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Alternative technologies and substances to bisphenol A (BPA) in thermal paper receipts

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Title:

Alternative technologies and substances to bisphenol A (BPA) in thermal paper receipts

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Preface

The project ”Alternative technologies and substances to bisphenol A (BPA) in thermal paper receipts” was carried out from July 2013 till December 2013 as part of the Danish EPA’s strategy on BPA issued 13 May 2013 (Danish EPA, 2013).

This report describes the project results, including a survey of selected alternative substances and technologies to the use of BPA in thermal paper receipts.

The project was carried out by COWI and the Danish Technological Institute. Participants from COWI were Frans M. Christensen (project manager) and Delilah Lithner (COWI Sweden). Participants from the Danish Technological Institute were Sie Woldum Tordrup, Karen Krzywkowski and Nils H. Nilsson.

The progress, development and results of the project were assessed by a reference group consisting of the following persons:

- Shima Dobel, the Danish Environmental Protection Agency
- Helle Fabiansen, Plastindustrien
- Jakob Lamm Zeuthen, Danish Chamber of Commerce
- Claus Hollmann, Schades Nordic A/S
- Karin Frøidt, COOP
- Anette Ravn Jensen, Danish Working Environment Authority
- Claus Jørgensen, The Danish Consumer Council

The project was financed by the Danish Environmental Protection Agency.

Danish EPA, December 2013

Executive summary

Background

This project addressing alternatives to the use of Bisphenol A (BPA) in thermal paper receipts is part of the Danish EPA's strategy on BPA (Danish EPA, 2013). The analysis includes alternative substances which could replace BPA in thermal paper used for receipts and tickets, as well as alternative technologies to thermal printing which could replace thermal paper receipts.

BPA is used as a developer in thermal paper and is today by far the most used developer. A previous project commissioned by the Danish EPA (Lassen et al., 2011) addressing BPA in thermal paper concluded that there was no health risk associated with BPA in thermal paper based on the guideline animal studies, which also forms the basis for the opinion on BPA of the European Food Safety Authority (EFSA). This opinion was originally drafted in 2006. Review of scientific information on BPA in 2008, 2009, 2010 and 2011 by EFSA did not identify any new evidence that would lead to changes in the conclusions of that opinion.

However, there is increasing concern with respect to possible endocrine disrupting properties of BPA at low dose exposure, e.g. causing developmental neurotoxicity, as a large number of non-guideline studies report effects of BPA exposure at very low doses, sometimes around only a few µg/kg bodyweight per day. Concern is especially related to population groups who frequently handle this type of paper and for particularly sensitive groups such as pregnant women and young children. This has led scientists and others to question the sufficiency of the current tolerable daily intake (TDI) of 0.05 mg/kg bodyweight/day established by EFSA. EFSA is currently updating its opinion on BPA. A draft of this updated opinion is expected by end 2013/early 2014.

This project focuses on alternatives related to BPA in thermal paper receipts. Such receipts include point-of-sale (POS) receipts (also known as till receipts) from purchase in stores, and tickets for instance for travelling, parking, cinema and other events. The main focus of this project has been on the point-of-sale (POS) receipts. BPA can be released from these receipts causing exposure by dermal contact. To what extent available alternative substances are preferable from a health point of view and alternative technologies such as electronic receipts in practice can serve the same function, is still uncertain.

Objective

The aim of the project is to identify solutions which reduce the exposure to BPA from thermal paper receipts. This includes investigating and assessing alternative substances as well as alternative technologies.

The alternative substances survey summarise environmental and health hazard properties based on other reviews and address migration (both theoretically based on physical chemical properties and by analytical migration studies on a few alternative substances). It has not been within the scope of the study to conduct actual risk assessments.

The alternative technologies survey addresses technical solutions that fulfil the same purpose as the thermal paper receipt, i.e. to provide documentation for proof of purchase. Identification of possible barriers for implementing new technology and possible mitigation of these is also addressed.

Approach/methodology

Initially, recent reports addressing BPA and alternatives to BPA from US EPA, the Danish EPA and the Swedish Chemicals Agency (KemI) were reviewed. These reports mainly address alternative substances and in particular the inherent health and environmental properties of BPA and alternatives.

The Danish EPA and the KemI studies largely refer to the July 2012 Draft US EPA report "Bisphenol A alternatives in thermal paper" (US EPA, 2012), which is also most comprehensive in terms of substance coverage. Thus, that report has been the main source for summarising health and environmental properties of BPA and alternatives.

Other activities were undertaken in order to: i) identify other aspects of the performance on alternative substances (cost, quality of print, technical aspects of substitution etc.) and ii) identify availability, acceptance, and barriers for alternative technologies.

These activities included:

- Internet searches, not the least to identify alternative technologies;
- Inquiries via questionnaires and telephone interviews with manufacturers, importers and distributors of thermal paper (receipts) in order to identify alternative substances in thermal paper on the market and trends, as well as issues related to performance of such alternatives;
- Inquiries via questionnaires and e-mails as well as telephone interviews with a range of (retail) stores and chain stores, in order to gain information about their use of BPA containing thermal paper and alternatives and to get their view on the trend towards technological alternatives, and
- Inquiries to relevant trade and consumer associations for information regarding thermal paper in general and any knowledge on alternatives. Associations contacted were:
  - Plastics Europe (through The Danish Plastics Federation "Plastindustrien")
  - The European Thermal Paper Association (ETPA)
  - The Imaging & Printing Association (I&P Europe)
  - The Danish Consumer Council (Forbrugerrådet).

The method for the analytical migration investigations conducted were performed similarly to a previous Danish EPA study (Lassen et al., 2011) and included:

- Total content of substance in paper sample (measured as total migration)
- Migration to sweat
- Migration to dry fingers
- Migration to sweaty fingers
- Migration to fingers with hand cream

Within the scope of this project, double-determination of three paper samples (one sample per substance analysed) were conducted. The substances analysed being: BPA, bisphenol S and Pergafast.

Results and discussion

Alternative substances

There are several alternatives to bisphenol A (BPA) as developer in thermal paper. US EPA (2012) identified 19 alternatives that are either in use or have been assessed to have the potential (based on physical chemical properties) to be used as developers in thermal paper. In the current survey only five of these 19 alternatives have been confirmed by manufacturers to be used in thermal paper for receipts or labels on the European market. These are bisphenol S, Pergafast and Urea Urethane (UU), which are used in thermal paper receipts, and D-8 (4-hydroxyphenyl 4-isoprooxyphenylsulfone) and D-90 (4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl]phenol), which are used in labels. Bisphenol S and D-90 are bisphenols, D-8 is a phenol, whereas Pergafast and UU are phenol free. UU seems to be less common and only scarce information could be obtained on this substance.

In general in was difficult to obtain detailed information regarding alternatives from thermal paper manufacturers due to company secrets / the competitive situation and likely also because of the political focus on BPA worldwide. However, some general information was obtained during the telephone interviews with the manufacturers on condition of anonymity.

The confirmed alternatives are all more expensive than BPA. Thermal paper with Bisphenol S is the most common and cheapest alternative (approx. 5-10% more expensive than BPA based paper). Thermal paper with Pergafast is quite common and is the most expensive alternative (usually 10-25% more expensive than BPA based paper). The price for thermal paper with D-8 or D-90 is somewhere in between the price for thermal paper with bisphenol S and Pergafast. Besides the higher cost for the alternatives compared to BPA, the other negative aspect mentioned by the paper manufacturers was that substituting a developer requires significant adjustments in the thermal paper manufacturing process such as modification in the chemistry of the paper (not only the developer), and quality adjustments. From the collected information, it appears that substitution is not a one-to-one substitution.

It should be noted that the Pergafast chemical is currently only produced by one manufacturer, which means there is no competition regarding price and no possibility for flexibility regarding delivery from multiple suppliers. Whether this lead to hesitations by paper manufacturer to substitute to this alternative has not been clarified in this project, but could be speculated.

Once the paper is produced, the alternatives seem not to have any functional drawbacks. On the contrary, the phenol free alternatives have better performance than BPA, because of their higher image stability. Compared to BPA based paper, image stability is similar or slightly higher for paper based on bisphenol S, higher for D-8 and D-90 and much higher for Pergafast. For customers substituting to thermal paper rolls without BPA, there are no technological challenges, since existing thermal printers can be used without adjustments.

All 19 alternatives identified by US EPA (2012) are associated with environmental and or health hazards, but the available data on these substances are either scarce or of low or very low quality, which makes it challenging to conclude with any certainty that one alternative is better than the other.

The US EPA assessments and/or EU classifications for the three alternative substances that were confirmed to be used in thermal paper receipts indicate the following:

- The two phenol-free alternatives i.e. Pergafast and UU are very persistent in the environment;
- Pergafast is toxic to aquatic life with long lasting effects and has been assigned a moderate hazard for reproductive and developmental effects and repeated dose effects;
- For UU data are very scarce, and
- Bisphenol S is noted to cause serious eye irritation and to be harmful to aquatic life with long lasting effects, and has been assigned a high hazard regarding repeated dose toxicity, and a moderate hazard for reproductive and developmental effects, and mutagenicity/genotoxicity.

Thermal paper receipt samples with confirmed content of BPA, bispenol S and Pergafast were obtained from one manufacturer. These were subject to the analytical experiments performed in this project.

Analyses of the contents showed that the total content of Pergafast in thermal paper receipts was detected to be comparable to BPA (around 1% w/w) while the amount of bisphenol S detected was slightly higher (around 1.2% w/w). This slightly higher bisphenol S concentration is in line with information found in literature.

The migration of Pergafast was generally much lower than for both BPA and bisphenol S, except in the case of migration to sweaty fingers where the migration was comparable to BPA and much higher than for bisphenol S. The migration of bisphenol S was generally slightly lower than for BPA, except in the case of migration to sweat where the migration was slightly higher than for BPA. The results for BPA migration to fingers are generally comparable to the trends seen in other studies (Lassen et al., 2011 and Biedermann et al., 2010), although differences in methodology and paper type has resulted in a lower migration in the Biedermann et al. (2010) study.

The results should be considered indicative rather than representative since analyses were performed on only one sample of paper per substance tested. The results however do confirm what is expected based on theoretical considerations, i.e. that bisphenol S generally migrates similar to BPA while the migration of Pergafast in most cases is hindered, probably due to its larger molecular size. However, migration of Pergafast to sweaty fingers was found to be high, a finding which was unexpected given the molecular size and since the migration to sweat directly was very low.

No data on dermal absorption have been identified for Bisphenol S and Pergafast, but based on professional judgement, dermal absorption of Bisphenol S is expected to be comparable to that of BPA, whereas that of Pergafast is expected to be considerably lower.

As indicated above, bisphenol S and Pergafast have known or suspected unwanted environmental and health properties, but are not as well studied as BPA.

Bisphenol S might possess health properties similar to those of BPA and seems to have similar migration and dermal absorption ability. Overall, current evidence is therefore too scarce to distinguish between thermal paper with respectively BPA and bisphenol S from a health and environmental perspective.

Despite unexpected findings of migration of Pergafast to sweaty fingers, Pergafast is generally found and expected to migrate and absorb through the skin to a lower extent than BPA. Although scarce, also hazard data indicate that Pergafast might be less inherently toxic to human health and thus could be expected to cause less health risks. On the other hand, Pergafast is assessed to be persistent and toxic to the environment. Thus, overall, based on the activities in this project, it is difficult to judge whether Pergafast would be preferable to BPA from a health and environmental point of view.

Overall, it should be stressed that generally few hazard data are available for alternative substances and that the few migration tests performed in this study should not be over-interpreted.

Alternative technologies
A range of partly overlapping alternative technologies has been identified in this project. Many of these relate to the move to the cashless society and involve techniques related to mobile payment: SMS text, custom applications (apps), Near Field Communication (NFC), Radio Frequency Identification (RFID), Contactless smart card payments and electronic receipts.

Other alternatives identified include receipt handling solutions at cash registers that reduce the amount of paper used for receipts or that reduce the handling of thermal paper for the most frequently exposed group (the cash register attendants), including self-service check-out, receipt printing facing customer and a "no-receipt" option (not printing the receipts if customer does not want/need it).

Other alternatives identified, but not addressed in great detail were paper with topcoating (which are not, or very seldom, used for receipts) and alternative printing technologies (considered outdated).

The report contains a thorough overview of these technologies (summarised in Table 11) addressing pros and cons, as well as possible ways to overcome disadvantages.

Today, the technologies addressed in this project are used alone or in combination, and several of the technologies are provided for the same purpose to accommodate different customer types. The transition to technologies supporting a cashless society has been confirmed during the project. Although the development of such technologies looks strong and some technologies look very promising, the process of phasing out paper receipts entirely may be a slow process and the prospects of each technology is still considered uncertain.

The most promising technologies which are expected to have a significant effect on the reduction of paper receipts and tickets are mobile payments via apps (with in-app purchases and receipt handling) and automated electronic receipts handling systems (e.g. via apps such as offered by eKvittering.dk).

Using electronic payment forms and receipt handling is expected to have a positive effect in reducing the consumption of thermal printing paper, but today some electronic payment is still accompanied by a paper receipt as proof of purchase. Technologies like apps for handling e-receipts automatically exist (e.g. eKvittering), and already have the potential of reducing the amount of thermal paper used for receipts today, if the technology was properly embraced by users and shop owners. This has not yet happened, but the outlook is positive as the wide public becomes more and more familiarised with the use of mobile devices. Technologies like mobile payments via apps have the potential to develop fast and thereby result in a significant reduction in the use of paper receipts in the very near future, and other types of mobile payment might follow soon thereafter.

Solutions at cash registers that reduce the amount of paper used for receipts or that reduce the handling of thermal paper for the most frequently exposed group (the cash register attendants), can be implemented. But due to the rising popularity of the use of mobile devices and the associated technologies these solutions are expected to provide, "cash register solutions" are considered temporary solutions which are therefore less likely to be implemented, although they are expected to be associated with lower cost of introduction as compared with the electronic solutions.

Because the market for alternative technologies for replacing paper receipts is complex, the possibilities of barrier mitigation for the introduction of the new technologies are also diverse. The need for sharing knowledge on new technologies, promoting and training are main issues to be addressed for almost all technologies identified in the project. For mobile payment via apps, a simple design and user interface is important as a means of barrier mitigation, as well as an adequate balance between convenience and security depending on the size of purchase (no PIN/PIN required). For automated receipt handling systems, the reduction of the lag time between purchase and delivery of an electronic receipt is a barrier which can be reduced either by choice/updating of the underlying systems or by introducing a means for direct scanning of receipts at the register (Quick Response (QR) code or NFC (Near Field Communication) tag). A segment among the elderly might not, or only very slowly, adapt to new technologies.

Danes are generally positive toward new technology and they are frequent owners of smartphones. Therefore, one might expect the growth of the mobile payment solutions to continue and that the consumer will gain knowledge and acceptance over time. A convenient payment system is already in place today (Dankort) and it is trusted and highly functional. This is expected to be one explanation why the growth rate of the alternative payment technologies in Denmark is lagging somewhat behind other European countries, but the trends are strong and this barrier is expected to be overcome within few years.

Conclusions

The most frequently used alternatives to BPA in thermal paper receipts appear to be bisphenol S and Pergafast. Based on: i) migration findings of this study, ii) absorption and exposure considerations and iii) considering readily available information on health and environmental properties, it cannot be concluded that these alternatives cause a lower impact on health and the environment than BPA. Bisphenol S is assessed to possess similar properties to BPA in relation to migration, as well as exposure to and impact on human health. Pergafast might possess a lower human health risk (lower migration and less severe toxicity), but is indicated to be toxic to and persistent in the environment. Overall, the migration findings in this report should be seen as indicative given the extent of the analytical migration investigations and the fact that generally less information is available for the BPA alternatives than for BPA should be noted.

The primary driving force for development of most of the identified alternative technologies is not the intention to reduce the use of BPA or to reduce of paper receipts in general. The development is rather a consequence of a transition to a cashless society, where more and more purchases are done electronically and without the exchange of actual money. The reduction or elimination of the paper receipt is only a side-effect of this transition.

Nevertheless, phasing out paper receipts as a result of using alternative technological solutions has potential due to this transition towards a cashless society. However, at present none of the technologies presented in this report can be considered mature enough to fully replace the paper receipt.

