
Toxics Link
for a toxics-free world
BPA in
THERMALPAPER
A monitoring study

About Toxics Link

Toxics Link is an Indian environmental research and advocacy organization set up in 1996, engaged in disseminating information to help strengthen the campaign against toxics pollution, and to provide cleaner alternatives. We work with other groups around the country as well as internationally in an understanding that this will help bring the experience of the ground to the fore, and lead to a more meaningful articulation of issues. Toxics Link engages in the emerging issues of highly hazardous pesticides (HHPs), Persistent Organic Pollutants (POPs), hazardous heavy metal contamination, pharmaceutical pollutants etc. from the environment and public health point of view. We also work on ground in areas of municipal, hazardous and medical waste management and food safety among others. We have successfully implemented various best practices and have brought in policy changes in the aforementioned areas apart from creating awareness among several stakeholder groups.

Our work on Endocrine Disrupting Chemicals (EDCs) management has spanned over a decade, entailing significant diverse body of work such as country specific research data, policy engagement, involvement in setting standards, and capacity building of all stakeholders.

Acknowledgment

We take this opportunity to thank all those who were instrumental in compiling and shaping this report.

We express our sincere gratitude to the Swedish Society for Nature Conservation (SSNC) for supporting this study.

Supervised by: Piyush Mohapatra

Research & Complied by: Alka Dubey

Temporary Address
E-224, First Floor, East of Kailash, New Delhi - 110065, India
Tel: 91-11-49931863

Permanent Address
H2 (Ground Floor), Jungpura Extension, New Delhi - 110014, India
Phone: 91-11-24328006, 24320711 | Fax: 91-11-24321747

Contents

Tables

Figures

Abbreviations

ADI	Average Daily Intake
ANSES	French Food and Environment Safety Agency
ATMs	Automated Teller Machine
BIS	Bureau of Indian Standards
BPA	Bisphenol-A
BPS	Bisphenol-S
CAGR	Compound annual growth rate
CDCs	Centres for Disease Control and Prevention
ECHA	European Chemicals Agency
EDCs	Endocrine disrupting chemicals
EDI	Estimated Daily Intake
EPA	Environmental Protection Agency
ESI-MS	Electrospray ionisation mass spectrometry
EFSA	European Food Safety Authority
ER	Epoxy resins
EU	European Union
FSSAI	Food Safety and Standards Authority of India
HS Code	Harmonized Commodity Description and Coding System
HPLC	High-performance liquid chromatography
KGS	kilo grams
LC-MS	liquid chromatography-mass spectrometry
LOQ	Limit of quantification
m	meter
ml	millilitre
PC	Polycarbonates
PPM	parts per million
POS	Point-of-sale
RFID	Radio-frequency identification
TDI	Tolerable daily intake
THF	Tetrahydrofuran
USD	US Dollar

Because of its reliability and convenience, thermal paper is widely used in many applications, such as labels, **tickets, medical charts, po nts of sale (POS) such as restaurants, kiosk, hotels, gas stations, supermarkets, and for labels, gaming, ticket & tags** and other applications of similar nature.

01

Introduction

i. Thermal Paper

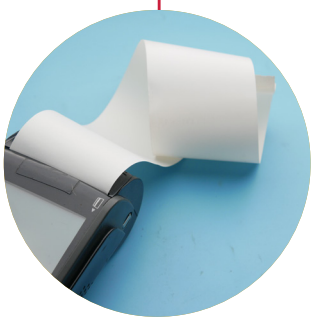
Thermal paper is a specialized paper to be printed from the thermal printer. Instead of traditional printing ink, the image is generated through the application of heat when specific areas of the thermal paper pass over the thermal print head. This process is commonly employed by small, low-maintenance thermal printers. The use of roll paper can reduce the amount of paper used and improve performance by printing a page equal to the length necessary to present the printed information. Because of its reliability and convenience, it is widely used in many applications, such as labels, tickets, medical charts, points of sale (POS) such as restaurants, kiosk, hotels, gas stations, supermarkets, and for labels, gaming, ticket & tags and other applications of similar nature.[1,2]

There are two primary types of thermal paper: Direct Thermal Paper and Thermal Transfer Paper.[3,4]

Direct thermal paper features a heat-sensitive coating on one side that undergoes a color change when exposed to heat, making it well-suited rapid and affordable printing of receipts and labels. Its printer-friendly design, devoid of ink, toner, or ribbon products, enhances durability, user convenience, and cost-effectiveness in comparison to laser, thermal transfer, and inkjet printers. This technology offers an extended lifespan, particularly beneficial for various barcode applications essential in package point-of-sale (POS), printed tickets, labels and tags, as well as RFID identification.

On the other hand, **thermal transfer paper** requires a thermal transfer ribbon to generate a print. The ribbon contains ink that is melted onto the paper through a thermal print head, yielding a distinct and resilient image. This quality makes it well-suited for applications that face tough conditions.

Types of Thermal Paper



Direct Thermal Paper

Utilises Chemicals that React to Heat

Thermal Transfer Paper

Relies on a Heated Ribbon to Transfer Ink Onto the Paper

a. Components of Thermal Paper[5]

Thermal paper is a highly engineered product, in which paper is coated with a thermal sensitive layer that reacts in the presence of heat to create the printed image.

The paper base of standard grade is coated with various chemicals for desired quality for thermal printing. **A pre-coat**, or base coat, is applied to the base paper that prevent heat transfer through all of the paper's layers hence allows high resolution and smoothness. Applied to the pre-coat is a **thermal layer** that contains the necessary reactive components. A **binder**, such as polyvinyl alcohol or latex, helps these coatings adhere to the paper.

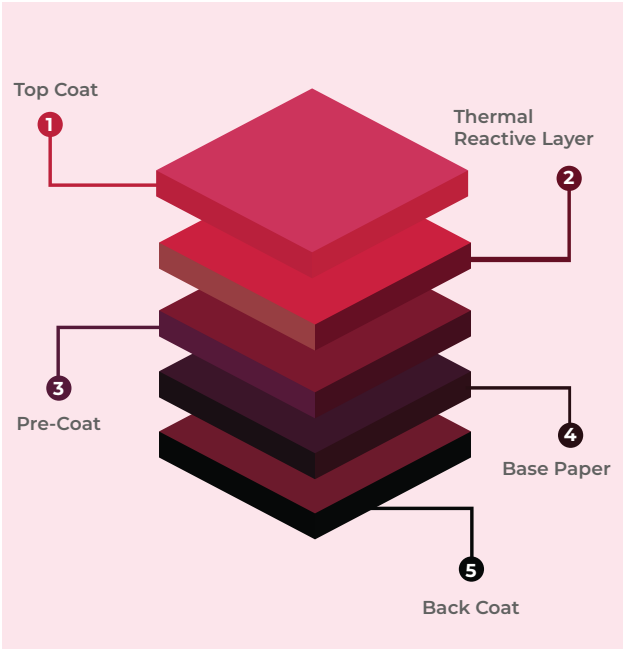


Figure 1: Cross-section of thermal paper

Additionally, thermal paper may contain a protective top coat and/or back coat. Top coats may be used for some applications to protect thermal paper from mechanical stress or chemical reactions. Similarly, back coats may be used to provide additional protection during lamination, printing, or other mechanical processes. Thermal paper used for receipts typically lacks the top and back coats.

The thermal layer includes three key compounds:

- a dye (also referred to as a colorformer),
- a developer (also referred to as a coreactant),
- a sensitizer (also referred to as a modifier).

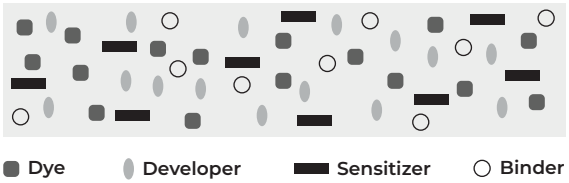


Figure 2: Elements of the thermal reactive layer

The combination of these compounds and their properties determines the image color, scanning characteristics and durability. These compounds are slurried and applied as an aqueous emulsion to the paper.

- **Leuco dye** is the most commonly used dye in thermal paper. It is colorless at room temperature. While printing, the thermal head of the printing unit applies heat pulses to the paper, leading to the melting of all compounds within the thermal layer. This process triggers the transfer of a proton from the developer to the leuco dye hence causing the change in structure of leuco dye that results in the production of color. Due to its low melting point, the sensitizer acts as a solvent that promotes the interaction of the developer with the dye.[6]

- **Developer** is specially used to donate protons to the dye hence triggering color formation. Developers used in thermal printing are weakly acidic such as **Bisphenol-A (BPA)**. It's important to consider certain parameters while selecting the developer such as its solubility, pKa, melting point, color, odor, purity, and vapor pressure. Besides performance characteristics of effective developers should also be considered:
  - Acidity such that it produces no background imaging,
  - Ability to fully react with the colorformer when heated,
  - Reaction at the temperature of the specific printer,
  - Stable at end use temperatures,
  - Appropriate stability for the application,
  - Appropriate performance vs. cost balance, and
  - Feasible in large-scale production.

