and 6,100 ppm BPS, respectively, and U.S. receipts in a 2012 study had up to 22,000 ppm BPS (Liao 2012). The reason for the variation is unknown.

For an in-depth review of research on new developer chemicals in thermal receipts and the implications for human exposure, see Bjornsdottir 2017.

Thermal paper tickets

In addition to the 208 receipts analyzed in this work, a number of paper tickets for theater, concerts, parking, train, plane, and bus were collected. These tickets were thicker and stiffer than other receipts such as those from stores and restaurants. The tickets showed a more complex mixture of coating ingredients and the developer was difficult to identify. Since many of the tickets had an inconclusive result, we have excluded the thicker paper tickets from the present analysis and hope to identify them in a future study.

Table 6. Comparison of receipt BPA and BPS measurements from multiple studies worldwide.

		Range measured in receipts, ug/g (ppm)	
Study	**Receipts from:**	**BPA**	**BPS**
present work, 2018	US, mostly Michigan (n=4)	3-14,500	27-71,000
Russo *et al.* 2017	Italy (n=50)	<LOQ-15,373	LOQ-3,580
Lu *et al.* 2013	China (n=42)	2,580-14,700	na
Liao *et al.* 2012	Japan (n=6)	na	0.55-6,130
	New York (n=81)	na	0.014-22,000
	Various US cities (n=10)	na	1-12,000
	Korea (n=11)	na	0.09-11
	Vietnam (n=3)	na	0.11-0.56
Geens *et al.* 2012	Belgium (n=44)	0.0044-21,000	na
Liao and Kannan, 2011b	US (n=83)	4.8-13,900	na
	Korea (n=11)	16-9,880	na
	Vietnam (n=3)	6,150-6,530	na
	Japan* (n=6)	<LOQ	na
Mendum *et al.* 2010	Boston (n=10)	3,000-17,000	na

na=not analyzed

LOQ=limit of quantification

*Japan banned BPA from thermal receipt paper in 2001

What can businesses do?

We recommend businesses with thermal receipt systems **switch to less hazardous, drop-in replacement papers**. On option is thermal paper with a phenol-free developer such as Pergafast 201 or one of the others detailed in EPA's 2014 report. That report gives screening-level toxicological hazard assessments of each developer. Pergafast 201 presents some developmental and reproductive hazards, although is expected to be poorly absorbed through the skin, in contrast to BPA and BPS. In another research report, Pergafast 201 and a developer called D8 were found using a cell assay to have no hormone effect (Goldinger 2015).

A potentially superior alternative is a new thermal paper from Dow called BLUE 4EST™ Thermal Paper (Dow, 2017). According to the creators of this paper, it is not only phenol-free

but uses a polymeric coating that does not come off like BPA and BPS and is approved for food contact.

We also recommend businesses **use electronic receipts and offer consumers the option of skipping the paper receipt.**

CONCLUSION

Our study suggests that BPS has replaced BPA to a large extent in U.S. thermal paper receipts, although BPA remains fairly common (75% BPS versus 18% BPA). A small number of businesses are using alternative, non-phenol developers or uncoated paper receipts.

Because receipts with freely available BPS and BPA are so ubiquitous, they are primary contributors to human exposure to these hormone-disrupting chemicals. We are particularly concerned about the effects of repeated, daily BPS and BPA exposure on young children, pregnant women, and workers who handle thermal paper.

Cashiers, waiters, bank tellers and many other employees handle as many as 30 receipts per hour. After a work shift, their urinary and blood levels of BPA and BPS are significantly higher than the general population. These chemicals easily transfer from receipt paper to hands and are rapidly absorbed into the blood through the skin. Combined with exposure from other sources like food packaging and adhesives, workers in particular can exceed tolerable intake values.

BPS was especially prevalent in the retail sector, comprising 85% of the 72 retail receipts, while 8% contained BPA. The service sector, including restaurants, appears to have moved toward BPS to a slightly lesser extent: Of the 61 service receipts, 68% had BPS and 26% had BPA.