Sammenfatning

Baggrund

Dette projekt vedrører alternativer til anvendelsen af bisphenol A (BPA) i kasseboner og andre kvitteringer af termopapir. Projektet er en del af den danske Miljøstyrelses strategi for BPA (Danish EPA, 2013). Analysen omfatter alternative stoffer, der kan erstatte BPA i termopapir (brugt til kvitteringer og billetter), samt alternative teknologier som ville kunne erstatte kvitteringer af termopapir.

BPA anvendes som fremkalder i termopapir og er i dag langt den mest anvendte fremkalder. Et tidligere projekt udarbejdet for Miljøstyrelsen (Lassen et al., 2011) omhandlende BPA i termopapir konkluderede, at der ikke var nogen sundhedsrisiko forbundet med BPA i termopapir. Denne konklusion baserede sig på resultater af dyreforsøg udarbejdet i overensstemmelse med standard-retningslinjer, som også danner grundlag for den aktuelle vurdering af BPA fra Den Europæiske Fødevaresikkerhedsautoritet (EFSA). Denne vurdering blev oprindeligt udarbejdet i 2006. Nye videnskabelige resultater vedrørende BPA blev gennemgået af EFSA i 2008, 2009, 2010 og 2011, men dette gav ikke EFSA anledning til at ændre sine anbefalinger vedrørende BPA.

Der er dog en voksende bekymring angående de mulige hormonforstyrrende egenskaber af BPA ved lav-dosis eksponering, f.eks. forårsagende udviklings-neurotoksicitet, da en lang række af studier, som ikke følger standard-retningslinjer, rapporterer virkninger af BPA ved meget lave doser – undertiden helt ned til et par µg/kg kropsvægt pr. dag. Denne bekymring er især rettet mod befolkningsgrupper, der ofte håndterer denne type papir, og mod særligt sårbare grupper såsom gravide kvinder og små børn. Dette har ført forskere og andre til at sætte spørgsmålstegn ved det nuværende tolerable daglige indtag (TDI) på 0,05 mg/kg kropsvægt pr. dag, som er fastsat af EFSA. EFSA er i øjeblikket i gang med at revidere vurderingen af BPA. Et udkast til denne revurdering forventes med udgangen af 2013/starten af 2014.

Dette projekt fokuserer på alternativer til BPA i kvitteringer og billetter af termopapir. Disse inkluderer kasseboner fra køb i butikker og billetter til f.eks. rejser, parkering, biografer og andre begivenheder. Det primære fokus i dette projekt har været kasseboner. BPA kan frigives fra disse kvitteringer og medføre eksponering via hudkontakt. Hvorvidt tilgængelige alternative stoffer er at foretrække ud fra et sundhedsmæssigt synspunkt og om alternative teknologier såsom elektroniske kvitteringer i praksis kan opfylde samme funktion er dog stadig usikkert.

Formål

Formålet med dette projekt er at identificere løsninger, som kan reducere eksponeringen for BPA fra kvitteringer af termopapir. Dette omfatter undersøgelse og vurdering af alternative stoffer, såvel som alternative teknologier.

Undersøgelsen af de alternative stoffer skal opsummere de miljø- og sundhedsmæssige egenskaber, baseret på andre undersøgelser, samt adressere migration (såvel teoretisk baseret på fysisk-kemiske egenskaber, som ved hjælp af analytiske migrationsstudier for nogle få alternative stoffer). Det er udenfor dette projekts rammer at udføre en egentlig risikovurdering.

Undersøgelsen af de alternative teknologier skal adressere tekniske løsninger, der opfylder samme formål som kasseboner af termopapir, dvs. at levere dokumentation som bevis for købet. Mulige barrierer for implementering af disse nye teknologier skal identificeres, og muligheder for afhjælpning af disse barrierer skal diskuteres.

Tilgang/metode

Indledningsvist blev nye rapporter omhandlede BPA og alternativer til BPA fra den amerikanske miljøstyrelse (US EPA), Miljøstyrelsen og den svenske kemikalieinspektion (KemI) gennemgået. Disse rapporter beskæftiger sig primært med alternative stoffer og især med de iboende sundheds- og miljømæssige egenskaber af BPA og alternativerne til BPA.

Undersøgelserne fra Miljøstyrelsen og KemI henviser i stor udstrækning til et udkast til en rapport fra US EPA fra juli 2012 "Bisphenol A alternatives in thermal paper" (US EPA, 2012), som også er den mest dækkende i relation til stofalternativer til BPA. Rapporten fra EU EPA har været den vigtigste kilde til opsummeringen af de miljø- og sundhedsmæssige egenskaber af BPA og alternativerne til BPA.

Andre aktiviteter blev udført med henblik på: i) at identificere andre aspekter af de alternative stoffers anvendelighed (omkostninger, kvalitet af print, tekniske aspekter vedr. substitution osv.) og ii) at identificere tilgængelighed af, accept af, og barrierer for alternative teknologier.

Disse aktiviteter omfattede:

- Internetsøgninger – ikke mindst for at identificere alternative teknologier;
- Forespørgsler via spørgeskemaer og telefoninterviews med fabrikanter, importører og distributører af kvitteringer af termopapir med henblik på at identificere alternative stoffer i termopapir på markedet og tendenser, samt problemer i forbindelse med performance af disse alternativer;
- Forespørgsler via spørgeskemaer og e-mails samt telefoninterviews med en række detailbutikker og butikskæder med henblik på at opnå information om anvendelsen af termopapir indeholdende BPA og alternativer, samt for at få butikkernes syn på tendensen mod alternative teknologier;
- Forespørgsler til relevante branche- og forbrugerorganisationer for at få oplysninger om termopapir i almindelighed og eventuel viden om alternativer. De kontaktede organisationer var:
  - Plastics Europe (gennem "Plastindustrien")
  - The European Thermal Paper Association (ETPA)
  - The Imaging & Printing Association (I&P Europe)
  - Forbrugerrådet.

De analytiske migrationsundersøgelser i projektet blev udført på samme måde som i en tidligere undersøgelse udført for Miljøstyrelsen (Lassen et al., 2011) og omfattede:

- Samlet indhold af stof i en papirprøve (målt som total migration)
- Migration til sved
- Migration til tørre fingre
- Migration til svedige fingre
- Migration til fingre smurt med håndcreme.

Indenfor rammerne af dette projekt blev der udført dobbeltbestemmelse på tre papirprøver (en papirprøve pr. stof). De analyserede stoffer var: BPA, bisphenol S og Pergafast.

Resultater og diskussion

Alternative stoffer

Der findes en del alternativer til bispenol A (BPA) som fremkalder i termopapir. US EPA (2012) identificerede 19 alternativer, som enten er i brug, eller er blevet vurderet til at have potentiale (baseret på fysisk-kemiske egenskaber) for at blive anvendt i termopapir. I nærværende undersøgelse er kun 5 ud af disse 19 alternativer blevet bekræftet af producenterne som anvendt i termopapir til kvitteringer eller etiketter på det europæiske marked. Disse er bisphenol S, Pergafast og Urea Urethan (UU), som anvendes i kvitteringer af termopapir, og D-8 (4- hydroxyphenyl 4 - isoprooxyphenylsulfon) og D-90 (4 - [4' - [(1'- methylethyloxy) phenyl] sulfonyl] phenol), der anvendes i etiketter. Bisphenol S og D-90 er bisphenoler, D-8 er en phenol, hvorimod Pergafast og UU er fri for phenoler. UU synes at være mindre udbredt og kun sparsomme oplysninger har kunnet indhentes om dette stof.

Det har generelt været vanskeligt at få detaljerede oplysninger om alternativer fra producenterne af termopapir på grund af forretningshemmeligheder/konkurrencesituationen, og højst sandsynligt også på grund af det politiske fokus på BPA på verdensplan. Det var dog muligt at indhente generel information gennem telefoninterviews med producenterne på betingelse af anonymitet.

Alle de bekræftede alternativer dyrere end BPA. Termopapir med bisphenol S er det mest anvendte og billigste alternativ (ca. 5-10% dyrere end BPA-baseret papir). Termopapir med Pergafast er ret anvendt og det dyreste alternativ (som regel 10-25% dyrere end BPA-baseret papir). Prisen for termopapir med D-8 eller D-90 ligger et sted imellem prisen for termopapir med bisphenol S og Pergafast. Udover de højere omkostninger for alternativerne i forhold til BPA er et andet negativ aspekt, nævnt af producenterne, at substitution af en fremkalder kræver væsentlige ændringer i fremstillingsprocessen af termopapir. Dette inkluderer ændringer i formuleringen (ikke kun ændring af fremkalderen) og andre justeringer af processen. Det fremgår således af den indsamlede viden, at en substitution ikke bare er en en-til-en substitution.

Det skal bemærkes, at Pergafast-kemikaliet i øjeblikket kun fremstilles af en enkelt producent, hvilket betyder, at der ikke er nogen konkurrence på pris og ingen mulighed for fleksibilitet i forhold til levering fra forskellige leverandører. Hvorvidt dette fører til tøven fra papirproducenterne til at substituere til dette alternativ er ikke blevet afklaret i dette projekt, men det kunne være tilfældet.

Når papiret først er produceret, synes alternativerne ikke til at have nogen funktionelle ulemper. Tværtimod viser de phenol-frie alternativer sig at fungere bedre end BPA, da de medfører bedre stabilitet af printet. Sammenlignet med BPA-baseret papir er print-stabiliteten tilsvarende eller lidt højere for papir baseret på bisphenol S, højere for D-8 og D-90 og meget højere for Pergafast. Der er ingen teknologiske udfordringer for butikker, der skifter til termopapirruller uden BPA, da eksisterende termo-printere kan anvendes uden justeringer.

Alle 19 alternativer identificeret af US EPA (2012) er forbundet med miljø- og/eller sundhedsmæssige risici, men tilgængelige data for disse stoffer er enten sparsomme eller af lav eller meget lav kvalitet, hvilket gør det udfordrende at konkludere med nogen form for sikkerhed, om et alternativ er bedre end et andet.

Vurderingerne fra US EPA og/eller EU klassificeringerne af de tre alternative stoffer, som i nærværende projekt er bekræftet anvendt i kvitteringer af termopapir, indikerer følgende:

- De to phenol-frie alternativer, dvs. Pergafast og UU er meget persistente i miljøet;
- Pergafast er giftigt for vandlevende organismer med langvarige effekter og er blevet vurderet at være moderat farlige (”moderate hazard”) for reproduktionstoksiske og udviklingsmæssige effekter, samt effekter efter gentagen eksponering;
- For UU er data meget sparsomme;
- Bisphenol S er vurderet til at forårsage alvorlig øjeirritation og til at være skadelig for vandlevende organismer med langvarige effekter, og er blevet vurderet til at være meget farlige (”high hazard”) for effekter efter gentagen eksponering, og moderat farlige (”moderate

hazard") for reproduktionstoksiske og udviklingsmæssige effekter, samt for mutagenicitet og gentoksicitet.

Prøver af kvitteringer af termopapir med et bekræftet indhold af BPA, bisphenol S og Pergafast blev modtaget fra en producent af termopapir og blev undersøgt som en del af projektet.

Indholdsanalyser viste, at det totale indhold af Pergafast i kvitteringer af termopapir var sammenligneligt med indholdet af BPA (omkring 1 vægtprocent), mens mængden af bisphenol S blev bestemt til at være en smule højere (omkring 1.2 vægtprocent). Den lidt højere koncentration af bisphenol S er i tråd med de oplysninger, der findes i litteraturen.

Migrationen af Pergafast var generelt meget lavere end migrationen af BPA og bisphenol S, undtagen i tilfælde af migration til svedige fingre, hvor migrationen var sammenlignelig med migrationen af BPA og meget højere end migrationen af bisphenol S. Migrationen af bisphenol S var generelt en smule lavere end migrationen af BPA, undtagen i tilfælde af migration til sved, hvor migrationen var en smule højere end migrationen af BPA. Resultaterne for migration af BPA til fingre er generelt sammenlignelige med de tendenser, der er fundet i andre studier (Lassen et al., 2011 og Biedermann et al., 2010), selvom forskelle i metode og papirtype har resulteret i lavere migration i undersøgelsen rapporteret i Biedermann et al. (2010).

Resultaterne skal betragtes som vejledende snarere end repræsentative, da analyserne kun er udført på én prøve af papir med hvert af tre testede stoffer. Resultaterne bekræfter imidlertid hvad man kunne forvente baseret på teoretiske overvejelser, nemlig at migrationen af bisphenol S generelt ligner migrationen af BPA, mens migrationen af Pergafast i de fleste tilfælde er mindre/hindres, sandsynligvis på grund af størrelsen på molekylet. Dog blev migrationen af Pergafast til svedige fingre fundet at være høj, hvilket ikke var forventet grundet molekylestørrelsen og den lave migration direkte til sved.

Ingen data for dermal absorption er blevet identificeret for bisphenol S og Pergafast, men, baseret på ekspertviden, vurderes den dermale absorption af bisphenol S at være sammenlignelig med BPA, hvorimod den dermale absorption af Pergafast forventes at være betydeligt lavere.

Bisphenol S og Pergafast har, som anført ovenfor, kendte eller mulige uønskede miljø- og sundhedsmæssige egenskaber, men de er ikke så godt undersøgt som BPA.

Bisphenol S kan muligvis besidde sundhedsmæssige egenskaber svarende til BPA's og synes at have lignende migration og dermal absorberingsevne. Samlet set er den nuværende evidens for sparsom til at skelne mellem termopapir med henholdsvis BPA og bisphenol S set ud fra et miljø- og sundhedsmæssige perspektiv.

Trods det uventede fund af migration af Pergafast til svedige fingre, er migrationen og hudabsorptionen af Pergafast generelt fundet og forventet at være mindre end for BPA. Omend sparsomme, indikerer data derudover, at den iboende toksicitet af Pergafast overfor mennesker muligvis er mindre end toksiciteten af BPA, og derved kunne Pergafast forventes at udgøre en lavere sundhedsrisiko end BPA. På den anden side vurderes Pergafast at være persistent og toksisk i miljøet. Således er det, baseret på aktiviteterne i dette projekt, vanskeligt at vurdere, hvorvidt Pergafast ud fra et miljø-og sundhedsmæssigt perspektiv er at fortrække frem for BPA.

Alt i alt bør det understreges, at der generelt er mangel på tilgængelige data for alternative stoffer, og at de begrænsede migrationsforsøg udført i denne undersøgelse ikke bør overfortolkes.

Alternative teknologier

En række delvist overlappende alternative teknologier er blevet identificeret i dette projekt. Mange er koblet til overgangen til et pengeløst samfund og indebærer teknologier relateret til mobil betaling: SMS-beskeder, brugerdefinerede applikationer (apps), "Near Field Communication" (NFC), "Radio Frequency Identification" (RFID), "Contactless smart card" betalinger og elektroniske kvitteringer.

Andre identificerede alternativer omfatter løsninger vedr. håndtering af kvitteringer ved kasseapparaterne, som reducerer håndteringen af termopapir for den hyppigst udsatte gruppe (kassemedarbejderen), herunder selvbetjeningskasser, bon-udskrivningen vendt mod kunden og en "ingen-kvittering" mulighed (ingen udskrivning af kvitteringer, hvis kunden ikke ønsker den/ikke behøver den).

Andre identificerede alternativer, som ikke er behandlet i detaljer i dette projekt er papir med overfladebehandling (som kun i ringe grad eller slet ikke anvendes til kvitteringer) og alternative print-teknologier (betragtes som forældede).

Denne rapport indeholder et grundigt overblik over disse teknologier (opsummeret i tabel 11), og behandler fordele og ulemper, såvel som mulige måder til at overvinde disse ulemper.

De gennemgåede teknologier anvendes i dag enten alene eller i kombination, og flere af teknologierne anvendes til det samme formål for at tilgodese forskellige kundetyper. Overgangen til teknologier, som understøtter et pengeløst samfund, er blevet bekræftet gennem dette projekt. Selvom trenden er overbevisende, og nogle af teknologierne virker meget lovende, er den totale udfasning af papirkvitteringer en langsom proces, og udsigterne for de forskellige teknologier vurderes stadig som usikker.

Den mest lovende teknologi, som forventes at have en betydelig effekt på reduktionen af kvitteringer og billetter, er mobil betaling via apps (med in-app køb og behandling af kvitteringer) og automatiserede elektroniske håndteringssystemer for kvitteringer (f.eks. via apps, så som eKvittering.dk).