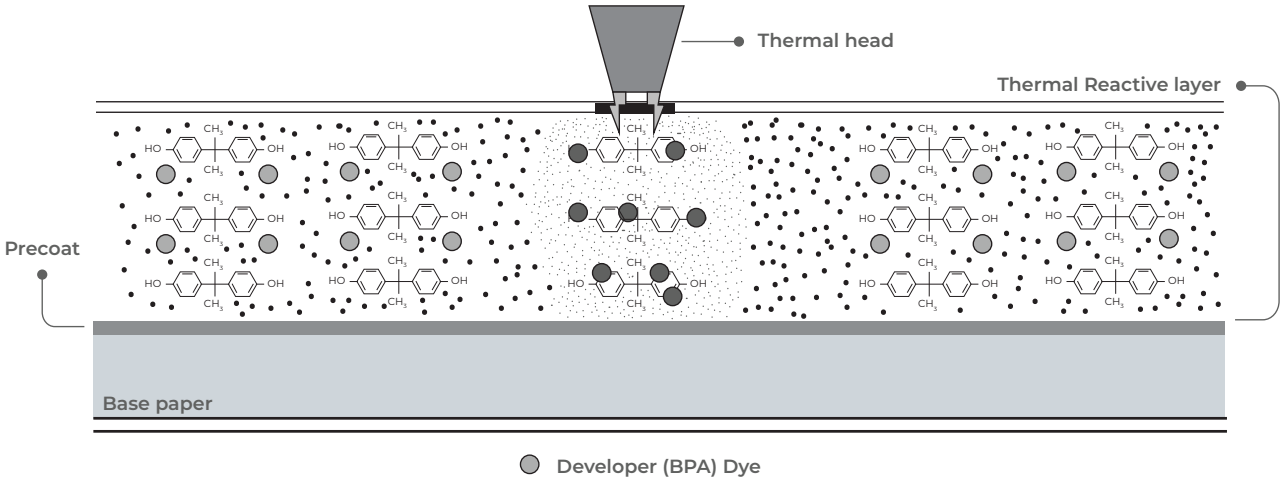


Figure 3: Schematic diagram of thermal paper identifying the thermal reactive layer that contains BPA as a developer and a leuco dye, as well as stabilizers and binders

- **Sensitizer:** The sensitizer is used as solvent that reduces the melting point of dye and developer hence providing the optimal conditions for the developer to transfer protons to dye upon heating that enables color formation. Sensitizers typically have a melting point between 45-65°C (Mendum, Stoler et al. 2011). Examples: Dimethyl terephthalate, Diphenyl sulfone, 2-Benzyloxynapthalene, N-phenylstearamide

- **Stabilizers** are used to inhibit recrystallization of the dye and developer i.e., inhibiting dye and developer to return their original colorless crystalline form, thereby stabilizing the printed image.

b. Thermal Printing Mechanism

In direct thermal printing, an image is generated by selectively heating specific regions of thermal paper. At room temperature, the dye exists in a colorless, neutral, unprotonated state. Upon heating the dye/developer/sensitizer system beyond the sensitizer's melting point, the developer (commonly bisphenol A (BPA)) releases a proton, leading to the solidification of the chemicals and the creation of a relatively stable image. The essential components of a thermal printing system include a printer head, thermal paper, and a platen (backing roll). The printer head comprises miniature heating units along its length, electronically delivering the necessary heat to the paper. As the thermal paper moves along the platen, the thermal head heats it, causing the dye and developer in the paper's coating to melt and react, ultimately resulting in the production of an image on the paper.

Overview of Thermal Printing Process

(based on Koehler Thermal Paper n.d. and Charters Paper Pty Ltd 2006)

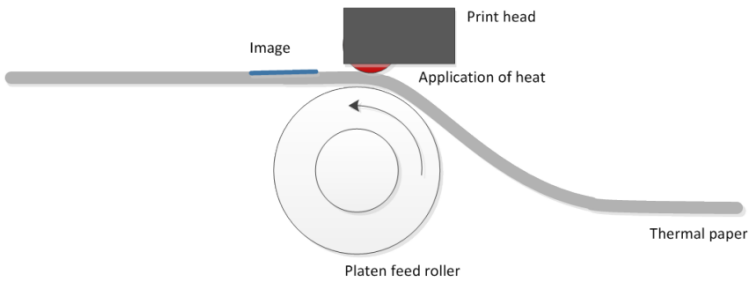


Figure 4: Overview of thermal printing process. Source: Koehler thermal paper n.d. and Charters paper Pty Ltd 2006

c. Market size of thermal paper

Due to its ease and durability, thermal paper has wider application. Its demand is also rising due to increased use of digital payments, POS systems and growing number of ATMs. The global thermal paper market size was estimated at USD 4.01 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 4.2% from 2023 to 2030.[7] A market survey agency has reported that India is importing thermal paper from around 17 different countries.[8]

India import thermal papers in four different HS codes based on their size and length[9]. These are:

- 48119093: Thermal paper for fax machines
- 48119094: Thermal paper in jumbo rolls (of size 1 m and above in width and 5,000 m & above in length)
- 48119095: Thermal paper in jumbo rolls (of size 1 m and above in width and less than 5,000 m in length)
- 48119096: Thermal paper in rolls of size less than 1 m in width

These jumbo rolls are later cut into smaller rolls as per the requirement for various applications. In the fiscal year 2023 the major import of thermal paper from HS code 48119096 was from Korea and Japan [10] (Table.1). However, there is no data of previous years available on government platform for this category of thermal paper. Similarly, paper of the HS code 48119094 was majorly imported from Korea[11] (Table 2).

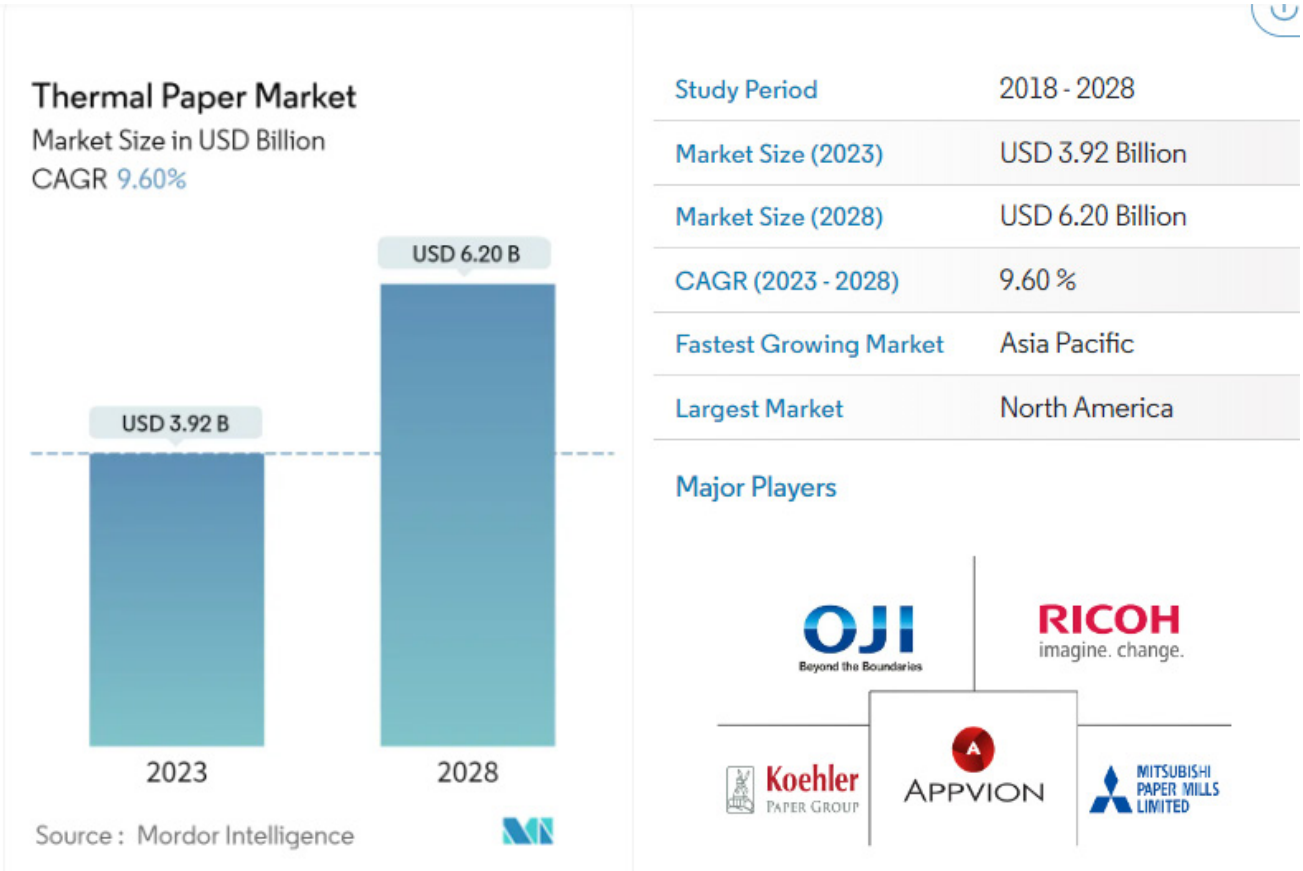


Table 1: Imported by India in financial year 2023-2024(Apr-Oct) [Commodity: 48119096 Thermal paper in rolls of size less than 1 m in width Unit: KGS]