One store, Best Buy, is using a non-phenol alternative we identified as likely Pergafast 201. Three other businesses--Culvers, Village Hardware, and Brooks Lumber, were found to be using receipt paper that contains *no* thermal coating.

We call on businesses to protect employees and customers by switching to a safer alternative and following the guidelines listed in the Recommendations section.

RECOMMENDATIONS

To minimize exposure, employees who handle thermal paper should:

- Ask customers: “Do you need a receipt?” or "Is an e-receipt okay?” Do not print a receipt unless asked and avoid printing ‘merchant copies’ of receipts.
- Use disposable gloves or protective food grade silicone fingertips on the index fingers and thumbs when tearing receipts, changing receipt rolls, or cleaning machines.

- Reduce contact with the coated side of receipts by folding the receipt in on itself before handing to customer.
- In general, avoid hand to mouth contact when handling receipts. Especially avoid handling receipts after using alcohol-based cleaners or when hands are wet, or when greasy from food or lotion.
- Wash and dry hands thoroughly during breaks, after changing receipt rolls or cleaning machines, and prior to and after eating or preparing food.
- Keep drink/meal receipts dry. Do not adhere them to the sides of moist glassware or place directly on food during its preparation (Minnesota PCA n.d.).

To minimize exposure, consumers should:

- Avoid getting printed receipts or choose an electronic receipt option.
- If you take a receipt, fold it printed side in. The backside is typically not coated.
- Consider keeping a flat bag or envelope in your backpack or purse in which to place receipts. BPA and BPS readily rub off onto items in your purse or wallet.
- Do not hand receipts to babies or children.
- Wash hands after handling receipts (Minnesota PCA n.d.).
- Put receipts into the trash instead of recycling to reduce contamination in recycled paper products.

Alternatives to traditional thermal paper receipts

Businesses can make two purchasing choices that go a long way toward reducing exposure to hormone-disrupting chemicals in receipts.

1. **Use electronic receipts and offer consumers the option of skipping the paper receipt.**
2. **Switch to less hazardous, drop-in replacement papers.**
   One option is thermal paper with a phenol-free developer such as Pergafast 201 or one of the other alternatives detailed in EPA's 2014 report. That report gives screening-level toxicological hazard assessments of each developer. Pergafast 201 presents some developmental and reproductive hazards, although is expected to be poorly absorbed through the skin, in contrast to BPA and BPS. In another research report, Pergafast 201 and a developer called D8 were found to have no hormone activity in a cell assay (Goldinger 2015).

   Another alternative is thermal paper with vitamin C (ascorbic acid) in the coating, but the coating also contains chemicals of questionable safety (Eckardt 2017) so we don't recommend this product without further research into toxicological hazards.

   A potentially superior alternative is a new drop-in replacement from Dow called BLUE 4EST™ Thermal Paper (Dow, 2017). According to the creators of this paper, it is not only phenol-free but uses a polymeric coating that does not come off like BPA and BPS and is approved for food contact.
   https://www.koehlerpaper.com/en/papier/thermal/index.php

Since e-receipts also reduce paper usage, they may help offset the cost of using alternative thermal paper by reducing the rate of paper usage.

With greater demand from the business world for receipt papers that don't spread harmful chemicals, costs of these alternatives will decrease.

Selected companies producing or selling alternative thermal paper:
Manufacturer of BLUE 4EST™ thermal paper; contact to find distributors

- Koehler

Distributor of phenol-free paper for those buying in bulk

- Pospaper (Pergafast 201)

Converter of phenol-free paper into small rolls

- RiteMade converts Pergafast and Vitamin C-based thermal paper

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APPENDIX

A table of the results can be downloaded at https://www.ecocenter.org/healthy-stuff/pages/receipt-paper-study-2018/findings