Anvendelsen af elektroniske betalingsmetoder og håndtering af kvitteringer forventes at have en positiv effekt i forhold til at reducere forbruget af termopapir. Dog er nogle elektroniske betalingsmetoder i dag stadig ledsaget af papirkvitteringer som dokumentation for køb. Teknologier, såsom apps til automatisk håndtering af e-kvitteringer eksisterer (f.eks. eKvittering.dk), og har allerede i dag potentiale til at reducere forbruget af termopapir, hvis teknologien blev taget imod af kunder og butiksejere. Dette er endnu ikke sket, men udsigterne er positive, da den brede offentlighed bliver mere og mere fortrolig med anvendelsen af mobile enheder. Teknologier, såsom mobil betaling via apps, har potentiale til at udvikle sig hurtigt og derved resultere i en betydelig reduktion af anvendelsen af papirkvitteringer i den nærmeste fremtid. Andre typer af mobil betaling kan muligvis følge efter snarest.

Løsninger ved kasseapparaterne, der reducerer mængden af papir anvendt til kvitteringer, eller som reducerer håndteringen af termopapir for den hyppigst udsatte gruppe (kassemedarbejderen) er mulige at implementere. Men på grund af den stigende popularitet af brugen af mobile enheder og de tilhørende teknologier, som disse løsninger er forventet at medbringe, betragtes "kasseapparat-løsninger" som en midlertidig løsning, som derfor er mindre tilbøjelig til at blive implementeret. Dette selvom kasseapparat-løsningerne forventes at være forbundet med lavere omkostninger ved implementering end de elektroniske løsninger.

Da markedet for alternative teknologier til at erstatte papirkvitteringer er komplekst, er mulighederne for at afhjælpe barriererne for introduktionen af disse teknologier også forskelligartede. Der synes at være et behov for at dele viden omkring de nye teknologier, promovering og uddannelse for næsten alle af de omhandlede teknologier. I forholdt til mobil betaling via apps, er et simplet design og brugerflade vigtig, samt en passende balance mellem bekvemmelighed og sikkerhed, afhængigt af størrelsen af købet (ingen pinkode/pinkode). For automatiske systemer for håndtering af kvitteringer er reducering af tid mellem køb og levering af en elektronisk kvittering en barriere, som kan reduceres enten ved valg/opdatering af det underlæggende system, eller ved at introducere et middel til direkte scanning af kvitteringen ved kasseapparatet (Quick Response (QR) koder eller NFC (Near Field Communication) ”tags”). Det ældre kundesegment vil måske ikke, eller kun meget langsomt, tilpasse sig nye teknologier.

Danskere er generelt positive overfor ny teknologi og de er hyppige ejere af smartphones. Derfor kan man forvente, at væksten i mobile betalingsløsninger vil fortsætte, og at forbrugere over tid vil acceptere og opnå viden om sådanne teknologier. Et praktisk betalingssystem eksisterer allerede i dag (Dankortet), hvilket er et accepteret og højst funktionelt system. Dette forventes at være forklaringen på, at væksten i anvendelsen af alternative teknologier til betaling i Danmark halter noget bagefter andre europæiske lande, men tendensen er overbevisende og det forventes at denne barriere er overvundet indenfor få år.

Konklusion

De mest anvendte alternativer til BPA i kvitteringer af termopapir er bisphenol S og Pergafast. Baseret på: i) migrationsstudier i dette projekt, ii) overvejelser vedrørende dermal absorption og eksponering og iii) let tilgængelig information om de miljø- og sundhedsmæssige egenskaber, kan det ikke konkluderes at disse alternativer udgør mindre miljø- og sundhedsmæssige risici end BPA. Bisphenol S vurderes at have egenskaber der minder om BPA i relation til migration, såvel som eksponering og sundheds-effekter. Pergafast udgør muligvis en lavere sundhedsrisiko (lavere migration og mindre alvorlige sundhedseffekter), men er vurderet til at være toksisk og persistent i miljøet. Samlet set, skal de begrænsede migrationsundersøgelser anses som indikative, og det skal bemærkes, at der generelt er mindre information om alternativerne til BPA end information om BPA.

Den primære drivkraft for udviklingen af de fleste af de identificerede alternative teknologier er ikke en intention om at reducere anvendelsen af BPA eller at reducere brugen af papirkvitteringer generelt. Udviklingen er snarere en konsekvens af en overgang til et pengeløst samfund, hvor flere og flere indkøb foregår elektronisk og uden udveksling af faktiske penge. Reduktionen eller afskaffelsen af papirkvitteringer er en mulig sideeffekt af denne overgang.

Ikke desto mindre har udfasningen af papirkvitteringer, som følge af anvendelsen af alternative teknologiske løsninger potentiale som konsekvens af denne overgang til et pengeløst samfund. Dog kan ingen af de teknologier, der præsenteres i denne rapport, på nuværende tidspunkt betragtes som modne til fuldt ud at erstatte papirkvitteringen.

1. Introduction

As part of the Danish EPA's strategy on bisphenol A (BPA) (Danish EPA, 2013), alternatives to the use of BPA in thermal paper receipts have been analysed in the course of this project. The analysis includes alternative substances which could replace BPA in thermal paper (used for receipts), as well as alternative technologies to thermal printing which could replace thermal paper, primarily as use in receipts and tickets. One obstacle to BPA substitution is that alternative substances do not necessarily seem to be safer to use and thus one aim of the project was to summarise existing knowledge related to risk/safety of alternative substances and investigate to which extent alternative substances might migrate out of the paper.

BPA is used as a developer in thermal paper and is today by far the most used developer. A previous project commissioned by the Danish EPA (Lassen et al., 2011) addressing BPA in thermal paper concluded that there was no health risk associated with BPA in thermal paper based on the guideline animal studies, which also forms the basis for the opinion on BPA of the European Food Safety Authority (EFSA). This opinion was originally drafted in 2006. Review of scientific information on BPA in 2008, 2009, 2010 and 2011 by EFSA did not identify any new evidence that would lead to changes in the conclusions of that opinion.

However, there is increasing concern with respect to possible endocrine disrupting properties of BPA at low dose exposure, e.g. causing developmental neurotoxicity, as a large number of non-guideline studies report effects of BPA exposure at very low doses, sometimes around only a few μg/kg bodyweight per day. Concern is especially related to population groups who frequently handle this type of paper and for particularly sensitive groups such as pregnant women and young children. This has led scientists and others to question the sufficiency of the current tolerable daily intake (TDI) of 0.05 mg/kg bodyweight/day established by EFSA. EFSA is currently updating its opinion on BPA. A draft of this updated opinion is expected by end 2013/early 2014.

This project focuses on alternatives related to BPA in thermal paper receipts. Such receipts include point-of-sale (POS) receipts (also known as till receipts) from purchase in stores, and tickets for instance for travelling, parking, cinema and other events. The main focus of this project has been on the point-of-sale (POS) receipts. BPA can be released from these receipts causing exposure by dermal contact. To what extent available alternative substances are preferable from a health point of view and alternative technologies such as electronic receipts in practice can serve the same function, is still uncertain.

Alternatives to BPA are addressed in only a few studies. Information and results from these have been used as basis for the work done in this project. The following recent reports are included as key background documents:

- The July 2012 Draft US EPA report "Bisphenol A alternatives in thermal paper" (US EPA, 2012).
  This report identifies 19 chemical alternatives that may substitute BPA as a developer in thermal paper. The main focus of the report is a hazard evaluation from an environmental and health perspective of BPA and the alternative substances. It also lists the physical-chemical properties of the substances. In addition, the report provides background

information about how thermal paper is made, general exposure and lifecycle information and aspects to consider when selecting a developer;

- The Swedish Chemicals Agency (KemI) report "Bisfenol A i kassakvitton – rapport från ett regeringsuppdrag 4/12" (KemI, 2012A) based on which KemI on 29 June 2012 proposed a Swedish ban of BPA in till receipts (KemI, 2012B). The report includes a risk assessment for people handling receipts and explores the possibilities and consequences of a Swedish ban. In addition the different alternative colour developers identified by the Draft US EPA (which mihgt replace BPA in thermal paper) are listed together with classifications made by industry for the substances;

- The Danish EPA Environmental Project No. 1483, 2013 " Survey of Bisphenol A and Bisphenol-A-diglycidylether polymer" with a brief chapter on alternatives: Alternative technologies and substances to bisphenol A (BPA) in till receipts (Larsen et al., 2013), and

- The Danish EPA Survey of Chemical Substances in Consumer Products, No. 110 2011 "Migration of bisphenol A from cash register receipts and baby dummies" (Lassen et al., 2011).

These reports contain information on BPA and alternative substances to BPA in for instance thermal paper and can be considered as state of the art. The main focus of the reports has been on BPA and alternative substances from an environmental and health perspective. In relation to substitution, other aspects such as marked share, costs, quality of print, use etc. are only either mentioned briefly or not at all. Very limited information on alternative technologies and their use is addressed in these background documents.

1.1 Objectives

The aim of the project is to identify solutions which reduce the exposure to BPA from thermal paper receipts. This includes investigating and assessing alternative substances as well as alternative technologies.

The alternative substances survey should summarise environmental and health hazard properties and address migration (both theoretically based on physical chemical properties and by analytical migration studies on a few alternative substances).

The alternative technologies survey should address technical solutions that fulfil the same purpose as the thermal paper receipt, i.e. to provide documentation for proof of purchase. Identification of possible barriers for implementing new technology and possible mitigation of these should also be addressed.

1.2 Delimitations

The survey only comprises alternatives to BPA expected to be in use today or that will be available in the near future (1-5 years). The survey primarily addresses alternatives for the Danish market but parallels to trends, experience and knowledge gained in foreign markets are included where identified and relevant.

Focus has been on alternatives for thermal paper receipts, mainly point-of-sale receipts (i.e. till receipts). Alternatives for other applications of thermal paper e.g. use in labelling applications are only considered briefly, since requirements for alternatives to labelling are substantially different than for point-of-sale receipts.

The summary of health and environmental properties should merely summarise other reviews and it has not been within the scope of the study to conduct actual risk assessments.

2. Approach

The survey was carried out in the period from July to December 2013.

Initially, a review of the reports mentioned under "Introduction" with special attention to alternative substances and technologies was conducted. The referenced reports focus mainly on inherent environmental and health aspects of substances for substitution. In order to gain a deeper insight into the alternative substances and technologies, a number of other sources have been consulted in order to map out alternatives in greater detail.

2.1 Internet search

Internet based searches were done in order to gain information relevant for the project. Specifically for searching alternative technologies, the search was initially broad using search terms like mobile payment, mobile payment applications, electronic payment, travel card, e-receipt, electronic receipt, alternative printing etc. As the project progressed, more specific search terms were pinpointed to locate detailed information especially regarding technologies using search terms like contactless smart card, Near Field Communication (NFC), Radio Frequency Identification (RFID), etc. To receive more information on alternative substances, searches were made to identify for instance manufacturers and distributors, data on thermal paper and printing, recent scientific publications on substances and migration from thermal paper, EU environmental and health classifications and any possible information regarding the alternatives.

2.2 Inquiries to manufacturers/importers/distributors

The major manufacturers of thermal paper in Europe were identified by previous reports and searches on the internet and their presence on the Danish marked was confirmed by members of the reference group following the project (see Preface). In relation to alternative substances, also manufacturers of thermal paper outside of the EU were identified and contacted for information. The manufacturers of thermal paper were contacted by phone, e-mail and/or via the manufacturers' webpages. Along with a request to participate in the survey, the manufacturers were also presented with a number of questions up front. In addition, manufacturers of receipt rolls (i.e. those cutting the paper and rolling it to smaller rolls sometimes referred to as "converters"), as well as distributors of receipts, were contacted. Information from the paper manufacturers was only received through the telephone interviews.

2.3 Inquiries to stores and chain stores

Danish stores and chains of stores were contacted in order to gain information about their use of BPA containing thermal paper and alternatives. Questions regarding the future trends in the development of technological alternatives were also included in the dialogue. Each were approached by telephone and via e-mail and asked to fill out a questionnaire.

2.4 Inquiries to relevant associations

Trade and consumer associations relevant to the scope of the project were contacted for information regarding thermal paper in general and any knowledge on alternatives. Associations contacted were:

- Plastics Europe (through The Danish Plastics Federation "Plastindustrien")
- The European Thermal Paper Association (ETPA)

- The Imaging & Printing Association (I&P Europe)
- The Danish Consumer Council (Forbrugerrådet)

2.5 Criteria for evaluation of alternatives

The alternatives were initially researched based on the expected potential and viability according to a specified set of criteria. The criteria initially set for substances and technologies respectively are listed below.

Intended criteria for evaluation of alternative substances:

- Health and environmental hazards
- Paper price and implementation costs
- Marked share
- Amount of substance used
- Technological challenges and experience
- Migration

Intended criteria for evaluation of alternative technologies:

- Price of introduction and operation
- Marked share
- Technological barriers and experience
- Barriers for and experience with consumer accept
- Trends

The intention was to use the criteria for prioritizing and selecting alternatives with the greatest potential in order to examine and assess these in further detail. This was, however, not possible due to the low availability of information on some criteria for alternative substances as well as alternative technologies. This is further motivated in chapter 4 and 5, specifying in more detail the approach/methodology.

3. Thermal paper - manufacture, use and trends

In this chapter a short introduction to thermal paper is given. Some of the information has been obtained from manufacturers of thermal paper and receipt rolls. The manufacturers have requested their identity kept confidential. Thus, it cannot be referenced which manufacturer provided which information.

The information provided by the manufacturers is not specific for their company, but rather a general answer for the thermal paper industry as a whole. There was a general cautiousness, and in several cases a wish not to participate in answering questions related to BPA, given the political focus on this substance worldwide. The cautiousness was naturally also related to company secrets and thus the competitive situation. A few manufacturers, however, provided valuable information even though it was given in general terms and was not company specific. Given this cautiousness, information has not been obtained via the circulated questionnaires, only via telephone interviews.

3.1 Use

Thermal paper has been used on a commercial scale since the late 1960s (first mainly in early copying machines and later in fax-machines) (US EPA, 2012, KemI, 2012A). Today thermal paper is used for many applications, for instance:

- Point-of-sale receipts (i.e. till receipts from cash registers)
- Tickets (i.e. transportation tickets (e.g. trains, airlines), entertainment tickets (e.g. cinema, theatre, sporting events, amusement parks, gaming, arenas), parking tickets, and lottery tickets.
- Labels (e.g. on food packaging, prescriptions and industrial barcodes) and tags (e.g. on luggage)
- Fax paper
- Other, e.g. health care applications such as EKG and ultra sound print-outs

The major application today is point-of-sale (POS) receipts, followed by self-adhesive labels (JRC-IHCP, 2010). Industrial fax paper which was previously a major application now only account for approximately 10% (JRC-IHCP, 2010).

3.2 Thermal paper and thermal printing

A thermal paper is coated with a thermal reactive layer which reacts in the presence of heat to create a printed text or image (US EPA, 2012). A cross section of the thermal paper is given in Figure 1.

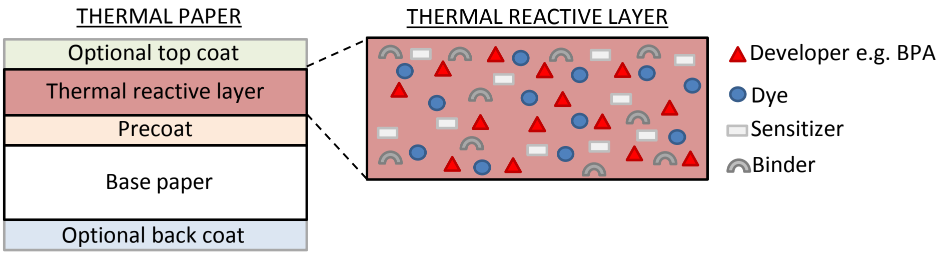

FIGURE 1
THERMAL PAPER (LEFT) AND THERMAL REACTIVE LAYER (RIGHT) IN CROSS SECTION (MODIFIED FROM US EPA, 2012)

The thermal paper consists of a base paper which is coated with a precoat and a thermal reactive layer. It is in the thermal reactive layer that BPA is usually present as a developer. Other parts of the thermal reactive chemistry include: a dye (which is colourless at room temperature), a sensitizer (which lowers the melting point and acts as a solvent for the dye and developer), and a binder (US EPA, 2012). The precoat provides a foundation for the images, prevents the heat from being transferred to the base paper and protects the sensitivity of the thermal reactive layer (Koehler Paper Group, n.d.). In addition thermal paper may for some applications be given a protective coating on the top or the back. A top coat protects from mechanical wear, and chemical or environmental influences. A back coat provides additional protection during mechanical processes such as printing and lamination (US EPA, 2012; Koehler Paper Group, n.d.).