S.No.	Country	Values in Rs. Lacs	Quantity in thousands
1	CHINA P RP	158.25	139.83
2	JAPAN	2,124.26	1,510.20
3	KOREA RP	2,498.03	1,842.70
4	THAILAND	123.1	75.94
5	U S A	55.24	59.48
	Total	4,958.87	3628.15

Table 2: Thermal paper import data [Commodity: 48119094 Thermal paper in jumbo rolls (of size 1 m and above in width and 5,000 m and above in length) Unit: KGS]

S.No.	Country	Values in Rs. Lacs		Quantity in thousands	
		2022-2023	2023-2024 (Apr-Oct)	2022-2023	2023-2024 (Apr-Oct)
1	CHINA PRC (People's Republic of China)	35.57	2.52	22.24	0.93
2	FINLAND	141.9	85.58	137.01	80.48
3	FRANCE	94.05		25.88	
4	GERMANY	34.64		43.64	
5	IRELAND	1.98			
6	ITALY	146.9	41.6	123.86	41.24
7	JAPAN		8.16		10.19
8	KOREA RP	1,657.33	4,664.56	1,007.33	3,025.90
9	U K	34.85		41.66	
10	U S A	20.62	110.09	40.22	117.93
	Total	2,167.84	4,912.50		

ii. Exposure of BPA from thermal paper

BPA or 2,4-isopropylidenediphenol [$(CH_3)_2C(C_6H_4OH)_2$] is a carbon-based synthetic compound belonging to the group of diphenylmethane derivatives and Bisphenols. It is used as a monomer in the production of polycarbonate (PC) plastics, epoxy resins and dye-developer or co-reactant.[12]

There are various reported sources of BPA exposure to human beings including food and beverages containers & packaging materials; however, considering the magnitude of use of the thermal paper, the level of exposure to human being is very high.

Thermal printing technology requires a color developer to activate the dye under the action of heat. **BPA is applied to the printing surface of thermal paper to be used as a developer because of its stability and heat-resistance.** Studies have found that individual thermal receipts can contain BPA that is 250 to 1,000 times greater than the amount reported in a can of food. In these papers, the coating includes

milligrams of unbound BPA per gram of paper.[13] It has been reported that BPA is present in the 640,000 tons of thermal receipt paper the U.S. uses each year.[14]

As BPA applied to thermal paper is not chemically bound, it can easily leach out, thus relatively large exposures may occur after normal handling.[15] While ingesting food and water from containers made with BPA accounts for higher BPA concentrations in humans, absorption of BPA from receipts through the skin is a contributor as well.[16] Dermal exposure contributed to the overall body burden of BPA among occupationally exposed populations, such as cashiers and workers.[17,18]

The research studies established the dermal absorption of BPA from the thermal paper into the skin.[19,20,21,22]

Champmartin *et al* (2020) had indicated that an average of 1.13 mg BPA transferred to a finger pad. As a worker may touch a receipt with all five finger pads of one hand, a total of 5.5- 115 mg BPA could potentially be transferred to the skin. Based on a skin contact area of 6 cm2, this amount of BPA represents a dose of approximately 1-19 mg/cm2. Transfer of BPA from thermal paper is greater on humid, sweaty, oily, or hand-lotion skin compared to dry skin[23,24].

BPA can cause damage in cell by

- Activation of CYP
- Binding with ERR inducing changes in estradiol level
- DNA methylation and histone change
- Binding with aryl hydrocarbon receptors
- Binding with peroxisomes proliferator-activated receptors

Figure 5: Application of Bisphenol-A

iii. Harmful impact of BPA

BPA is a well-known endocrine disrupting chemical (EDCs). It can prevent the binding of natural hormones to their receptors and/or mimic hormones such as estrogen and androgen hormones hence causing damages to reproductive system. BPA can also affect the immune system and neuroendocrine system in human.[25,26,27] Recently, it has been shown that BPA could induce carcinogenesis and mutagenesis in animal models.[28]

BPA is currently classified as a category 1B reproductive toxicant and also a skin sensitizer under the EU CLP Regulations.[29] Considering these, BPA has been banned/restricted in various products globally. Recently, EFSA has revised the TDI of BPA from 4 micrograms per kilogram of body weight per day (kg/bw/day) to 0.2 nanograms/kg/bw/day.[30]

Figure 6: Health impacts of BPA

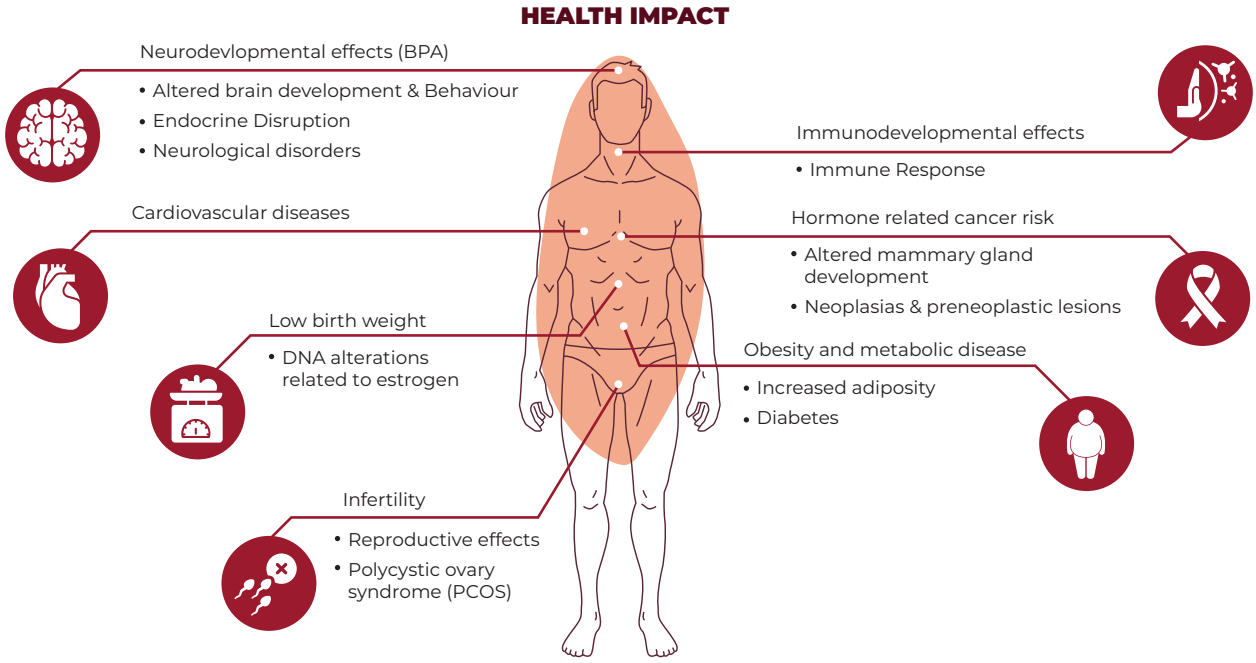


Table 3: Global Regulation of BPA in Baby Feeding Bottles

Country	Regulation of BPA in baby feeding bottles
Canada	First country to **ban** the import, sale, and advertisement of baby bottles containing Bisphenol A.
USA	Banned
European Union	Banned the use of Bisphenol-A (BPA).
Australia	The Australian Govt. has introduced a **voluntary phase out** of BPA use in baby feeding bottles. The Australia and New Zealand Food Safety Authority (Food Standards Australia New Zealand) suggests the use of glass baby bottles.
Japan	Voluntary phase out by the industries
Belgium	Banned
China	Banned
Malaysia	Banned
South Africa	Banned
Turkey	Banned
India	The Bureau of Indian Standards (BIS) has revised the standards for baby feeding bottles in 2015 as per IS 14625:2015 and prohibited the use of BPA in baby feeding bottles and sippy cups.

Research suggests that the pharmacokinetics of BPA vary between oral and dermal exposures. Dermal exposure leads to a longer apparent half-life and a higher ratio of free to total d6-BPA compared to oral exposure. Scientific studies indicate that the skin absorbs BPA with minimal metabolism, allowing it to enter the systemic circulation directly. Consequently, a higher proportion of urinary samples show detectable levels of free BPA following dermal exposure compared to oral intake. These findings suggest that dermal exposures to BPA may carry greater toxicological significance than oral exposure through diet. [xviii, xx]

BPA metabolism in human body

When BPA is ingested orally, it undergoes absorption into the mesenteric blood vessels, subsequent transport to the liver, and rapid metabolization in a process known as 'first pass metabolism.' As a result of these processes, the predominant form of BPA circulating in the bloodstream after oral exposure is in a conjugated state (e.g., BPA-glucuronide, BPA-sulfate), although some unconjugated BPA does enter circulation. Conversely, when BPA enters the body through alternative routes such as dermal or inhalation, it bypasses first-pass metabolism, allowing a considerably higher amount of unconjugated BPA to circulate in the bloodstream. These toxicokinetic findings imply that the mode of exposure can significantly impact the concentration of unconjugated BPA in circulation. This holds significance because, in the case of BPA, only the unconjugated form can bind to estrogen receptors, leading certain groups to assert that solely the unconjugated form is biologically active and consequently poses a hazard.
Source: Bernier MR, Vandenberg LN(2017) Handling of thermal paper: Implications for dermal exposure to bisphenol-A and its alternatives. PLoS ONE12(6):e0178449.

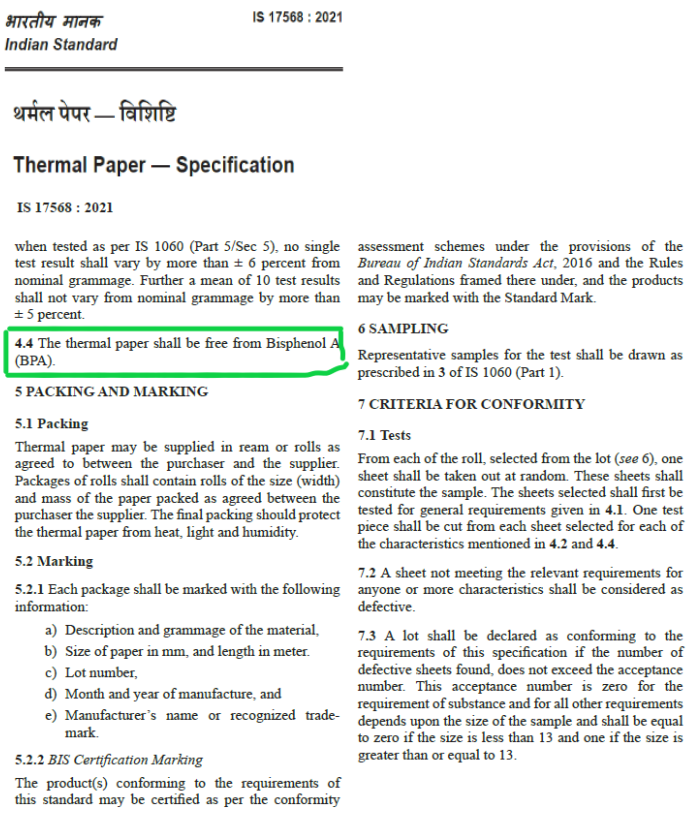
02

Global Regulatory Measures to restrict BPA in thermal paper

a. Regulations

The countries are taking necessary regulatory measures to restrict the use of BPA in thermal paper considering the harmful impact of BPA in human health and environment.

- BPA has been banned in thermal paper in Japan since 2001.[31]
- On January 2011 the **Taiwan** Standard for thermal paper issued that dyes used in thermal paper must not contain BPA.[32]
- The **European Commission** has restricted use of BPA in thermal paper at concentrations equal to or exceeding 0.02% by weight from 3 January 2020.[33] Since then the use of BPA-based thermal paper has been reduced by 43 % to 136 kilotonnes.[34]
- In **South Korea** under the Article 28 of "Electrical Appliances and Consumer Products Safety Control Act" the concentration of BPA in thermal paper is restricted to be less than 0.02% that entered into force in August 2021.[35]
- In many states in the United States of America, there are regulations restricting the use of BPA in thermal paper. These includes Connecticut[36], Minnesota, Massachusetts[37], Illinois[38] etc.
- In India the Bureau of Indian Standards (BIS), the standard making body, has published **IS 17568:2021** 'Thermal Paper- Specification' in 2021 restricting the use of BPA in thermal papers.



भारतीय मानक
Indian Standard

IS 17568 : 2021

थर्मल पेपर — विशिष्टि

Thermal Paper — Specification

IS 17568 : 2021

when tested as per IS 1060 (Part 5/Sec 5), no single test result shall vary by more than ± 6 percent from nominal grammage. Further a mean of 10 test results shall not vary from nominal grammage by more than ± 5 percent.

4.4 The thermal paper shall be free from Bisphenol A (BPA).

5 PACKING AND MARKING

5.1 Packing

Thermal paper may be supplied in ream or rolls as agreed to between the purchaser and the supplier. Packages of rolls shall contain rolls of the size (width) and mass of the paper packed as agreed between the purchaser the supplier. The final packing should protect the thermal paper from heat, light and humidity.

5.2 Marking

5.2.1 Each package shall be marked with the following information:

a) Description and grammage of the material,
b) Size of paper in mm, and length in meter.
c) Lot number,
d) Month and year of manufacture, and
e) Manufacturer's name or recognized trade-mark.

5.2.2 *BIS Certification Marking*

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed there under, and the products may be marked with the Standard Mark.

6 SAMPLING

Representative samples for the test shall be drawn as prescribed in 3 of IS 1060 (Part 1).

7 CRITERIA FOR CONFORMITY

7.1 Tests

From each of the roll, selected from the lot (*see* 6), one sheet shall be taken out at random. These sheets shall constitute the sample. The sheets selected shall first be tested for general requirements given in **4.1**. One test piece shall be cut from each sheet selected for each of the characteristics mentioned in **4.2** and **4.4**.

7.2 A sheet not meeting the relevant requirements for anyone or more characteristics shall be considered as defective.

7.3 A lot shall be declared as conforming to the requirements of this specification if the number of defective sheets found, does not exceed the acceptance number. This acceptance number is zero for the requirement of substance and for all other requirements depends upon the size of the sample and shall be equal to zero if the size is less than 13 and one if the size is greater than or equal to 13.

Figure 7: Summary of the tolerable daily intake (TDI)

The European Commission has restricted use of BPA in thermal paper at concentration equal to or exceeding

0.02%

b. Alternatives to BPA

There are many safer alternatives to BPA available in the market. In 2015 the USA Environmental Protection Agency (EPA) released a list of 19 BPA potential alternatives for use in thermal paper[39]. The chemicals used as an alternative to BPA in thermal papers are:

- Bisphenol S, BPS
- Pergafast 201® (PF201)
- Wincon 8, D-8
- BPAP, 4,4'-(1-Phenylethylidene)bisphenol
- D-90, 4-[4'-[(1'-methylethyloxy) phenyl] sulfonyl]phenol
- 4-(4-hydroxy3-prop-2-enylphenyl)sulfonyl-2-prop-2-enylphenol (TGSA)
- BPS-MAE , 4-(4-phenylmethoxyphenyl) sulfonylphenol
- Urea urethane (UU)
- DD70, 1,7-bis(4-hydroxyphenylthio)-3,5-dioxaheptane
- PHBB, 4-hydroxy-, phenylmethyl ester, Benzyl 4-hydroxybenzoate
- Ascorbic acid
- PPSMU, NKK-1304, and Blue4est®

BPS is the most commonly used alternatives to BPA in thermal paper. However, the studies have also raised concerns on the use of BPS as it has similar chemical analogues to BPA hence similar mechanism to disrupt endocrine function leading to equal or even greater toxicological effects. Research has shown that BPS exhibits estrogenic and antiandrogenic activities comparable to those of BPA.[40,41]

In light of new research findings, the Swiss authorities have restricted BPS as well from thermal papers since 2020. BPS should not be more than by mass of 0.02% (200 mg/kg or ppm). [42] The US EPA has classified BPS and PF201 as high-hazard colour developers for repeated dose toxicity and developmental toxicity, respectively. D-8 is also considered of moderate hazard with limited evidence of endocrine activity. [43] These findings indicate the need for evaluation of health impacts, while selecting alternative chemicals to replace BPA.

c. Bisphenol

i. BPS & its market size

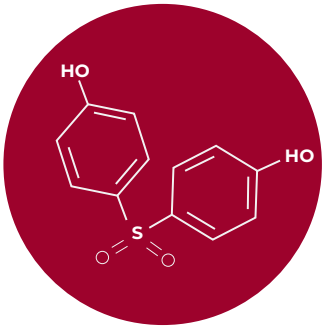


Figure 8: Chemical structure of BPS

Given the harmful impacts of BPA, restrictions and societal pressure, Bisphenol-S was introduced as an alternative to BPA to produce "BPA free" products. BPS has the advantage of possessing heat and light stability compared to BPA, and also less acidic than BPA. As a result, it has been introduced in various industrial applications as an important alternative to BPA. [44] BPS is classified as bisphenol and has two sulfonyl group (SO_2) as the central linker of the molecule unlike the dimethylmethylene group ($C(CH_3)_2$) of BPA.