The top coat can, for instance, be made of polyvinyl alcohol (PVA) (Manufacturer, personal communication - source confidential). Top-coated paper is rarely used for till receipts (i.e. POS applications) (US EPA, 2012) since such enhanced durability is not needed for this purpose (Manufacturers, personal communication - source confidential) and as this makes the paper thicker causing the need for more frequent shifts to new rolls and increased storage/transportation volumes. In the Nordic countries approximately 2% of the market of till rolls (POS) is top-coated according to one manufacturer (personal communication, source confidential). In cases when a better durability of the receipt is requested, another developer is chosen (Manufacturer, personal communication - source confidential). The price for top-coated till receipt is twice as high as the non-top coated till receipts according to one manufacturer (personal communication - source confidential). Top coat is more often used for parking tickets, travelling tickets and bank receipts (ATM rolls) than for till receipts (Manufacturer, personal communication - source confidential).

During the printing process parts of the thermal paper is exposed to heat from a print head and a chemical reaction occurs in the thermally reactive layer. The developer (e.g. BPA) acts as a weak acid and donates protons to the dye which becomes visible on the parts where the paper has been heated (KemI, 2012A).

3.3 Manufacturers and distributors

In Europe there are in total less than 10 thermal paper manufacturers (coaters). The four largest are Koehler, Kanzan, Michubishi and Juju Thermal. Examples of other European thermal paper manufacturers are Sihl and Torraspapel. According to one manufacturer, the European thermal manufacturers account for approximately 60% of the world sales of thermal paper (manufacturer, personal communication). For thermal paper manufacturers in Europe there is a trade organisation named European Thermal Paper Association (ETPA).

Thermal paper is also imported to Europe from thermal paper manufacturers in for instance Korea (e.g. Hansol) and USA (e.g. Appvion, Inc. (formerly Appleton Papers Inc.)). Examples of other thermal paper manufacturers are Kanzaki (USA), Ricoh (USA, Japan and China), Nippon Paper

Group (Japan), Oji Paper group Co. Ltd. (e.g. Japan, China and Thailand) and Shanghai Hanhong Paper Co. Ltd (China).

There are also companies which purchases thermal paper from the paper manufacturers and produce small rolls for instance for till receipts. The biggest till roll manufacturer in Europe is Schades[1], also having the main market in Denmark. In addition, there are 'pure' distributors only selling thermal paper rolls.

3.4 Trends in sales

According to the manufacturers, the overall sale of thermal paper in Europe and the US is still increasing.

In Europe the increase is between 0 and 10% per year according to several manufacturers (personal communication – source confidential). Single applications are being replaced (Manufacturer, personal communication - source confidential), but which ones was not specified. According to one manufacturer the sales of labels are increasing (personal communication, source confidential). Today approximately 60% of the thermal paper is used for till receipts (according to one manufacturer) and is, according to a couple of manufacturers, regarded as a stable market in Europe (personal communication – source confidential). According to the reference group of this project, the volume of labels sold today is about the same as the volume of till receipts sold.

In the US there is an overall increase in sales of thermal paper. Some segments of thermal paper are according to one manufacturer growing (e.g. tickets, labels, entertainment sector) while others (i.e. point-of-sales which includes the till receipts) is on a decline (personal communication – source confidential). The reason for the decline is guessed to be e-receipts (Manufacturer, personal communication - source confidential).

The volume of thermal paper reported by the European Thermal Paper Association (ETPA) to be used in Western Europe 2005/2006 was 1890 tonnes/year (JRC-IHCP, 2010). This is 35% more than figures in the 2003 EU risk assessment report for BPA.

3.5 Share of BPA-free thermal paper

The share of BPA free paper varies between Europe and the US, with a larger share of BPA free thermal paper in the US (Manufacturer, personal communication - source confidential). In Europe the share of BPA free paper is estimated by two manufacturers to be around 20% and another said it was less than 10% (personal communication- source confidential). Most of the replacement paper uses bisphenol S as alternative (Manufacturer, personal communication – source confidential). For one supplier who only sells the till rolls (third part) the share is approximately 40% BPA free till rolls (e.g. BPA substituted by bisphenol S), and 10% bisphenol free till rolls using developers not based on bisphenols (personal communication- source confidential).

In Japan, BPA was phased out in thermal paper in 2001 (US EPA, 2012). The largest thermal producer in the US (Appvion) substituted BPA from its thermal paper formulation with Bisphenol S by 2006, because of growing concern about the safety of BPA (Appleton, 2010).

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[1] During the course of this project Schades was acquired by the South Korean paper maker Hansol Paper.

4. Survey of alternative substances to BPA in thermal paper receipts

In this chapter alternative substances to BPA as a developer in thermal paper receipts are addressed. A significant amount of data presented here comes from the US EPA (2012) Draft report. Information has also been obtained based on dialogue under confidentiality with thermal paper manufacturers. Thus, it cannot be referenced which manufacturer provided which information.

4.1 Overview of alternative substances identified

The US EPA (2012) has identified 19 alternative substances to BPA in thermal paper. This selection of substances includes substances which are in commercial use as developers in thermal paper, and substances which have the potential to be used as substitute developers to BPA, based on having the right physical and chemical properties (e.g. acidity, water solubility and melting point) for developers (US EPA, 2012). No other compilations of alternative developers have been identified. Other reports dealing with alternative substances in thermal paper (e.g. KemI, 2012A and Larsen et al., 2013) refer to the US EPA (2012) list. The identified alternative substances are listed in Table 1.

The manufacturers of thermal paper using alternative substances do not specify the identity of the alternative substances which have been used; instead they categorize the paper as bisphenol A free, bisphenol free and/or phenol free. All these categories are free from bisphenol A, but some may also be free from bisphenols or even phenols, see Figure 2.

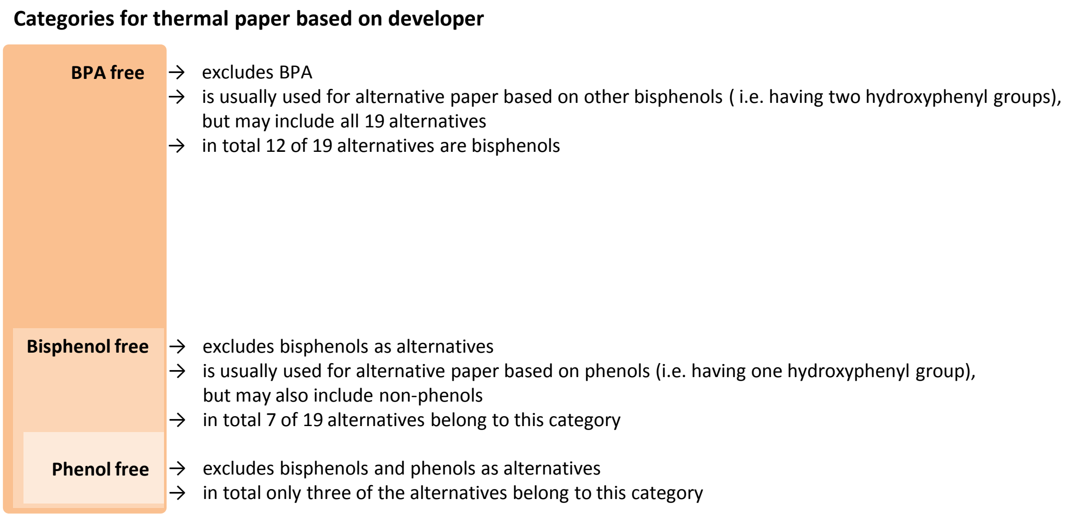


FIGURE 2
CATEGORIES FOR THERMAL PAPER BASED ON TYPE OF DEVELOPER

According to the US EPA report, 13 of the substances are known to be used in thermal paper and the rest are either unknown or proprietary.

TABLE 1

US EPA'S DRAFT LIST (2012) OF BPA AND ALTERNATIVE SUBSTANCES TO BPA THAT ARE EITHER USED OR HAVE THE POTENTIAL TO BE USED AS A DEVELOPER IN THERMAL PAPER. IN ADDITION, THE LAST COLUMN SHOWS HOW THEY CAN BE CATEGORISED. SOURCE: MODIFIED FROM US EPA (2012)

CAS No	Chemical Name	Common name	Molecular formula	Known to be used in thermal paper	Categorised as*
80-05-7	2,2-bis(p-hydroxyphenyl) propane	Bisphenol A, BPA	C15H16O2	Yes	**BPA**
620-92-8	Bis(4- hydroxyphenyl) methane	Bisphenol F, BPF	C13H12O2	Yes	**BPA free**
79-97-0	2,2"-Bis(4-hydroxy-3-methylphenyl)propane	Bisphenol C, BPC	C17H20O2	unknown	**BPA free**
5129-00-0	Methyl bis(4-hydroxyphenyl) acetate	MBHA	C15H14O4	unknown	**BPA free**
24038-68-4	4,4"-Isopropyllidenebis(2-phenylpheno)	BisOPP-A	C27H24O2	unknown	**BPA free**
1571-75-1	4,4"-(1-Phenylethylidene) bisphenol	Bisphenol AP, BPAP	C20H18O2	Yes	**BPA free**
PROPRIETARY	Substituted phenolic compound #1	N/A	N/A	unknown	**BPA free**
PROPRIETARY	Substituted phenolic compound #2	N/A	N/A	proprietary	**BPA free**
94-18-8	Benzyl 4-hydroxybenzoate	PHBB	C14H12O3	Yes	BPA free **bisphenol free**
80-09-1	4-Hydroxyphenyl sulfone	Bisphenol S	C12H10O4S	Yes	**BPA free**
5397-34-2	2,4"-Bis(hydroxyphenyl) sulfone	2,4-BPS	C12H10O4S	Yes	**BPA free**
41481-66-7	bis-(3-allyl-4-hydroxyphenyl) sulfone	TGSA	C18H18O4S	Yes	**BPA free**
97042-18-7	Phenol,4-[[4-(2-propen-1-yloxy)phenyl]sulfonyl]-	BPS-MAE	C15H14O4S	Yes	BPA free **bisphenol free**

CAS No	Chemical Name	Common name	Molecular formula	Known to be used in thermal paper	Categorised as*
63134-33-8	4-Hydroxy-4"-benzyloxydiphenylsulfone	BPS-MPE	C19H16O4S	Yes	BPA free **bisphenol free**
95235-30-6	4-hydroxyphenyl 4-isoprooxyphenylsulfone	D-8	C15H16O4S	Yes	BPA free **bisphenol free**
191680-83-8	4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl]phenol	D-90	C28H26O9S2 (n = 1); C44H42O14S3 (n = 2)	Yes	**BPA free**
93589-69-6	1,7-bis(4-Hydroxyphenylthio)-3,5- dioxaheptane	DD-70	C17H20O4S2	unknown	**BPA free**
232938-43-1	N-(p-Toluenesulfonyl)-N'- (3-p-toluenesulfonyloxyphenyl)urea	Pergafast 201	C21H20N2O6S2	Yes	BPA free bisphenol free **phenol free**
151882-81-4	4,4'-bis(N-carbamoyl-4-methylbenzenesulfonamide) diphenylmethane	BTUM	C29H28N4O6S2	Yes	BPA free bisphenol free **phenol free**
321860-75-7	Urea Urethane Compound	UU	C42H36N6O8S	Yes	BPA free bisphenol free **phenol free**

*Bold text in the last column indicates the most logical categorisation.

4.2 Information on alternative substances to BPA in till receipts

According to one manufacturer not all 19 substances listed by the US EPA have the right properties to be used for thermal printing paper (Manufacturer, personal communication – source confidential). Only around 5-6 alternatives to BPA are commonly used in thermal paper production worldwide (Manufacturer, personal communication – source confidential). However the identity of these substances is considered classified information.

Therefore, the European thermal paper manufacturers do not declare which alternative substances they use, neither on their web-pages nor to the manufacturers of till rolls (i.e. those who cut the paper and roll them onto small rolls). The only information given is whether the thermal paper is BPA free, bisphenol free or phenol free. Thus direct contact with thermal paper manufacturers did not lead to identification of all the alternatives used. They did however identify the most commonly used alternatives.

The only alternative substances to BPA mentioned for till receipts were (Manufacturers, personal communication – source confidential):

- Bisphenol S (BPA-free)
- Pergafast 201 (phenol-free)

- Urea Urethane compound (UU) (phenol-free)

However, more alternative substances are used (Manufacturers, personal communication – source confidential).

Bisphenol S is the most common replacement (Manufacturers, personal communication – source confidential). In the study made by the Swedish Chemicals Agency (KemI, 2012A) bisphenol S and Pergafast were the only alternative substances identified to be used in Sweden (KemI, 2012A).

For the use in labels also the following alternatives were mentioned:

- D-8 (4-hydroxyphenyl 4- isoprooxyphenylsulfone) (bisphenol-free)
- D-90 (4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl]phenol) (BPA-free)

However, these are, according to one manufacturer, not used in till receipts (manufacturer, personal communication).

4.2.1 Environmental and health aspects

A summary table of the inherent hazards of the 19 alternative substances and bisphenol A that were evaluated in the US EPA (2012) Draft report can be found in table "Table 4-4 Screening Level Hazard Summary" in US EPA (2012). Data from this table has been used in the first four columns of Table 2 below. In order to increase the readability of the table the endpoint hazards that were assigned a very low (VL) and low (L) hazard have been omitted. Thus, only the endpoints which are evaluated as very high (VH), high (H) or moderate (M) are shown in Table 2. However, in Table A (in Appendix 1) these very low and low hazards are included.

In addition, EU hazard classification data from the Classification and Labelling Inventory database has been added in column 5. The EU classification data consist mainly of industry self-classifications, i.e. notified self-classifications according to CLP criteria. CLP is the EU Regulation on classification, labelling and packaging of substances and mixtures. For those substances where harmonized classifications (according to table 3.1 Annex VI to the CLP Regulation) are available these are indicated.

The last column summarises what can be concluded based on US EPA (2012) and EU classifications.

Table 2 and Table A (in Appendix 1) are coded to indicate severity of hazard and data quality.