According to a market research agency, the global Bisphenol -S market demand in 2022 was 52 thousand tonnes and is expected to reach 81.21 thousand tonnes by 2032, i.e., growing at a CAGR of 4.52%. 42% of the total BPS demand is from thermal paper production driven by the growing consumption of thermal paper for labelling in the food and beverage industry, along with increased online shopping. Major players operating in the Bisphenol S market include BASF SE, Konishi Chemical Ind. Co., Ltd., Solvay S.A., Nisso Metallochemical Co., Ltd., and more.[45]

According to a market research agency, Indian BPS demand was 2.08 thousand tonnes in FY2021 and is forecasted to reach 16.73 thousand tonnes by FY2030, growing at a CAGR of 26.09%. Domestically, most of the Bisphenol S demand comes from thermal paper consumption in POS billing machines and food and beverage labelling[46].

ii. Use of BPS in thermal printing

BPS is used as an alternative to BPA to be used as a developer for high-performance thermal paper. Pivnenko *et al* (2018) reported that approximately 200 tons of BPS were estimated to be present in the European paper cycle. [xxxviii] In 2018 the European Chemicals Agency (ECHA) had conducted an EU market survey and reported that the amount of BPS used in thermal papers had almost doubled between 2016 and 2017. This increase is anticipated to continue in future following the REACH regulation on the BPA restriction (EU No 1907/2006). The report also highlighted that the annual production and/or import of BPS in the EU ranges between 10,000 and 100,000 tons per year[47]. In 2022, the volume of BPS-based thermal paper placed on the EU market is estimated to be 307 kilotonnes (61 % of total) while that of other developers is expected to stand at 199 kilotonnes (39 %)[48].

iii. Harmful impact of BPS

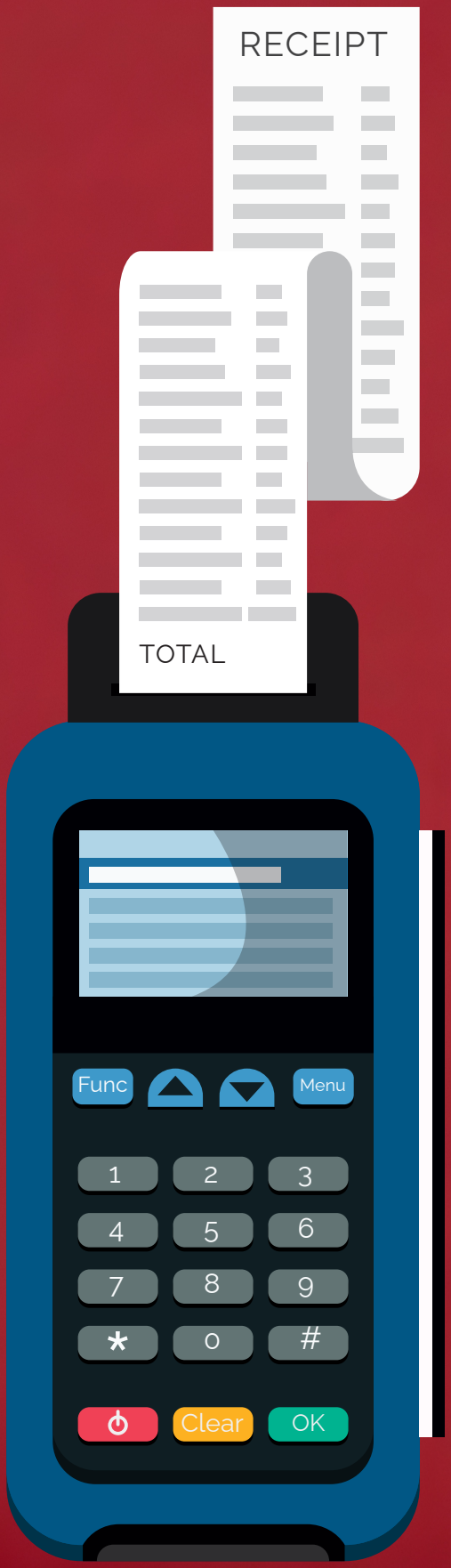
The European Chemicals Agency (ECHA) is currently assessing BPS for its endocrine disrupting properties. [49] However, studies have reported that BPS exerts biological disruptive effects which are similar to or even more prominent than those of BPA[50,51]. BPS can bind to the estrogen receptor that disrupts the reproductive system[52], and can also induce cancer cell proliferation[53]. BPS has an even greater half-life and ability to penetrate the skin than BPA[54] . The scientific studies had reported that over 88% of BPS exposure for most humans comes from handling thermal receipts[55]. It has been detected in 89.4% of urine samples from a representative cohort of the U.S. population[56] and in pregnant women from Netherland[57].

The French Food and Environment Safety Agency (ANSES) reported that BPS is more easily absorbed by the body and remain for a longer period of time that lead to increased internal exposure to an endocrine-active compound. The study also stated that BPS is fully absorbed by the organism in contrast to BPA which is only absorbed partly. Similarly, BPS takes 3.5 times longer than BPA to not longer detectable in the blood[58].

BPS has also been detected in various matrices and products such as personal care products, dairy products, fish and seafood, cereals, and vegetables, indoor dust, river water, sewage, sediment and sludge etc., pointing towards the magnitude of its presence in the environment[59,60,61].

	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 e al 2015)	Median	521	1.753
	Maximum	not reported	3.280
BPA (Luet al 2013) China	Median	10	577
	Maximum	57	4,957
BPA (Liao et al 2012) China	Median	4	312
	Maximum	11	821
BPA and BPS (Rocha et al, 2015) Brazil	Cashier workers had much higher BPA and BPS in their urine after a work shift.		

Source: Ecocentre.org



In 2018, Toxics Link's study reported BPA in all sample ranging from **300 ppm** to **6600 ppm**. After this study, in 2021, the Bureau of Indian Standards (BIS) has studied the performance characteristics of various types of thermal paper and later came up with the standard that restrict the use of BPA.

03
Rationale of the Study

a. Objectives

The BPA is a globally recognized toxic chemical. Therefore, considering the harmful impacts of the chemical, many countries have started phasing out BPA from the thermal paper and other consumables. In 2018, Toxics Link conducted a detailed assessment on the presence of BPA in thermal paper collected both from offline markets as well as online. The study reported BPA in all sample ranging from 300 ppm to 6600 ppm. After this study, in 2021, the Bureau of Indian Standards (BIS) has studied the performance characteristics of various types of thermal paper and later came up with the standard that restrict the use of BPA. Incidentally many countries have phased out the use of BPA in thermal paper considering widespread environmental and health challenges from its use.

Thus, the present study is aimed to build upon our previous research report of 2018 and to assess the current implementation status of the BIS standards came in 2021 by analyzing the prevailing use of BPA in the thermal paper. The present study also tries to understand the prevalence of BPS as an alternative to BPA. Additionally, the study also draws a worldwide progression of BPA restrictions in thermal paper and to examine the linkages of BPA ban in thermal paper in other countries to the import of these thermal paper to India from these countries.

b. Sampling and Methodology

In this study, total twenty (20) samples of thermal papers were collected from different markets in New Delhi. These samples were categorised from five different sectors that includes food eateries (both local & international brands), Delhi metros, bank ATMs, manufacturers/suppliers and grocery/ stationary shops. After the cash receipts were collected, they were kept in dark wrapping with aluminium foil, stored in a ziploc bag, and sent to the SGS Labs (Chennai) for analysis.

The samples were extracted and analysed for BPA & BPS by the AFIRM test method[62] using LC-MS. Briefly, approximately 1 g of the paper was extracted with 20 ml of THF in an ultrasonic bath at 60 °C for 60 mins. After cooling the extract to room temperature, about 1 ml of the extraction solution was filtered into an HPLC vial using a disposable syringe equipped with a membrane filter. The detection and quantification of BPA & BPS were conducted using LC/MS with gradient elution and ESI mass spectrometer.

S.No.	Categories	Number of samples
1.	Food eateries	6
2.	Delhi metros	3
3.	Bank ATM receipts	3
4.	Grocery shops	5
5.	Manufacturers from e-platform	3

04
Study Findings

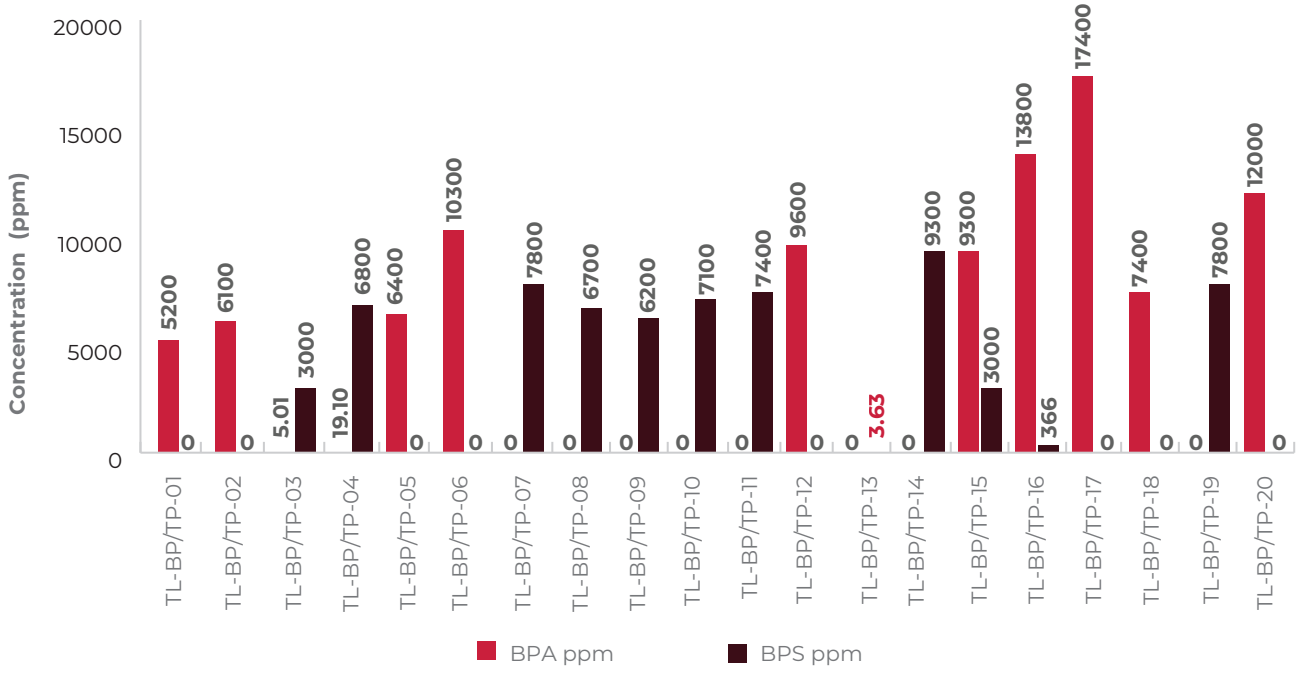
In all the tested samples, at least one of the Bisphenol analogs was detected. The study represents the availability of thermal papers in Indian markets that contain BPS as an alternative to BPA. The manufacturers are selling such products as “BPA free” products. In one of such product BPA was found to be 5.01 ppm while BPS was 3000 ppm. In fact, in all those samples BPS was found, BPA was either not detectable or found in traces. BPS was measured in twelve samples investigated with levels ranging between < LOQ to 9300ppm. That shows the implementation of the BIS standard IS 17568: 2021 in the country.

Table 4: Assessment of bisphenol analogs in thermal receipts

Analytes	Detection number	Maximum conc. (ppm)	Minimum conc. (ppm)
BPA	13	17400	3.63
BPS	12	9300	52.8

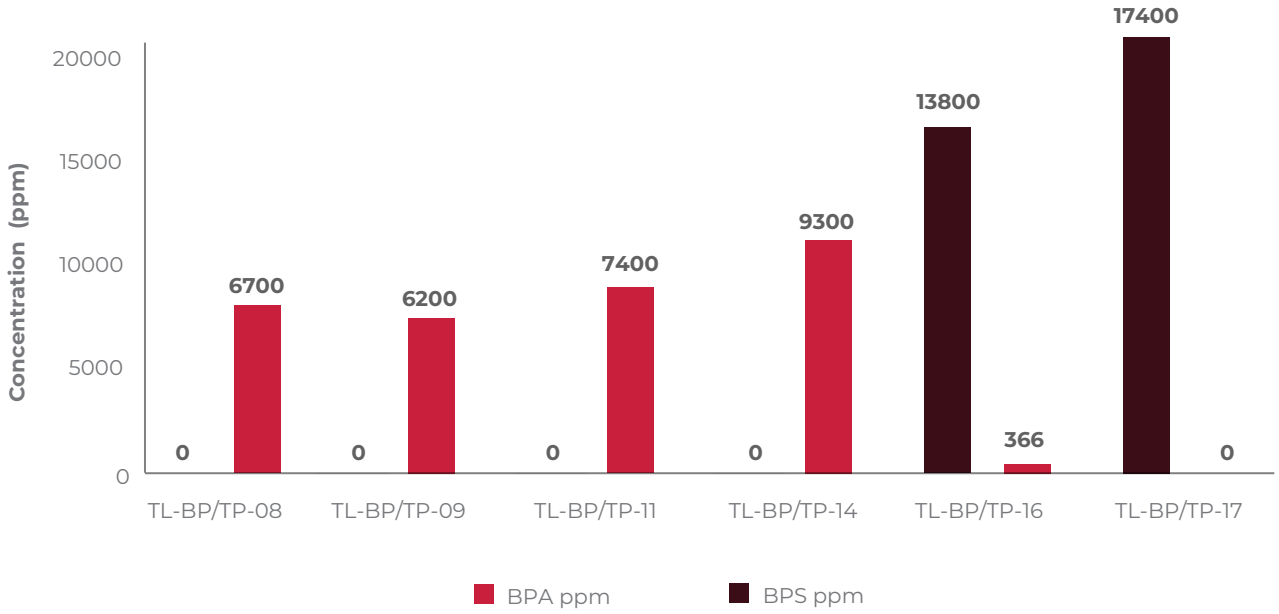
However, BPA has also been reported in thirteen out of twenty samples in concentrations ranging between < LOQ to 17400 ppm.

Figure 9: Concentration of bisphenol analogs in ppm



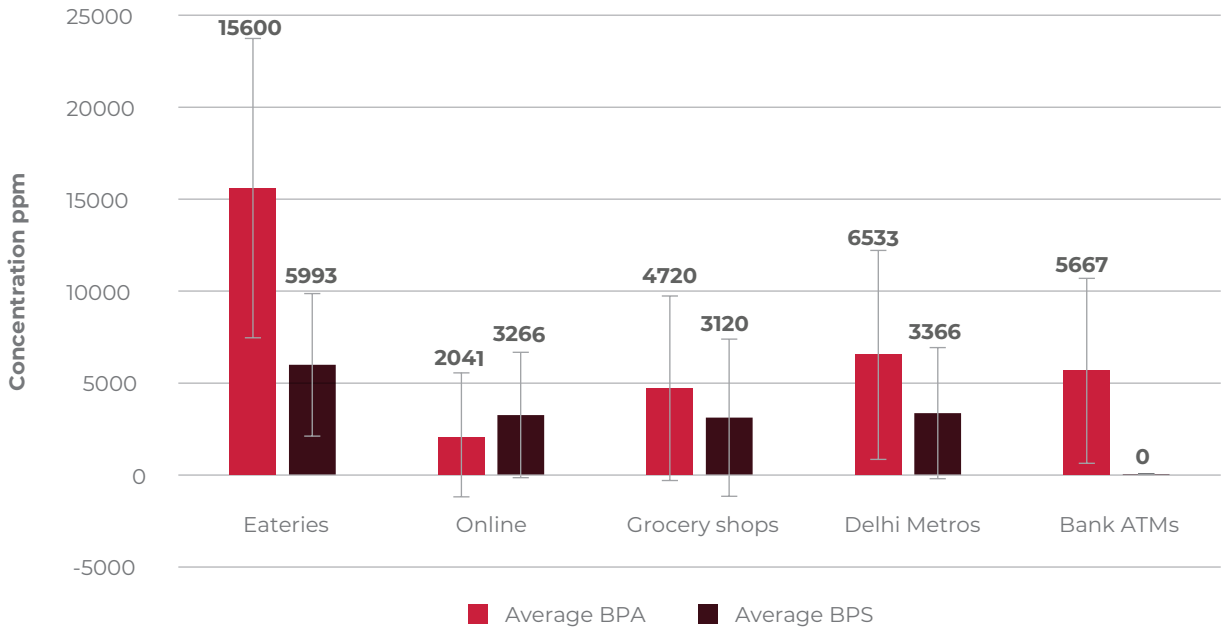
For this study six samples were collected from food eateries, out of which two were from global food chain brands while four were from local eateries. High BPA concentration was found in branded samples while BPS was detected in samples collected from local eateries although no direct relationship can be concluded whether BPA containing thermal papers are specially used in branded food chains despite global development as the number of samples were limited.