Severity of hazard is indicated by colour:

Red – very high hazard
Pink – high hazard
Blue – medium hazard

Data quality is indicated by font style:

Upright text – high quality data
Italicised text – low quality data
Italicised text and ^{VLQ} – very low quality data

Visually, the legends used are the following:

Text and colour coding for Table 2	US EPA hazard column	EU classification column
_ Red colour – very high hazard	VH – very high	Hazard categories 1
_ Pink colour – high hazard	H - high	Hazard categories 2
_ Blue colour – medium hazard	M – medium	Hazard categories 3
Upright text - high quality data	Based on empirical data	Harmonised classification
Italicized text - low quality data	*Assigned using values from estimation software and professional judgement*	*Notified classification by industry*
Italicized text and ^{VLQ} - very low quality data	*Based on analogy to experimental data for a structurally similar compound*	

TABLE 2

HAZARD DATA FOR BPA AND 19 ALTERNATIVE SUBSTANCES TO BPA IN THERMAL PAPER. ASSESSMENTS BY US EPA (2012) AND NOTIFIED OR HARMONISED EU HAZARD CLASSIFICATIONS

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high –VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria: Hazard category code 1, 2, 3, 4	EU notified or harmonised classification according to CLP criteria: Hazard statement code and statement	Summary of US and EU hazard data
80-05-7	2,2-bis(p-hydroxyphenyl) propane	Bisphenol A, BPA (bisphenol)	Reproductive – H Developmental – H Acute (aquatic) – H Chronic (aquatic) – H Carcinogenicity – M *Neurological – M* Repeated Dose – M Skin Sensitizer – M Eye Irritation – M Dermal Irritation – M	Skin Sens 1 Eye Dam 1 STOT SE 3 Repr 2 *Aq Chronic 3* *Muta 1B* *Carc 1B* *Aq Chronic 2* *Acute Tox 4* *Asp Tox 1*	<u>Harmonised</u> H317 May cause an allergic skin reaction H318 Causes serious eye damage H335 May cause respiratory irritation H361f***Suspected of damaging fertility *<u>Notified</u>* *H411 Toxic to aquatic life with long lasting effects* *H340 May cause genetic defects ** *H350 May cause cancer ** *H412 Harmful to aquatic life with long lasting effects** *H302 Harmful if swallowed** *H304 May be fatal if swallowed and enters airways** ** only 1 notification*	High quality data show high and severe hazard for human health (i.e. reproductive and developmental effects, and allergic skin reaction). In addition high level of hazard for the aquatic environment.
620-92-8	Bis(4-hydroxyphenyl) methane	Bisphenol F, BPF (bisphenol)	Eye Irritation - VH *Reproductive - H^{VLQ}* *Developmental – H^{VLQ}* Repeated Dose – H *Chronic (aquatic) – H* *Carcinogenicity – M* Neurological – M *Dermal Irritation – M^{VLQ}* Acute (aquatic) – M	*Skin Irrit 2* *Skin Sens 1* *Eye Irrit 2* *STOT SE 3* *Aq Chronic 3*	*<u>Notified</u>* *H315 Causes skin irritation.* *H317 May cause an allergic skin reaction* *H319 Causes serious eye irritation.* *H335 May cause respiratory irritation* *H412 Harmful to aquatic life with long lasting effects*	Very high hazard for eyes and may cause allergic skin reaction (high exposure is expected). In addition very low quality data indicate high level of hazard for human health (i.e. reproductive and developmental effects)

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high –VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria		Summary of US and EU hazard data
				Hazard category code 1, 2, 3, 4	Hazard statement code and statement	
79-97-0	2,2''-Bis(4-hydroxy-3-methylphenyl)propane	Bisphenol C, BPC (bisphenol)	*Reproductive – H[VLQ]* *Developmental – H[VLQ]* *Eye Irritation - H[VLQ]* Acute (aquatic) – H *Chronic (aquatic) – H* *Carcinogenicity – M* Mutagenicity/Genotox. – M *Neurological – M* *Repeated Dose – M[VLQ]* *Skin Sensitizer – M[VLQ]* *Dermal Irritation – M[VLQ]* Persistence – M *Bioaccumulation – M*	 *Skin Irrit 2* *Eye Irrit 2* *STOT SE 3* *Muta 2* *STOT RE 2*	*Notified* *H315 Causes skin irritation* *H319 Causes serious eye irritation* *H335 May cause respiratory irritation* *H341 Suspected of causing genetic defects* *H373 May cause damage to organs*	Suspected of causing genetic defects and may cause damage to organs. In addition very low quality data indicate high level of hazard for human health (i.e. reproductive and developmental effects)
5129-00-0	Methyl bis(4-hydroxyphenyl)acetate	MBHA (bisphenol)	*Reproductive – H[VLQ]* *Developmental – H[VLQ]* *Acute (aquatic) – H* *Chronic (aquatic) – H* *Carcinogenicity – M* *Neurological – M* *Repeated Dose – M[VLQ]* *Eye Irritation – M[VLQ]* *Dermal Irritation – M[VLQ]* *Persistence – M*	No available data	-	Lack of data. Very low quality data indicate high level of hazard for human health (i.e. reproductive and developmental effects).

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high –VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria Hazard category code 1, 2, 3, 4	EU notified or harmonised classification according to CLP criteria Hazard statement code and statement	Summary of US and EU hazard data
24038-68-4	4,4‘’-Isopropyllidenebis(2-phenylpheno)	BisOPP-A (bisphenol)	*Reproductive – H*^{VLQ} *Developmental – H*^{VLQ} *Chronic (aquatic) – H* *Persistence – H* *Carcinogenicity – M* *Neurological – M* *Repeated Dose – M*^{VLQ} *Skin Sensitizer – M*^{VLQ} *Eye Irritation – M*^{VLQ} *Dermal Irritation – M*^{VLQ} *Bioaccumulation – M*	 *Skin Irrit 2* *Eye Irrit 2*	*Notified* *H315 Causes skin irritation.* *H319 Causes serious eye irritation*	Very low quality data indicate high level of hazard for human health (i.e. reproductive and developmental effects, also notified to cause serious eye irritation. Low quality data indicate high level of hazard for the aquatic environment (chronic toxicity and persistence).
1571-75-1	4,4‘’-(1-Phenylethylidene)bisphenol	Bisphenol AP, BPAP (bisphenol)	*Reproductive – H*^{VLQ} *Developmental – H*^{VLQ} *Acute (aquatic) – H* *Chronic (aquatic) – H* *Persistence – H* *Carcinogenicity – M* *Neurological – M* *Repeated Dose – M*^{VLQ} *Skin Sensitizer – M*^{VLQ} *Eye Irritation – M*^{VLQ} *Dermal Irritation – M*^{VLQ} *Bioaccumulation – M*	 Aq Acute 1 Aq Chronic 1 *Eye Irrit 2*	Harmonised H400 Very toxic to aquatic life H410 Very toxic to aquatic life with long lasting effects *Notified* *H319 Causes serious eye irritation*	Very toxic to aquatic life with long lasting effects. In addition very low quality data indicate high level of hazard for human health (i.e. reproductive and developmental effects).

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high –VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria		Summary of US and EU hazard data
				Hazard category code 1, 2, 3, 4	Hazard statement code and statement	
PROPRIETARY	Substituted phenolic compound #1	N/A (bisphenol)	*Reproductive – H*[VLQ] *Developmental – H*[VLQ] *Acute (aquatic) – H* *Carcinogenicity – M* *Neurological – M* *Repeated Dose – M*[VLQ] *Skin Sensitizer – M*[VLQ] *Eye Irritation – M*[VLQ] *Dermal Irritation – M*[VLQ] *Chronic (aquatic) – M* *Persistence – M*	-	-	Lack of data Very low quality data indicate high level of hazard for human health (i.e. reproductive and developmental effects).
PROPRIETARY	Substituted phenolic compound #2	N/A (bisphenol)	*Reproductive – H*[VLQ] *Developmental – H*[VLQ] *Acute (aquatic) – H* *Chronic (aquatic) – H* *Persistence – H* *Bioaccumulation – H* *Carcinogenicity – M* *Neurological – M* *Repeated Dose – M*[VLQ] *Skin Sensitizer – M*[VLQ] *Eye Irritation – M*[VLQ] *Dermal Irritation – M*[VLQ]	-	-	Lack of data Very low quality data indicate high level of hazard for human health (i.e. reproductive and developmental effects).

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high –VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria		Summary of US and EU hazard data
				Hazard category code 1, 2, 3, 4	Hazard statement code and statement	
94-18-8	Benzyl 4-hydroxybenzoate	PHBB (phenol)	Acute (aquatic) – H *Chronic (aquatic) – H* *Carcinogenicity – M* *Mutagen./Genotox. – M* *Developmental – M* *Neurological – M* *Skin Sensitizer – M[VLQ]*	 *Skin Irrit 2* *Eye Irrit 2* *STOT SE 3* *Aq Chronic 2*	*<u>Notified</u>* *H315 Causes skin irritation* *H319 Causes serious eye irritation* *H335 May cause respiratory irritation* *H411 Toxic to aquatic life with long lasting effects*	High hazard for aquatic life (however exposure for aquatic life is expected to be less than for human health) and low quality data indicate moderate hazard for human health.
80-09-1	4-Hydroxyphenyl sulfone	Bisphenol S (bisphenol)	Repeated Dose – H *Carcinogenicity – M* Mutagen./Genotox. – M Reproductive – M Developmental – M *Neurological – M* Acute (aquatic) – M Chronic (aquatic) – M Persistence – M	 *Aq Chronic 3* *Eye Irrit 2*	*<u>Notified</u>* *H412 Harmful to aquatic life with long lasting effects.* *H319 Causes serious eye irritation*	High repeated dose hazard and moderate hazard regarding mutagenicity, reproductive and developmental effects. Is commonly used as an alternative.
5397-34-2	2,4’’-Bis(hydroxyphenyl)sulfone	2,4-BPS (bisphenol)	*Repeated Dose – H[VLQ]* *Carcinogenicity – M* Mutagen./Genotox. – M *Reproductive – M[VLQ]* *Developmental – M[VLQ]* *Neurological – M* *Acute (aquatic) – M* *Persistence – M*	 *Acute Tox 4* *Acute Tox 4* *Skin Corr 1B* *Acute Tox 4* *Muta 2* *Skin Irrit 2* *Eye Irrit 2*	*<u>Notified</u>* *H302 Harmful if swallowed* *H312 Harmful in contact with skin* *H314 Causes severe skin burns and eye damage* *H332 Harmful if inhaled* *H341 Suspected of causing genetic defects* *H315 Causes skin irritation* *H319 Causes severe eye irritation*	Suspected of causing genetic defects.

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high –VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria Hazard category code 1 , 2 , 3 , 4	EU notified or harmonised classification according to CLP criteria Hazard statement code and statement	Summary of US and EU hazard data
41481-66-7	bis-(3-allyl-4-hydroxyphenyl) sulfone	TGSA (bisphenol)	Skin Sensitizer – H Acute (aquatic) – H *Chronic (aquatic) – H* *Persistence – H* *Carcinogenicity – M* *Reproductive – M*[VLQ] *Developmental – M*[VLQ] *Neurological – M* Repeated Dose – M *Respiratory Sensitizer – M*	 Skin Sens 1 Aq Chronic 2	Harmonised H317 May cause an allergic skin reaction H411 Toxic to aquatic life with long lasting effects	High level of hazard as a skin sensitizer and for the aquatic environment (acute toxicity).
97042-18-7	Phenol,4-[[4-(2-propen-1-yloxy)phenyl]sulfonyl]-	BPS-MAE (phenol)	Acute (aquatic) – H Chronic (aquatic) – H *Persistence – H* *Carcinogenicity – M*[VLQ] Mutagen./Genotox. – M *Reproductive – M*[VLQ] *Developmental – M*[VLQ] *Neurological – M* *Respiratory Sensitizer – M*	No available data	-	Lack of data High level of hazard for the aquatic environment.

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high –VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria		Summary of US and EU hazard data
				Hazard category code 1, 2, 3, 4	Hazard statement code and statement	
63134-33-8	4-Hydroxy-4'-benzyloxydiphenylsulfone	BPS-MPE (phenol)	Acute (aquatic) – VH *Repeated Dose – H[VLQ]* *Chronic (aquatic) – H* *Persistence – H* *Carcinogenicity – M* *Mutagenicity/Genotox. –M[VLQ]* *Reproductive – M[VLQ]* *Developmental – M[VLQ]* *Neurological – M* *Bioaccumulation – M*	 *Acute Tox 4* *Acute Tox 4* *Skin Irrit 2* *Eye Irrit 2* *Acute Tox 4*	*Notified* *H302 Harmful if swallowed* *H312 Harmful in contact with skin* *H315 Causes skin irritation.* *H319 Causes serious eye irritation* *H332 Harmful if inhaled*	Moderate hazard for human health, but very high hazard for aquatic life (however this exposure for aquatic life is expected to be less than for human health)
95235-30-6	4-hydroxyphenyl 4-isoprooxyphenyl sulfone	D-8 (phenol)	*Repeated Dose – H[VLQ]* Acute (aquatic) – H *Chronic (aquatic) – H* *Carcinogenicity – M* *Mutagen./Genotox. – M* *Reproductive – M[VLQ]* *Developmental – M[VLQ]* *Neurological – M* *Persistence – M[VLQ]*	 Aq Chronic 2	Harmonised H411 Toxic to aquatic life with long lasting effects	Moderate hazard for human health, but high hazard for aquatic life (however exposure for aquatic life is expected to be less than for human health).

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high – VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria		Summary of US and EU hazard data
				Hazard category code 1, 2, 3, 4	Hazard statement code and statement	
191680-83-8	4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl] phenol	D-90 (bisphenol)	*Persistence – VH* *Bioaccumulation – H* *Carcinogenicity – M* *Neurological – M* Eye Irritation – M	No available data	-	Lack of data Very low quality data indicate very high persistence
93589-69-6	1,7-bis(4-Hydroxyphenylthio)-3,5-dioxaheptane	DD-70 (bisphenol)	*Eye Irritation – H VLQ* *Acute (aquatic) – H* *Chronic (aquatic) – H* *Persistence – H* *Carcinogenicity – M* *Reproductive – M* *Developmental – M VLQ* *Neurological – M* *Repeated Dose – M* *Skin Sensitizer – M VLQ* *Dermal Irritation – M VLQ*	Aq Chronic 2	Harmonised H411 Toxic to aquatic life with long lasting effects	Low quality data indicate moderate hazard for human health, but high hazard for aquatic life (however exposure for aquatic life is expected to be less than for human health).
232938-43-1	N-(p-Toluenesulfonyl)-N'- (3-p-toluenesulfonyloxyphenyl)urea	Pergafast 201 (non-phenol)	Acute (aquatic) – VH Persistence – VH *Chronic (aquatic) – H* *Carcinogenicity – M* Reproductive – M Developmental – M Repeated Dose – M	Aq Chronic 2	Harmonised H411 Toxic to aquatic life with long lasting effects	Very high hazard for the environment (persistence and acute aquatic toxicity), as well as moderate hazard for human health (i.e. reproductive and developmental effects and repeated dose toxicity). Is one of the few available alternatives.

CAS No	Chemical Name	Common name (group of substance)	US EPA (2012) Hazard level summary Very high –VH, High – H, and Moderate – M hazard	EU notified or harmonised classification according to CLP criteria		Summary of US and EU hazard data
				Hazard category code 1, 2, 3, 4	Hazard statement code and statement	
151882-81-4	4,4'-bis(N-carbamoyl-4-methylbenzenesulfonamide) diphenylmethane	BTUM (non-phenol)	*Acute (aquatic) – H* *Chronic (aquatic) – H* *Persistence – H* *Carcinogenicity – M* Repeated Dose – M	Carc 2	Harmonised H351 Suspected of causing cancer	Suspected of causing cancer. In addition low quality data indicate high level of hazard for the environment (persistence and aquatic toxicity
321860-75-7	Urea Urethane Compound	UU (non-phenol)	Persistence – VH *Carcinogenicity – M*	No available data	-	Lack of data Very high persistence.

From this table, it can be seen that all of the alternative substances possess environmental and/or health hazardous properties, which could be considered unwanted. BPA is the substance for which there is most knowledge and the substance that, based on existing data, seems to be most hazardous to human health compared to the alternatives. However, data is lacking or is of very poor quality for several of the alternative substances, as well as for many endpoints.

Many of the assessments of alternative substances in the US EPA report are based on professional judgement of the molecule's likely properties given their structural similarity to other more well-known molecules (such as BPA), rather than specific data for the molecules themselves. In addition only 7 of the 20 substances have harmonized EU classifications. Any comparative evaluation based on this data is, therefore, implicitly uncertain.

Consequently, on the web-site from which the US EPA report can be downloaded, it is stated that: "This draft report does not identify functional chemicals with low concern for all human health and environmental hazard endpoints; all of the alternatives are associated with some trade-offs" (US EPA, 2013).

Twelve of the 19 alternative substances are bisphenols, and only tree alternatives are phenol free (i.e. Pergafast 201, BTUM and UU). Several studies (e.g. Audebert et al., 2011; Chen et al., 2002; Feng et al., 2012; Grignard et al., 2012; Kitamura et al., 2005; Kuruto-Niwa et al., 2005; Okuda et al., 2011; Rivas et al., 2002; Yoshihara et al., 2004) have shown that many bisphenol analogues such as bisphenol S, F, AF, and B possess estrogenic activity and genotoxicity. In addition, Okuda et al. (2011) and Yoshihara et al. (2004) have reported that BPA and various other BPA related compounds can be metabolically activated and that these active metabolites can have much more potent estrogenic activity than that of their parent compounds.

Further details of the hazardous properties of BPA and the 19 alternatives can be found in Table A in Appendix 1, including most data from Table 2, but sorted by effects. In addition the US EPA hazards assigned very low (VL) – very high (VH) hazards are shown. The same colour coding and font styles as in Table 2 are used to indicate severity and data quality.

Table (A1 in appendix 1) highlights the types of environmental and human health hazards that are most common for the alternatives and BPA. The environmental hazards acute and chronic aquatic toxicity, and persistence in the environment are most frequent hazards among the substances assigned a high (pink) or very high (red) hazard. Among the health hazards eye irritation, dermal irritation, reproductive effects and developmental effects are the most frequent endpoints assigned a high hazard. However, for reproductive and developmental effects the data is of very poor quality (based on analogy to structurally similar compounds). Carcinogenicity and neurological effects have been assigned a moderate hazard for almost all substances. Among the phenol free substances the persistence in the environment is high or very high. Two alternatives (2,4-BPS and BPC) are suspected of causing genetic defects and one alternative (BTUM), which is phenol free, is classified as suspected of causing cancer.