Figure 10: Analysis of bisphenol analogs in samples collected from food eateries



Both BPA & BPS were reported higher in samples collected from eateries in comparison to other sectors. The average value of BPA & BPS found in different sectors is represented in fig 11.

Figure 11: Distribution of average concentration of bisphenol analogs in different sectors



There are many recent studies that have investigated the presence of BPA in thermal paper receipts in different countries all over the world[63],[64],[65]; however, the BPA concentration detected in this study is extremely high especially in the context of the standards set by the EU (200ppm). In our previous study conducted in 2018, BPA was analysed in twelve samples. The maximum BPA concentration reported was 6600 ppm while the minimum was 300 ppm[66].

It is pertinent to mention that BPA & BPS are added in their free form and they are not chemically bound in thermal receipt paper. As a result, they can easily be released from the thermal receipts paper to any other objects in contact with it, including skin or paper money.

Moreover, the recycling of thermal paper receipts may cause BPA & BPS contamination in the recycled materials and contaminate new paper products.[67] Minnesota pollution control agency has reported the BPA contamination in the recycling stream in cities across the country.[68]

Three thermal paper samples were gathered from Delhi's metro stations, commonly utilized as travel tickets and recharge receipts. Among the samples, either BPA or BPS was identified in one each, with one sample containing both BPA and BPS. These metro receipts represent a significant and recurrent exposure pathway to bisphenol analogues for the public. Moreover, the substantial usage and improper disposal of these receipts on the ground pose a serious environmental threat, as BPA and BPS have the potential to leach out from the papers.

05

Conclusion and Recommendations

Bisphenol-A (BPA) is a widely recognized global endocrine-disrupting chemical (EDC), leading to stringent restrictions on its usage in various products, including thermal paper. Notably, India has prohibited use of BPA in baby feeding bottles, packaging for infant food and thermal paper. Unlike many countries, there is no established Tolerable Daily Intake (TDI) limit for BPA in food in India, which is critical to prevent the upstream use of BPA in various products.

The study's findings revealed that despite the regulation, BPA is still in use in thermal papers, with levels ranging from below detection limit to 17400 ppm. Thus, considering the multiple use and exposure to different communities, the chemical has multiple bearings and can potentially jeopardise the public health especially workers, cashiers, consumers.

Furthermore, given the stringent global regulations on BPA use in thermal paper, the substantial import of thermal paper into India warrants a thorough investigation to ensure compliance with these regulations and prevent potential health and environmental hazards.

In this context, Toxics Link would like to propose the following recommendations in the context of the current study:

Violation of BIS standards

The study has revealed the wider prevalence of BPA containing thermal paper in the Indian market, indicating a blatant violation of BIS standards as IS 17568: 2021 that explicitly prohibits the use of BPA in thermal paper.

Periodic Monitoring

The studies have indicated the BPA containing thermal papers are still used in supermarket, Delhi metros and the famous food joints. Moreover, there is a significant influx of thermal paper from the countries that have already phased out BPA in their thermal paper production. Therefore, it is crucial to undertake periodic monitoring to prevent the influx of BPA-laden thermal paper across the country.

Mandatory standards for better compliance

The **current BIS standard is voluntary** in nature. Hence, there is a need for mandatory standard to regulate toxic chemicals like BPA leading to better compliance and enforcement. Further, mandatory standards in thermal paper in India will be in alignment with the international efforts to regulate the use of these harmful substances.

Suitable disposal of thermal papers

The research reveals remarkably elevated levels of Bisphenol analogs in thermal papers within India. Unfortunately, there is currently no effective disposal infrastructure in place to manage these thermal papers in an environmentally sound manner. Consequently, there is a possibility of significant risk of BPA contamination across various paper-based products, environmental matrices, including water bodies. Thus, it is imperative to develop a comprehensive guideline for the proper disposal of thermal papers to minimise the wider environmental exposure.

Adoption of alternatives

The study established the availability of BPA free products in the Indian markets and use of BPS as an alternative. The scientific researches have also highlighted the possible health implications of BPS and some countries have even restricted its use in thermal paper. Therefore, considering these aspects, efforts are also required to investigate the possible environmental and health implications of BPA in Indian context. Further, there are better environmentally friendly alternatives available to BPA and BPS, so efforts can be made to replace these better alternatives with the BPA/BPS.

Awareness Generation

The relevant agencies should step in to create awareness among the stakeholders about the existing BIS standards and to prevent the possible impact of BPA from thermal papers. Some of the suggested measures are as follows:

- Avoid taking receipts unless one really need them as very often these receipts end up in the trash and contaminating the environment
- Go for on-line receipts as far as possible
- Wash your hands after touching the thermal receipts
- Use gloves to minimize the risks while handling BPA coated receipts.

Endnotes

1 https://telemarkcorp.com/how-to-select-thermal-paper-for-a-business

2 https://pandapaperroll.com/receipt-paper-types/

3 https://www.jujothermal.com/technical-guide/thermal-paper-technology/

4 https://www.reportsanddata.com/report-detail/thermal-paper-market

5 https://www.epa.gov/sites/default/files/2015-09/documents/bpa_ch3.pdf

6 https://www.epa.gov/sites/default/files/2015-08/documents/bpa_final.pdf

7 https://www.mordorintelligence.com/industry-reports/thermal-paper-market

8 https://www.reportsanddata.com/report-detail/thermal-paper-market

9 https://tradestat.commerce.gov.in/eidb/search.asp?fl=Icomcntq.asp

10 https://tradestat.commerce.gov.in/eidb/Icomcnt.asp

11 https://tradestat.commerce.gov.in/eidb/Icomcnt.asp

12 Banaderakhshan R., Kemp P., Breul L., Steinbichl P., Hartmann C., Fürhacker M. Bisphenol A and its alternatives in Austrian thermal paper receipts, and the migration from reusable plastic drinking bottles into water and artificial saliva using UHPLC-MS/MS. Chemosphere, 2022. 286 (3): 131842

13 Bernier MR, Vandenberg LN. Handling of thermal paper: Implications for dermal exposure to bisphenol A and its alternatives. PLoS One. 2017. 1; 12(6): e0178449.

14 https://www.pca.state.mn.us/sites/default/files/p-p2s10-13.pdf

15 EFSA. (2015) Scientific Opinion on the risks to public health related to the presence of bisphenol A (BPA) in foodstuffs. EFSA J; 13: 3978.

16 https://www.pca.state.mn.us/business-with-us/bpa-and-bps-in-thermal-paper

17 Heinälä M., Ylinen K., Tuomi T., et al. Assessment of occupational exposure to bisphenol A in five different production companies in Finland. Ann Work Expo Health, 2017. 61: 44–55.

18 Reale E., Vernez D., Hopf N.P. Skin Absorption of Bisphenol A and Its Alternatives in Thermal Paper. Ann Work Expo Health, 2021. 65 (2): Pages 206–218.

19 Hormann A.M., Vom Saal F.S., Nagel S.C., et al. Holding thermal receipt paper and eating food after using hand sanitizer results in high serum bioactive and urine total levels of bisphenol A (BPA). PLoS One, 2014. 9: e110509.

20 Liu J., Martin J.W. Comparison of bisphenol A and bisphenol S percutaneous absorption and biotransformation. Environ Health Perspect, 2019. 127: 67008.

21 Toner F., Allan G., Dimond S.S., et al. In vitro percutaneous absorption and metabolism of Bisphenol A (BPA) through fresh human skin. Toxicol In Vitro, 2018. 47: 147–55.