When comparing the US EPA assessment with the European (self-)classifications, fewer classifications that fit the endpoints are available in the European version. On the other hand, the EU classifications seem in several cases to be more severe than in the US EPA assessments. However, these are not completely comparable since different assessment systems are used.

4.2.2 Selection of alternatives for further study

As described in section 2.5, the intention was to select substances from the US EPA list for further study/evaluation. The selection was supposed to be made according to criteria based on environmental and health, as well as price and performance aspects (see section 2.5). However, since only five alternatives were confirmed by manufacturers to be actually used for thermal paper (including both receipts paper and labels), the selection could not be made using those criteria. Instead all five of the confirmed substances, i.e. bisphenol S, Pergafast, UU, D-8 and D-90, are described further in this chapter. Even for these five substances the availability of information is scarce.

4.2.3 Performance aspects and technological challenges

The only performance aspect mentioned by the manufacturers was difference in stability between different developers. A low stability means the print lasts shorter time and is more susceptible to external effects such as sunlight, oils and plasticisers.

The least stable among BPA and the five confirmed alternative substances is BPA, but BPA is regarded as stable enough under standard conditions (i.e. normal storage with no excessive exposure to e.g. sunlight, heat, water, oil alcohol, and plasticisers). Bisphenol S is slightly more stable than BPA according to some manufacturers, but not according to others (personal communication – source confidential).

The phenol-free alternatives Pergafast and UU are the most stable (Manufacturer, personal communication – source confidential) and therefore more suitable to use when e.g. the archival requirements are larger. According to BASF, which is the only manufacturer of Pergafast, thermal papers containing Pergafast as colour developer produce images that are more stable compared to the corresponding BPA-containing thermal papers. In particular, the images are more stable towards the effects of oils, fats and plasticizers. This is advantageous when printed thermal papers have to be archived, or when they are used under harsh environmental conditions (personal communication, BASF).

Non-topcoated thermal receipt paper containing BPA usually has an image stability guarantee of 5-7 years if the storage conditions are in accordance with those specified for the paper, for instance avoidance of light, constant temperature (e.g. 18-25°C) and humidity (e.g. 50±10% relative humidity). The stability for phenol free non-topcoated thermal receipt paper is higher, usually 10 years. According to information on one manufacturer's webpage even a stability guarantee of 25 years was given for one of the phenol free non-topcoated Fax/POS thermal papers.

The alternatives to BPA were said not to have any functional negative drawbacks once the paper is produced, on the contrary the phenol free alternatives have better performance than BPA, because of their higher stability. In most applications where thermal paper receipts are used such increased stability is, however, not necessary.

On the other hand, there are technological challenges for the thermal paper manufacturers when switching from one substance to another since there are many adjustments needed in the production of the thermal paper (manufacturers, personal communication). Not only the BPA is replaced, but a lot of adjustments are needed for the entire product, for instance modifying other parts of the chemistry of the product formulation and quality adjustments (Manufacturer, personal communication – source confidential). From the collected information, it appears that substitution is not a one-to-one substitution. One manufacturer said it took several years to complete the adjustments for manufacturing with bisphenol S (personal communication – source confidential). Further details about the process adjustments needed were not revealed during the interview. In the case of bisphenol S, it was noted that this substance is less reactive than bisphenol A, which influences the adjustments required.

For customers substituting to thermal paper rolls without BPA in their thermal printers, there are according to one manufacturer no technological challenges (manufacturer, personal communication). Nothing needs to be changed and the same thermal printers can be used regardless of which type of developer is used. One simply has to switch the rolls (manufacturer, personal communication). If a customer requests a very unusual quality of the paper it could be more difficult, but because of the increased availability on the market it should not be a problem (manufacturer, personal communication).

4.2.4 Economic aspects

The cheapest developer is BPA, which is a high production volume chemical (HPV). The low price of BPA is, according to one manufacturer (personal communication – source confidential), the reason why it has dominated and still is the dominating substance used as developer in thermal paper. Since BASF is the only producer of the chemical Pergafast, the price for this developer is according to one manufacturer likely to remain high (Manufacturer, personal communication – source confidential).

Regarding paper price, there is a trend that the prices for BPA free thermal paper are decreasing because of increased market demand. According to one manufacturer the price for BPA free paper two years ago was approximately 40% higher than for BPA-containing paper, but today this figure is approximately 20%, and is expected to further decrease by continuing and increasing demand (personal communication).

There are slightly different figures provided by the manufacturers and distributors on the difference in price for thermal paper free from BPA compared to thermal paper containing BPA. However, the relative order is the same. Paper based on Bisphenol S being the cheapest alternative followed by paper based on bisphenol free, D-8 and D-90 as a middle segment, and the most expensive paper is based on phenol free developers, e.g. Pergafast, see Table 3. The biggest difference in price was given by a distributor.

TABLE 3
PERCENTUAL DIFFERENCE IN PRICE FOR THE DIFFERENT CATEGORIES OF BPA FREE THERMAL PAPER COMPARED TO BPA CONTAINING THERMAL PAPER SHOWN FOR DIFFERENT MANUFACTURERS AND SUPPLIERS.

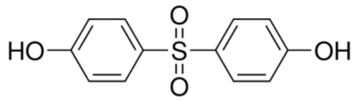
Category of alternative paper	Source 1 (manufacturer)	Source 2 (manufacturer)	Source 3 (distributor)	Source 4 (manufacturer)
BPA free (lowest price)	bisphenol S 5-10% more	BPA free 5% more	BPA free 20-30% more	bisphenol S 10-12% more
Bisphenol free (medium price)	D-8 and D-90 a bit more expensive than bisphenol S but cheaper than Pergafast	Bisphenol free 15-20% more	Bisphenol free 30-40% more	
Phenol free (highest price)	Pergafast >10% more	Phenol free 20-25% more		

4.2.5 Available information on known alternative substances

In this section the five alternative substances confirmed by manufacturers to be used as alternatives to BPA in thermal paper are presented in more detail. These include bisphenol S, Pergafast 201 and UU used in thermal paper receipts and D-8 and D-90 used in thermal paper labels. Most of the information in this section has been taken from the US EPA (2012) report.

4.2.5.1 Bisphenol S

CAS No: 80-09-1
Chemical name: 4-Hydroxyphenyl sulfone
Molecular structure:



Physical chemical properties
Bisphenol S is a bisphenol compound. The physical chemical properties for bisphenol S are shown in Table 4.

Use
Bisphenol S is today the most common replacement for BPA as a thermal developer and is used in thermal paper receipts categorised as BPA free.

Classifications and assessments
There is no harmonised EU classification for bisphenol S, however, industry has notified the following self-classifications according to CLP criteria:

- H412: Harmful to aquatic life with long lasting effects.
- H319: Causes serious eye irritation.

According to US EPA (2012) there is a high hazard regarding:

- Repeated dose

and as moderate hazard regarding:

- Mutagenicity/Genotoxicity
- Reproductive effects
- Developmental effects
- *Carcinogenicity (low quality data)*
- *Neurological effects (low quality data)*
- Acute aquatic toxicity
- Chronic aquatic toxicity

In addition there are a few studies (e.g. Chen et al., 2002; Kitamura et al., 2005; Kuruto-Niwa et al., 2005; Grignard et al., 2012) that indicate that bisphenol S also have endocrine disrupting properties. According to Chen et al. (2002) acute toxicity and estrogenicity was considerably lower for bisphenol S than BPA. However, Kuruto-Niwa et al. (2005) and Grignard et al. (2012) found a comparable estrogenic activity for BPA and bisphenol S. Kitamura et al. (2005) found that bisphenol S as well as BPA are potent anti-androgens (i.e. preventing androgenic hormones from expressing their biological effects on responsive tissues), which means they show endocrine disrupting activities.

Toxicokinetics
No data.

Environmental transport
An environmental transport evaluation for bisphenol S is available in the US EPA report (2012) and is based on experimental and estimated physical and chemical properties. According to this bisphenol S is expected to:

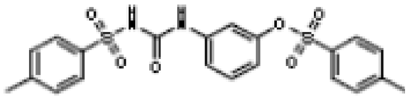
- partition primarily to soil (based on fugacity models)
- exist in both neutral and anionic forms at environmentally-relevant pH (based on pKa).
- have a slight mobility in soil in its neutral form and more mobile in its anionic form (based on Koc)
- not have leaching through soil to groundwater as an important transport mechanism
- be non-volatile from surface water (based on volatilization half-lives)
- exist in a particulate phase in the atmosphere (based on vapour pressure)
- be removed from air by wet or dry deposition of particulates.

Persistence
According to the US EPA report (2012) the persistence is assessed to be of Moderate concern. This is based on degradation tests (under anaerobic and aerobic conditions), and that Bisphenol S is not expected to undergo hydrolysis, not absorb UV light (at environmentally significant wavelengths), and has an 8.8 hour vapour phase reaction with atmospheric hydroxyl radicals. The estimated half-live in soil is 30 days.

Bioconcentration
According to the US EPA report (2012) there is a Low concern for bioaccumulation (based on two experimental bioconcentration factors (BCF) being well below the low criteria cut-off of 100).

4.2.5.2 Pergafast 201

CAS No: 232938-43-1
Chemical name: N-(p-Toluenesulfonyl)-N'-(3- p-toluenesulfonyloxyphenyl)urea
Molecular structure:



Physical chemical properties
Pergafast 201 is a urea compound which is phenol free. The physical chemical properties for Pergafast are shown in Table 4.

Use: Pergafast seems to be the most common phenol free alternative to BPA in thermal paper receipts. BASF is the only producer of Pergafast.

Classifications and assessments
Pergafast has a harmonised EU classification which is:

- H411 Toxic to aquatic life with long lasting effects

According to the US EPA report (2012), the following environmental hazards have been assessed as very high:

- Persistence
- Acute aquatic toxicity

and as high hazard regarding:

- *Chronic aquatic toxicity (low quality data)*

A moderate hazard has been assigned for:

- Reproductive effects
- Developmental effects
- Repeated dose effects
- *Carcinogenicity (low quality data)*

Toxicokinetics
According to the US EPA report (2012), Pergafast has (based on professional judgement of analogy with similar compound) poor absorption through the skin if in solution and is not expected to be absorbed through the skin. It also has poor absorption from the lungs and gastrointestinal tract.

Environmental transport
An evaluation of environmental transport for Pergafast is available in the US EPA report (2012) and is based on experimental and estimated physical and chemical properties. According to this Pergafast is expected to:

- partition primarily to soil (based on fugacity models)
- exists in both neutral and anionic forms at environmentally-relevant pH (based on pKa).
- have a slight mobility in soil (based on Koc)
- not have leaching through soil to groundwater as an important transport mechanism
- be non-volatile from surface water (based on volatilization half-lives)
- exist in the particulate phase in the atmosphere (based on vapour pressure)
- be removed from air by wet or dry deposition of particulates.

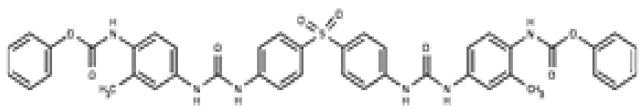
These bullet points are the same as for bisphenol S.

Persistence
According to the US EPA report (2012), the persistence is assessed to be of very high concern since little or no biodegradation was observed under aerobic conditions (based on experimental guideline studies).

Bioconcentration
According to the US EPA report (2012) there is a low concern for bioaccumulation since measured BCF factor in fish is <100.

4.2.5.3 Urea urethane compound (UU)

CAS No: 321860-75-7
Chemical name: Urea Urethane Compound
Molecular structure:



Physical chemical properties
UU is a polymeric urea compound which is phenol free. The physical chemical properties for UU are shown in Table 4.

Use: The extent to which urea urethane compound is used as a phenol free alternative is unknown, however, it is less common than Pergafast.

Classifications and assessments
For UU there is lack of data. There are no EU hazard classifications. According to the US EPA report (2012) there is a very high hazard regarding persistence (based on high quality data) and a moderate hazard regarding *carcinogenicity (based on low quality data*).

Toxicokinetics
According to the US EPA report (2012), UU is (based on professional judgement of analogy with similar compound) not absorbed by skin and is poorly absorbed by the lung, but can be absorbed in the gastrointestinal tract

Environmental transport
An evaluation of environmental transport for UU is available in the US EPA report (2012) and is based on QSAR (Quantitative Structure-Activity Relationship) estimations. These were performed on a representative (i.e. expected to be the predominant) component of the polymer mixture that has a MW <1,000. According to this, UU is expected to:

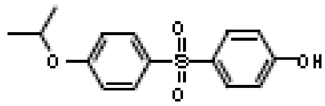
- partition predominantly to soil and sediments (based on fugacity models)
- have a low mobility in soil (based on expected strong absorption to soil)
- not volatilize from water or moist soil at any appreciable rate (based on Henry's Laws constant)
- exist solely as a particulate if released to the atmosphere
- not have atmospheric oxidation as a significant route of environmental removal

Persistence
According to the US EPA report (2012), the persistence is assessed to be of very high concern based on a biodegradation test, QSAR models suggesting a biodegradation half-life of >180 days. The larger oligomers in the polymeric mixture (MW >1000) are expected to have a very high persistence.

Bioconcentration
According to the US EPA report (2012), there is a low concern for bioaccumulation since both the measured and estimated BCFs for UU are <100 (4.6 and 7.9 respectively), and polymeric components in the mixture with the molecular weight >1,000 is not expected to be bioaccumulative due to their large size.

4.2.5.4 D-8

Chemical name: 4-hydroxyphenyl 4-isoprooxyphenylsulfone
CAS No: 95235-30-6
Molecular structure:



Physical chemical properties
D-8 is a phenolic compound which is bisphenol free. The physical chemical properties for D-8 are shown in Table 4.

Use: According to one manufacturer D-8 is used as an alternative to BPA in thermal paper labels.

Classifications and assessments
D-8 has a harmonised EU hazard classification which is:

- H411 Toxic to aquatic life with long lasting effects

According to the US EPA report (2012), the following environmental hazards have been assessed as high:

- Acute aquatic toxicity
- *Chronic aquatic toxicity (low quality data)*
- *Repeated dose toxicity (very low quality data)*

A moderate hazard has been assigned for:

- C*arcinogenicity (low quality data)*
- *Mutagenicity/Genotoxicity (low quality data)*
- *Neurological effects (low quality data)*
- *Repeated dose effects (low quality data)*
- *Reproductive effects (very low quality data)*
- *Developmental effects(very low quality data)*
- *Persistence(very low quality data)*

Toxicokinetics
According to the US EPA report (2012) D-8 is estimated to have a poor absorption through the skin when in solution and is, therefore, not expected to be absorbed through the skin. However, it is estimated to have good absorption via the lungs and gastrointestinal tract (based on data for the analogue bisphenol A).

Environmental transport
An evaluation of environmental transport for D-8 is available in the US EPA report (2012) and is entirely based on QSAR. According to this D-8 is expected to:

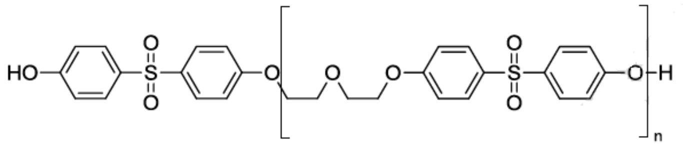
- have a moderate mobility in soil (based on Koc)
- not have volatilization from water surfaces as an important fate process (based on Henry's Laws constant)
- exist in a particulate phase if released to the air (based on vapour pressure)
- be removed from the atmosphere by wet of dry deposition from particulate phase

Persistence
According to the US EPA report (2012), the persistence is assessed to be of moderate concern (based on estimation on analogy to bisphenol A).

Bioaccumulation
According to the US EPA report (2012), there is a LOW concern for bioaccumulation since the estimated fish BCF and bioaccumulation factor (BAF) values are both <100.

4.2.5.5 D-90

Chemical name: 4-hydroxyphenyl 4-isoprooxyphenylsulfone
CAS No: 95235-30-6
Molecular structure:



Physical chemical properties
D-90 is a polymeric bisphenol compound. The physical chemical properties for D-90 are shown in Table 4.

Use: According to one manufacturer D-90 is used as an alternative to BPA in thermal paper used for labels (personal communication- source confidential).

Classifications and assessments
For D-90 there is no EU hazard classification.

According to the US EPA report (2012), the following environmental hazard has been assessed as very high:

- Persistence*

A high hazard has been assigned for:

- *Bioaccumulation (very low quality data)**

A moderate hazard has been assigned for:

- *Eye irritation*
- *Carcinogenicity (low quality data)*
- *Neurological effects (low quality data)*

* The assessment is made for the highest hazard designation of any of the oligomers with MW <1,000

Toxicokinetics
No data.

Environmental transport
An environmental transport evaluation for D-90 is available in the US EPA report (2012) and is based entirely on estimations on QSARs that were performed on two representative components of the polymer mixture. According to this D-90 is expected to:

- partition predominantly to soil and sediment (based on fugacity models)
- have a low mobility in soil (based on expected strong absorption to soil)
- exist solely in a particulate phase if released to the atmosphere
- not have atmospheric oxidation as a significant route of environmental removal

Persistence
According to the US EPA report (2012) the persistence is assessed to be of very high concern (based entirely on estimations that were performed on two representative components of the polymer). These estimations gave the following: primary aerobic degradation would be in the order of weeks, ultimate biodegradation would be in the order of months for one component and recalcitrant for the other, and volatilisation half-life would be > 1 year. In addition the substance was likely not to be susceptible to direct photolysis (based on absence of functional groups that absorb light at environmentally relevant wave lengths).

Bioaccumulation
According to the US EPA report (2012) there is a high concern for bioaccumulation since the estimated BAF value is >1,000 for the low MW-oligomers which indicates that this component has the potential to bioaccumulate.

4.3 Migration of BPA and alternative substances from thermal paper receipts

In this section, the potential for migration based on physical chemical properties is discussed and analytical studies on total contents and migration are presented. This includes review of previous studies as well as analytical work performed in this study on thermal receipt paper with BPA, bispehnol S and Pergafast, respectively. Also some considerations regarding possible dermal absorption of these substances are presented.

Migration of chemical substances means the transfer of a chemical substance from its original location (e.g. in an item) to its surroundings. In the case of thermal paper this could be release of a chemical substance from the thermal paper to e.g. skin.

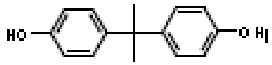
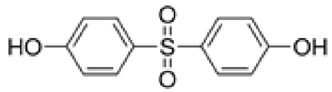
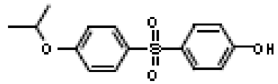
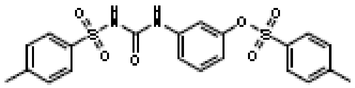
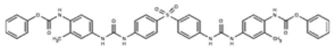
4.3.1 Factors determining migration and indications for migration

Migration is a diffusion process which is a function of time, temperature, thickness of the material, amount of migrant in the material, partition coefficient and distribution coefficient (Watson, 2001). There are also many other factors determining the migration potential or migration rate, for instance distribution of migrant in the material, physical-chemical characteristics of the substance (such as molecular size, boiling point, vapour pressure and solubility in the item where it is present), and environmental properties of the media or item which comes in contact with the item (such as acidity, temperature, hydrophobicity, moisture content etc.).

Since migration depends on so many different factors, it is challenging to make predictions of potential for migration. In this project, relevant data available for guesstimating migration behaviour are physical chemical properties, which are shown in Table 4. These can only be used to give very rough indications for migration, and only in a relative sense compared to BPA.

TABLE 4

PHYSICAL CHEMICAL PROPERTIES FOR BPA AND THE 5 ALTERNATIVE DEVELOPERS IDENTIFIED TO BE ON THE MARKET IN THIS PROJECT. SOURCE US EPA (2012)

CAS No	Chemical Name	Common Name	Molecular Weight (MW)	Dissociation constant in water (pKa)	Melting point (°C)	Boiling point (°C)	Vapour Pressure (mmHg @ 25 °C)	Water solubi-lity (g/L)	Henry's law constant (atm•m3 /mole)	Log Kow*	Molecular structure
80-05-7	2,2-bis(p-hydroxyphenyl)propane	Bisphenol A	228.29	9.59-11.30	55	60.5	3.99×10-8	120-300	<1×10-8	3.32	
80-09-1	4-Hydroxyphenyl sulfone	Bisphenol S	250.27	8	240.5	>300	<1×10-8	1.1×10-3	<1×10-8	1.2	
95235-30-6	4-hydroxyphenyl 4-isoprooxyphenylsulfone	D-8	292.35	8.2	129	>300	<1×10-8	21	<1×10-8	3.1	
191680-83-8	4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl]phenol	D-90	570.6 (n=1); 891.00 (n=2)	6.9-7.5	ND	>300	<1×10-8	0.54; <1×10-3	<1×10-8	3.8 ; 5.9	
232938-43-1	N-(p-Toluenesulfonyl)-N'-(3- p-toluenesulfonyloxyphenyl)ure a	Pergafast 201	460.5	12.5; 5.3; -3.8; -13.6	157.7	250 (dec)	<1×10-8	35	<1×10-8	2.6	
321860-75-7	Urea Urethane Compound	UU	784.9	10.3	ND	>300	<1×10-8	<1×10-3	<1×10-8	6.5	

4.3.2 Assessment of migration based on physical chemical properties

The migration of BPA and the five identified alternatives confirmed to be in use in thermal paper today can be expected to be different due to the unique properties of each substance as indicated in Table 4. But some similarities can be pointed out which can give an indication of the migration properties of the alternative substances.

Bisphenol S is the alternative substance which bears the closest resemblance to BPA. BPA and Bisphenol S are quite similar both in chemical structure and size of the molecule. Some differences are notable such as a low partition coefficient (K_{ow}) for bisphenol S indicating that BPA is more hydrophobic than bisphenol S. Hydrophobic molecules can have a higher driving force for migration into e.g. human tissue and as shown by e.g. Biederman et al (2010) affects BPA migration out of the receipts. These differences in hydrophobicity make it likely that BPA migrates more easily into hydrophobic media such as lipids of human tissue compared to bisphenol S. Solubility of the substances in water also differs with BPA being more water-soluble than bisphenol S. This low water solubility might result in a lower migration of bisphenol S into aqueous media.

D-8 is also very similar in chemical structure and molecular size when compared to BPA and bisphenol S. The partition coefficient (K_{ow}) for D-8 is close to that of BPA indicating a similar driving force for migration into e.g. human tissue. Solubility of the substance in water is a little lower than that of BPA which could result in a lower migration into sweat or other aqueous media.

The properties of bisphenol S and D-8 are overall considered close to the properties of BPA. Of the five identified alternative substances bisphenol S and D-8 are expected to have migration potential similar (or slightly lower) to that of BPA. It should be noted, however, that migration is a complex phenomenon and only a very qualitative estimation of migration potential can be made based on the available physico-chemical properties.

D-90 has some structural similarity to BPA, but not as similar as bisphenol S and D-8. The molecular weight of D-90 is more than double that of BPA. Small molecules usually migrate faster than larger molecules and the larger size of D-90 can be expected to lead to a lower migration of D-90 compared to BPA. The partition coefficient (K_{ow}) of D-90 is higher than for BPA indicating that D-90 is more hydrophobic than BPA. Hydrophobic molecules can have a higher driving force for migration into e.g. human tissue. Solubility of the substances in water also differs with D-90 being less water-soluble than BPA. This low water solubility might result in a lower migration into sweat or any other aqueous media. Thus overall, D-90 possesses properties (molecular weight, water solubility) which could lead to lower migration as compared with BPA, whereas on the other hand higher hydrophobicity might trigger higher migration.

Pergafast 201 has a higher molecular weight and a very different chemical structure than BPA. The high molecular weight can be expected to lead to a lower migration of Pergafast compared to BPA. Pergafast 201 contains functional groups resulting in a charge of the molecule that depends on the acidity (pH) of the media surrounding the molecule. Since the charge of the molecule can be a driving force for migration, pH will potentially influence the migration for Pergafast 201 more than for BPA. Water solubility and partition coefficient of Pergafast 201 is quite close to that of D-8 and BPA. Overall the migration of Pergafast 201 is not expected to be similar to BPA – at least not under all conditions and not to all types of media. The molecular weight is expected to reduce the migration were as the effect of the pH is more uncertain but is expected to play a minor role compared to the hindrance of migration due to size.

UU has a high molecular weight and a different structure than BPA. The high molecular weight can be expected to lead to a lower migration of UU compared to BPA. Water solubility of UU is very low and the partition coefficient of UU is very high compared to BPA, indicating a very hydrophobic molecule. Hydrophobic molecules can have a higher driving force for migration into e.g. human tissue. The low water solubility might result in a lower migration into sweat or any other aqueous media.

4.3.3 Amounts and concentrations in thermal paper receipts

The amount of BPA applied to thermal paper receipts is (according to manufacturers) typically 1% (w/w), i.e. 10 mg/g paper (personal communication – source confidential). In Europe thermal paper receipts normally weigh 55 g/m² paper, while in North America they are normally thinner and weigh 48 g/m² paper (Manufacturer, personal communication – source confidential). The amount of BPA (1% of total paper weight) would then be approximately 0.55 g/m² in Europe.

Thermal paper is provided in different grades with differences in concentrations of BPA depending on specific needs. A guess is that the difference could be up to 20-25% (Manufacturer, personal communication – source confidential). The reason for different grades is that different printers need different quality both in terms of run-ability (i.e. paper thickness) and print head temperature (more or less sensitive) (Manufacturer, personal communication – source confidential).

In a Danish EPA study by Lassen et al. (2011), BPA was detected in 75% (i.e. 9 of 12) of thermal paper receipts collected from different cash registers. Of these, 58% (i.e. 7 of 12) had BPA concentrations ranging between 0.87-1.7 %(w/w), (i.e. 8.7-17 mg/g paper). Similar results are reported by Geens et al. (2012) for thermal paper receipts collected from different stores in Belgium, where 73% of the receipts had BPA concentrations ranging between 0.9 and 2.1 %(w/w). For the remaining 25%, BPA could be detected, but only in trace amounts ($1{\cdot}10^{-8}$ - $<1{\cdot}10^{-6}$ %(w/w)). The higher detection rate in the Belgian study could be due to the detection limit being 10 times more sensitive than in the Danish study. Geens et al. (2012) compared measured concentrations of BPA in thermal paper from seven recent international studies (2010-2012) having analysed a total of 234 thermal papers. The detection frequency of BPA in the receipts ranged between 44 and 98%. The highest measured concentration in these studies ranged between 1.4-2.8 %(w/w), i.e. 14-28 mg/g paper.

For bisphenol S, about 20% more of the substance is needed, i.e. around 1.2 %(w/w) (if the corresponding BPA based paper would contain 1 %(w/w)) (Manufacturer, personal communication – source confidential).

In a study by Liao et al. (2012), concentrations of bisphenol S in 111 thermal receipt paper from USA (n=91), Japan (n=6), Korea (n=11) and Vietnam (n=3) were measured. These ranged between 0.000138-2.2 %(w/w). Bisphenol S is quite common in US thermal paper receipts and it was also in thermal receipt paper from the US that the highest measured concentration (22 mg/g) was found. Only trace amounts were found in the receipts from Korea and Vietnam (however the sample size was very small).

4.3.4 Previous studies on migration of BPA from thermal paper to the skin

Studies on migration from thermal paper to skin has been identified for BPA (in a few studies), but no information has been identified for the alternative substances.

The amount of BPA migrating from thermal paper receipts to the skin has been determined by Biedermann et al. (2010). It should be noted that the results are based on a small sample size. After holding thermal paper receipts for 5 seconds, the total amount of BPA transferred to two fingers ranged between 0.7 and 6.0 µg) (n=6).

This transfer increased by approximately ten times if the skin was greasy (n=2). An even higher increase (an average of 63 times increase) was seen for wet fingers compared to dry fingers on thermal recorder paper used in chromatography (n=2). The amount of BPA transferred was, according to Biedermann et al. (2010), not directly related to the concentration in the thermal paper; (it was suggested that causes could be differing BPA distribution in the paper surface and varying integrity of the fibre layer). Neither repeated contact (10 times instead of 1 time) nor prolonged contact (60 s compared to 5 s) increased the BPA concentration on the fingers significantly (Biedermann et al., 2010). The authors suggested that equilibrium between the BPA concentration in the paper and the surface layer of the skin may have been reached.

The extent to which BPA is removed from the fingers has also been studied. When touching clean BPA free paper, Biedermann et al. (2010) showed that the amount of BPA on the fingers was not significantly reduced. This means the BPA remained on the fingers. Washing hands with water immediately after touching showed that more BPA was removed to a higher extent when the water was warm (99% removal) than when it was cold (95% removal). The amount of BPA that remained in the fingers after washing also depended on when the washing took place, due to penetration into the skin.

A study on BPA migration has also been performed by Lassen et al. (2011) with analysis done on 12 printed cash register receipts. The content of BPA in 7 out of 12 analysed cash register receipts varied from 8.7 to 17 mg/g paper. Bisphenol S was found in three of the cash register receipts, but no migration analyses were done for bisphenol S containing paper. Migration analyses were carried out for BPA containing paper, both migration of BPA to artificial sweat and the quantity of BPA released to fingers in a realistic handling situation (methods modified from Biedermann et al. (2010) were applied). Immersion of the cash register receipts in artificial sweat for 5 seconds showed a migration from the receipts of 7-21 µg BPA/cm^2, equivalent to 10-37% of the content of BPA in the receipts. No correlation between the quantity of BPA in the cash register receipts and the migrating quantity was seen, which is in accordance with results from the Biedermann et al. (2010) study. Handling tests showed a significant difference in the migrated quantity of BPA depending on whether the fingers were dry (with natural humidity), humid or treated with lotion (also in accordance with the Biedermann et al. (2010) study). The average quantity of BPA left on the fingers in the three situations was 11 (n=4), 103 (n=4) and 28 (n=2) µg BPA respectively.

4.3.5 Previous studies on dermal absorption and exposure estimates

BPA has a moderate water solubility and relatively low molecular weight, which according to Zalko et al. (2011) greatly favours skin penetration.

Penetration of BPA into the skin was also shown by Biedermann et al. (2010). Comparing levels of BPA extracted with ethanol from fingers that had been washed in warm water and soap immediately after touching and 2 hours after touching, respectively, showed that more BPA could be extracted from the fingers when washing had been delayed for 2 hours. This means more of the BPA on the fingers had penetrated into the skin. When washing was made immediately more than 90% was removed by washing, while only 73% was removed when the washing was delayed for 2 hours.

The daily exposure to BPA has been estimated by Biedermann et al. (2010). If touching the thermal paper receipts that transferred the highest amount of BPA (3 µg/digit), the uptake into the skin from ten digits during a 10 h working day was estimated to be 41 µg/day. If the hands were not washed the 30 µg left on the ten fingers could also be resorbed, which could increase the potential maximum exposure to 71 µg/day.

Since there is no information regarding the transfer rates of bisphenol S, Liao et al. (2012) based their estimations of daily intake on data derived from Biedermann et al. (2010) regarding transfer and absorption. Contact time was set to 5 seconds. The estimated daily intake for the general population (contact 2 times/day) and for occupationally exposed individuals (contact 150 times/day), based on a median bisphenol S concentration of 5 mg/g, was *calculated* to be 0.291

µg/day and 21.8 µg/day, respectively (i.e. 75 times higher for occupationally exposed individuals as compared to consumers) (Liao et al., 2012).

No original literature on dermal absorption has been identified in this project for the alternative substances bisphenol S and Pergafast. Based on professional judgement, US EPA (2012) assesses poor absorption of Pergafast through the skin if in solution and thus concludes that Pergafast is not expected to be absorbed through the skin. In line with this, the high molecular weight of Pergafast is likely a limiting factor with respect to dermal absorption. All in all, a limited (if at all) dermal absorption of Pergafast must be assumed – in any case lower than that for BPA.

Regarding bisphenol S, physico-chemical properties and the analytical results regarding migration to artificial sweat and fingers (dry, sweaty and with cream) indicate that the similarity in the properties of bisphenol S and BPA might lead to a similar dermal absorption. US EPA (2012) indicates "no data" regarding dermal absorption of bisphenol S.