22 Demierre A.L., Peter R., Oberli A., et al. Dermal penetration of bisphenol A in human skin contributes marginally to total exposure. Toxicol Lett, 2012. 213: 305–8.

23 Champmartin C., Marquet F., Chedik L., et al. Human in vitro percutaneous absorption of bisphenol S and bisphenol A: A comparative study. Chemosphere, 2020. 126525

24 Danish EPA . (2014) Alternative technologies and substances to bisphenol A (BPA) in thermal paper receipts. Copenhagen, Denmark: The Danish Environmental Protection Agency (Environmental Project)

25 Ohore O.E., Zhang S. Endocrine disrupting effects of bisphenol-A exposure and recent advances on its removal by water treatment systems. A review. Scientific African, 2019. 5: e00135, ISSN 2468-2276.

26 Hafezi S.A., Abdel-Rahman W.M. The Endocrine Disruptor Bisphenol A (BPA) Exerts a Wide Range of Effects in Carcinogenesis and Response to Therapy. Curr Mol Pharmacol, 2019.12(3):230-238.

27 Fenichel P., Chevalier N., Brucker-Davis F. Bisphenol A: an endocrine and metabolic disruptor. Ann. Endocrinol. (Paris) 2013. 74:211–220.

28 Ya Ma, et al. The adverse health effects of bisphenol A and related toxicity mechanisms. Environ Res, 2019. 176: 108575,

29 EC (European Commission), 2016a. Commission regulation No 2016/2235 of 12 December 2016 amending Annex XVII to regulation (EC) No 1907/2006 of the European parliament and of the council concerning the registration, evaluation, authorisation and restriction of chemicals (REACH) as regards bisphenol A. Off. J. Eur. Union L 337, 3-5

30 https://www.efsa.europa.eu/en/topics/topic/bisphenol

31 Gys C., Bamai Y. A., et al. Biomonitoring and temporal trends of bisphenols exposure in Japanese school children. Environ Res, 2020. 110172.

32 https://www.cttlab.com/en/news_details.php?serial=421

33 EC (European Commission), 2016b. Commission Regulation (EU) No 2016/1179 of 19 July 2016 amending, for the purposes of its adaptation to technical and scientific progress, Regulation (EC) No 1272/2008 of the European Parliament and of the Council on classification, labelling and packaging of substances and mixtures. Off. J. Eur. Union L195, 11e25. E

34 https://echa.europa.eu/documents/10162/2564887/bpa_thermal_paper_report_2020_en.pdf/59eca269-c788-7942-5c17-3bd822d9cba0?t=1591700365310

35 https://baclcorp.com.cn/show.asp?para=en_2_49_3589

36 Barraza L. A New Approach for Regulating Bisphenol A for the Protection of the Public's Health. The Journal of Law, Medicine & Ethics, 2013. 41(1_suppl): 9–12.

37 https://malegislature.gov/Bills/192/S1423.Html

38 https://www.leafscore.com/grocery/which-states-protect-consumers-against-bpa/

39 USA Environmental Protection Agency, 2015a. Bisphenol A Alternatives in Thermal Paper, Final Report. https://www.epa.gov/sites/production/files/2015-08/documents/bpa_final.pdf.

40 Pivnenko K., Laner D., Astrup T. F. Dynamics of bisphenol A (BPA) and bisphenol S (BPS) in the European paper cycle: Need for concern. Resour Conserv Recycl, 2018. 133: 278-287.

41 Yang Y., Yang Y., Zhang J., Shao B., Yin J. Assessment of bisphenol A alternatives in paper products from the Chinese market and their dermal exposure in the general population. Environ Pollut, 2019. 244: 238-246.

42 Demierre A., Reinhard H., Zeltner S., Sabine Frey, Evaluating the efficiency of the 2020 ban of BPA and BPS in thermal papers in Switzerland. Regul Toxicol Pharmacol, 2024. 146: 105526,

43 https://www.epa.gov/sites/default/files/2014-05/documents/bpa_final.pdf

44 Herrero O´., Aquilino M., Sa´nchez-Argu¨ello P., Planello´ R. The BPA-substitute bisphenol S alters the transcription of genes related to endocrine, stress response and biotransformation pathways in the aquatic midge Chironomus riparius (Diptera, Chironomidae). PLoS ONE, 2018. 13(2): e0193387

45 https://www.globenewswire.com/news-release/2023/11/13/2778867/0/en/Global-Bisphenol-S-Market-Analysis-Growth-Demand-Supply-and-Industry-Trends-2015-2032.html

46 https://www.researchandmarkets.com/reports/5310851/india-bisphenol-s-market-analysis-plant

47 https://echa.europa.eu/-/bpa-being-replaced-by-bps-in-thermal-paper-echa-survey-finds

48 https://echa.europa.eu/documents/10162/2564887/bpa_thermal_paper_report_2020_en.pdf/59eca269-c788-7942-5c17-3bd822d9cba0?t=1591700365310

49 https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/sp.efsa.2020.EN-1844

50 Eladak S., Grisin T., et al. A new chapter in the bisphenol A story: Bisphenol S and bisphenol F are not safe alternatives to this compound. Fertil Steril, 2015. 103: 11 21.

51 Thoene M., Dzika E., Gonkowski S., Wojtkiewicz J. Bisphenol S in food causes hormonal and obesogenic effects comparable to or worse than bisphenol A: A literature review. Nutrients, 2020 12:

52 Qiu W., Zhao Y., Yang M., Farajzadeh M., Pan C., Wayne, N. Actions of Bisphenol A and Bisphenol S on the Reproductive Neuroendocrine System During Early Development in Zebrafish. Endocrinology, 2016. 157(2): 636-647.

53 Khatun S., Ferdous H., Hossain, S., Sultana S., Choi I., Lee Y.S. Detection of Endocrine Disruptor Bisphenol A and Bisphenol S in Bangladeshi Thermal Paper Receipts. Enviro. Sci Proc, 2022. 20

54 Usman A., Ahmad M. From BPA to its analogues: Is it a safe journey? Chemosphere, 2016. 158: 131–142.

55 Liao C., Liu F., Kannan K. Bisphenol S, a new bisphenol analogue, in paper products and currency bills and its association with bisphenol-A residues. Environ Sci Technol 2012. 46 (12): 6515–6522.

56 Lehmler H.J., Liu B., Gadogbe M., Bao W. Exposure to bisphenol A, bisphenolF, and bisphenol S in U.S. adults and children: The National Health andNutrition Examination Survey 2013-2014. ACS Omega, 2018. 3(6):6523–6532.

57 https://echa.europa.eu/-/bpa-being-replaced-by-bps-in-thermal-paper-echa-survey-finds

58 Gayrard V., Lacroix M.Z., et al. Oral systemic bioavailability of bisphenol A and bisphenol S in Pigs. Environ Health Perspect,2019. 127(77005).

59 Glausiusz J. Toxicology: the plastics puzzle. Nature, 2014. 508: 306e308.

60 Liao C., Kannan, K. A survey of bisphenol A and other bisphenol analogues in foodstuffs from nine cities in China. Food Additives & Contaminants: Part A, 2014. 31(2): 319–329.

61 TYang Y., Lu L., Zhang J., Yang Y., Wu Y., Shao B. Simultaneous determination of seven bisphenols in environmental water and solid samples by liquid chromatography–electrospray tandem mass spectrometry. J Chromatogr A, 2014. 1328: 26-34.

62 https://afirm-group.com/wp-content/uploads/2023/04/2023_AFIRM_RSL_2023_0419a.pdf

63 Frankowski R., Zgoła-Grze´skowiak A., Grze´skowiak T., Sójka K. The presence of bisphenol A in the thermal paper in the face of changing European regulations–a comparative global research. Environ Pollut, 2020. 265: 114879.

64 Eckardt M., Simat T.J. Bisphenol A and alternatives in thermal paper receipts—A German market analysis from 2015 to 2017. Chemosphere, 2017. 186: 1016–1025.

65 Bjornsdotter M.K., Jonker W., Legradi J., Kool J., Ballesteros-Gomez. Bisphenol A alternatives in thermal paper from The Netherlands, Spain, Sweden and Norway. Screening and potential toxicity. Sci Total Environ, 2017. 601: 210–221.

66 BPA - Thermal Paper - revised (19-12-2017).indd (toxicslink.org)

67 Jurek A., Leitner E. Analytical determination of bisphenol A (BPA) and bisphenol analogues in paper products by GC-MS/MS. Food Additives & Contaminants: Part A, 2017. 34(7): 1225–1238.

68 https://www.pca.state.mn.us/business-with-us/bpa-and-bps-in-thermal-paper