4.3.6 Analytical investigation on migration from thermal paper receipts

Only three alternative substances to BPA have been confirmed to be present in thermal paper used for thermal paper receipts (bisphenol S, Pergafast 201 and UU). The analytical migration analyses in the project has focused on migration from thermal paper receipt samples of two of these (bisphenol S and Pergafast 201), i.e. for paper samples where the content of the substances has been confirmed by the manufacturer providing the samples (manufacturer- source confidential). One sample with each substance was provided to the project as well as one reference sample containing BPA. The paper samples are all approximately 55 g/cm^2 and no printing has been done on the paper before testing.

4.3.6.1 Migration Methods

The analytical work included determining the total content of the substance, determining the migration to artificial sweat and determining the migration to fingers. The methods used are based on the work reported by Lassen et al. (2011) and Biedermann et al. (2010).

Total content

A subsample amount of 5x6 cm was removed from each type of paper in double determination. Extraction was carried out with 10 ml methanol in incubator at 60°C overnight, subsequently diluted in 10% methanol and analysed as stated in Table 5.

TABLE 5
ANALYTICAL METHOD FOR DETERMINING BPA, BISPHNEOL S OR PERGAFAST 201 IN THERMAL PAPER

Analyses of BPA, Bisphneol S or Pergafast 201 in thermal paper	
HPLC instrument	**Agilent HP1260, HPLC pump, auto sampler, UV-DAD and fluorescence detector**
HPLC parameters	Column: Kinetex C18 5u 100A, Phenomenex, 150 x 4.6 mm Room temperature Mobile phase: Acetonitrile/ water Programme: Gradient Detector: UV 230, 227, 260 and 278 nm FLD 225/ 460 nm
Detection limit	0.1 mg/kg

Migration to artificial sweat
A subsample amount of 5x6 cm was removed from each type of paper in double determination. Migration was carried out by immersing the sample in 20 ml artificial sweat for 5 seconds and the content of BPA, bisphenol S and Pergafast respectively was analysed as stated in Table 5.

The applied artificial sweat is described in DS/EN ISO 105-E04, which is used in connection with ØKO-TEX certification (Öko-Tex Standard 100). The artificial sweat in DS/EN ISO 105-E04 consists of 1-histidine-monohydrochloride-1-hydrate, sodium chloride, sodium dihydrogene phosphate and sodium hydroxide for adjustment of pH to pH 5.5.

The migration tests were carried out at 37°C as that is close to the body temperature and is used in DS/EN-71-3, DS/EN ISO 105-E04. When carrying out the migration investigations, the artificial sweat is preheated before the test items are immersed.

Migration to fingers
Dry fingers are prepared by washing and drying with clean paper towels before initiation of test. The thermal paper sample is held between six fingers for a period of 5 seconds and rinsed with up to 10 ml ethanol.

Sweaty fingers are obtained by dipping the six fingers used for the test in artificial sweat and air drying for a few seconds before continuing with the procedure as described for the dry fingers test. The applied artificial sweat is the same as used for migration to sweat.

For fingers with hand cream, the six fingers used for the test are applied with an appropriate amount of hand cream and the cream is left to absorb for a few minutes before continuing with the procedure as described for the dry fingers test. The applied hand cream is of the brand ”Derma Helse, Decuderm without perfume, skin neutral, special care”.

Carry-over of the chemical substances between individual tests can give a false high result and the carry over between tests is therefore determined for all three substances. The carry over test was performed after the test with dry and sweaty fingers and before the test with ”fingers with cream on them” and the recovery test, since the sweaty fingers are expected to give the highest migration and thus the highest carry over, if the cleaning procedure between tests is inadequate. Results show low carry over for all three substances.

Recovery tests are done in order to confirm that any applied substance can indeed be extracted and determined by the chosen analytical method. The recovered percentage of substance should ideally be close to 100% for the method to be optimal. The recovery tests were carried out by depositing a solution containing a known amount of substance on two fingertips (see Table 6). The fingers were subsequently rinsed as in the other tests performed. Results show recoveries from 48% to 126% which is considered acceptable, since the recovery will depend on many factors e.g. the rate of dermal absorption which is expected to vary for the different substances.

TABLE 6
CARRY OVER AND RECOVERY TESTS. RESULTS FROM CARRY OVER AND RECOVERY TESTS PERFORMED TO VALIDATE THE METHODS USED FOR MIGRATION AND ANALYSES

	Bisphenol A			Bisphenol S			Pergafast 201		
	µg deposited on 6 fingers			µg deposited on 6 fingers			µg deposited on 6 fingers		
Carry over	6.6			3.5			1		
	µg deposited on 2 fingers	µg - Recovered	Recovery %	µg deposited on 2 fingers	µg d - Recovered	Recovery %	µg deposited on 2 fingers	µg– Recovered	Recovery %
Low recovery	1	0.48	48	1	1.2	119	1.1	0.86	80
High recovery	10	8.6	85	10.4	6	57	10.7	13.5	126

4.3.6.2 Migration Results

Total content and migration to artificial sweat
Results of the total content of each chemical substance in thermal paper and migration from thermal paper to artificial sweat are shown in Table 7.

TABLE 7
RESULTS FOR TOTAL CONTENT AND MIGRATION TO SWEAT. STD.DEV.: THE STANDARD DEVIATION ON THE MEAN OF TWO REPETITIONS.

Total content							Migration to artificial sweat					
Substance	mg/kg	mg/kg mean	Std. dev.	µg/cm²	µg/cm² mean	Std. dev.	mg/kg	mg/kg mean	Std. dev.	µg/cm²	µg/cm² mean	Std. dev.
Bisphenol A	10842	10835	9.9	61.9	61	1.2	410	416	9.1	2.3	2.3	0.04
	10828			60.1			423			2.3		
Bisphenol S	11599	11564	50	64.6	64.9	0.29	1285	1223	88	6.9	6.6	0.51
	11528			65.1			1161			6.2		
Pergafast	10348	10385	52	56.5	56,8	0.45	21.2	20.1	1.5	0.11	0.11	0.01
	10421			57.1			19.1			0.1		

Migration to fingers

Results of migration from thermal paper to dry fingers, sweaty fingers (moistened with artificial sweat) and fingers treated with hand cream are shown in Table 8.

TABLE 8
RESULTS OF MIGRATION TO FINGERS. THE TABLE SHOWS ANALYTICAL RESULTS FOR MIGRATION TO DRY, SWEATY AND LOTIONED FINGERS

	Bisphenol A			Bisphenol S			Pergafast 201		
Migration	µg deposited on 6 fingers	Mean	Standard deviation	µg deposited on 6 fingers	Mean	Standard deviation	µg deposited on 6 fingers	Mean	Standard deviation
Dry fingers	6.6	6.6	0.1	4.4	4,8	0,49	1.7	2.4	0.95
	6.5			5,1			3		
Sweaty fingers	90	106	23	9.4	19	14	99.7	103	3.9
	123			29			105		
Fingers with hand cream	23	19	6,3	5,3	7.1	2,6	5.2	4	1.6
	14			8,9			2.9		

4.3.6.3 Discussion of analytical migration results

Figure 3 shows the results of the analytical work presented in Table 7 and Table 8.

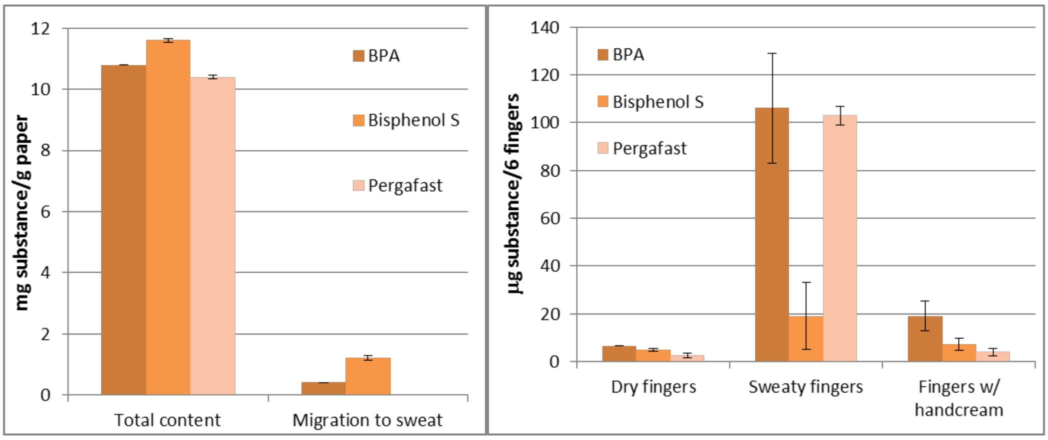


FIGURE 3

ANALYTICAL RESULTS ON MIGRATION OF BPA, BISPHENOL S AND PERGAFAST 201. TO THE LEFT: TOTAL EXTRACTION AND MIGRATION TO ARTIFICIAL SWEAT FROM THERMAL PAPER. TO THE RIGHT: MIGRATION FROM THERMAL PAPER TO DRY, SWEATY AND FINGERS TREATED WITH HAND CREAM

Content of substance in paper samples

Three samples have been analysed in this project; one containing BPA, one containing bisphenol S and one containing Pergafast. Due to the limited sample size, results should be considered indicative rather than representative for all thermal papers containing these three substances.

The total content of BPA, Bisphenol S and Pergafast in the thermal papers analysed is 10.8, 11.6 and 10.4 mg/g respectively. This corresponds well with the expected content of 10 mg/g BPA and 12 mg/g bisphenol S in thermal paper as reported by the thermal manufacturers as discussed above (Section 4.3.3). No literature information has been identified regarding the content of Pergafast, but the results indicate that the content of Pergafast is comparable to that of BPA and bisphenol S in the analysed samples.

Migration to artificial sweat

2.3 µg/cm^2 of BPA, 6.6 µg/cm^2 of bisphenol S and 0.11 µg/cm^2 of Pergafast migrates to the artificial sweat. In Lassen et al. (2011) a higher migration of 7-21 µg/cm^2 of BPA was seen using the same analytical method. This indicates that the analysed migration for the particular sample tested is rather low compared to previous results.

Although bisphenol S and BPA are structurally similar, the migration into artificial sweat is much higher for bisphenol S with respect to amounts (2.3µg/cm^2 for BPA and 6.6 µg/cm^2 for bisphenol S) as well as percentage of total content. (3.8% of total for BPA and 10.2% of total for bisphenol S). This can be a result of the lower K_{ow} of bisphenol S compared to BPA meaning that bisphenol S is more hydrophilic, although the water solubility of bisphenol S is indicated to be lower, see Table 4. For Pergafast a much lower amount of the substance migrates into artificial sweat (0.2% of total Pergafast in paper), which is consistent with the theoretical considerations regarding a slower release due to a higher molecular weight.

Migration to fingers

For migration to dry fingers, the highest migration is seen for BPA, whereas migration for bisphenol S is slightly lower and even lower again for Pergafast. The same trend is seen for migration to fingers treated with hand cream. The migration is generally higher to fingers treated with hand cream for all substances, but the increase seen is higher for BPA than for the two alternatives (2.9, 1.5 and 1.7 times the level in dry fingers for BPA, bisphenol S and Pergafast respectively). This correlates well with the expectations according to the physical/chemical properties where BPA is seen to be a more hydrophobic molecule (high Kow) and the low migration of Pergafast again explained by the higher molecular weight. The higher migration of BPA to fingers treated with hand cream also correlates well with the findings of Biedermann et al. (2010) (oily fingers) and Lassen et al. (2011), data for the two studies compared to the analytical work done in this project are summarized in Table 9. The Lassen et al. (2011) and results from the current study are comparable, which was expected since the exact same methods have been used. The results for Biedermann et al. (2010) are obtained using a slightly different method than the one used by Lassen et al. (2011) and the current study. The "oily" fingers in the Biedermann study result from touching a tissue paper wetted with some vegetable oil and the thermal paper used was in this case recorder paper from chromatographic instruments and not receipt paper. Both factors will influence the migration and the comparison of results can only be indicative.

The migration to sweaty fingers is also higher for all substances compared to migration to dry fingers. This confirms results on BPA migration presented by Lassen et al. (2011), as well as by Biedermann et al. (2010), see Table 9. Again, the Lassen et al. (2011) results are most comparable to the results from the current study since the methodology used is the same, whereas the results from Biedermann et al. (2010) show a lower migration. This is expected to be a consequence of a different method for obtaining "humid" fingers by Biedermann et al. (2010) (prepared "with some saliva") and as already mentioned a different type of thermal paper (recorder paper) was used. The increase for BPA and Pergafast is much higher than for bisphenol S. The high migration for Pergafast was unexpected based on the theoretical considerations based on physical/chemical properties and also contradicts the results seen in migration to artificial sweat where the migration of Pergafast is low. The analytical work has been documented and documentation was double-checked, but no obvious explanation for this finding can be given at this point. Furthermore, carry-over of substances between tests is low (see Table 6) and the retention time of the sample on the chromatogram confirms that the substance detected is indeed Pergafast.

TABLE 9
COMPARISON ON MIGRATION RESULTS FOR MIGRATION TO FINGERS. BIEDERMANN ET AL. (2010) DATA IS MODIFIED FROM "TABLE 3, RECORDER PAPER" IN THAT REFERENCE. LASSEN ET AL. (2011) DATA IS MODIFIED FROM "TABLE 4.2" IN THAT REFERENCE

BPA migration to fingers (μg/finger)			
	Current project	Biedermann et al., 2010	Lassen et al., 2011*
Dry fingers	1.1	0.3	1.8
Sweaty/humid fingers	17.7	8.8	17.2
Fingers with hand cream/ oily fingers	3.2	0.5	4.7

*Data from Lassen et al. (2011) is recalculated based on the use of 6 fingers for migration not 8 as stated in the report (number of fingers used has been confirmed by Ulla Christensen, Danish Technological Institute).

4.4 Discussion/summary

This survey shows that there are several alternatives to bisphenol A (BPA) as developer in thermal paper. US EPA (2012) identified 19 alternatives that are either in use or have been assessed to have the potential (based on physical chemical properties) to be used as developers in thermal paper. In the current survey only five of these 19 alternatives have been confirmed by manufacturers to be used in thermal paper for receipts or labels on the European market. These are bisphenol S, Pergafast and Urea Urethane (UU), which are used in thermal paper receipts, and D-8 (4-hydroxyphenyl 4- isoprooxyphenylsulfone) and D-90 (4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl]phenol), which are used in labels. Bisphenol S and D-90 are bisphenols, D-8 is a phenol, whereas Pergafast and UU are phenol free. UU seems to be less common and only scarce information could be obtained on this substance.

In general in was difficult to obtain detailed information regarding alternatives from thermal paper manufacturers due to company secrets / the competitive situation and likely also because of the political focus on BPA worldwide. However, some general information was obtained during the telephone interviews with the manufacturers on condition of anonymity.

The confirmed alternatives are all more expensive than BPA. Thermal paper with Bisphenol S is the most common and cheapest alternative (approx. 5-10 % more expensive than BPA based paper). Thermal paper with Pergafast is quite common and is the most expensive alternative (usually 10-25% more expensive than BPA based paper). The price for thermal paper with D-8 or D-90 is somewhere in between the price for thermal paper with bisphenol S and Pergafast. Besides the higher cost for the alternatives compared to BPA, the other negative aspect mentioned by the paper manufacturers was that substituting a developer requires significant adjustments in the thermal paper manufacturing process such as modification in the chemistry of the paper (not only the developer), and quality adjustments. From the collected information, it appears that substitution is not a one-to-one substitution.

It should be noted that the Pergafast chemical is currently only produced by one manufacturer, which means there is no competition regarding price and no possibility for flexibility regarding delivery from multiple suppliers. Whether this lead to hesitations by paper manufacturer to substitute to this alternative has not been clarified in this project, but could be speculated.

Once the paper is produced the alternatives seem not to have any functional drawbacks. On the contrary, the phenol free alternatives have better performance than BPA, because of their higher image stability. Compared to BPA based paper, image stability is similar or slightly higher for paper based on bisphenol S, higher for D-8 and D-90 and much higher for Pergafast. For customers substituting to thermal paper rolls without BPA, there are no technological challenges, since existing thermal printers can be used without adjustments.

All 19 alternatives identified by US EPA (2012) are associated with environmental and or health hazards, but the available data on these substances are either scarce or of low or very low quality, which makes it challenging to conclude with any certainty that one alternative is better than the other. The most frequent environmental properties that are assessed in the US EPA (2012) report as high or very high hazards, or have harmonised or notified EU classifications in the two highest categories (1 or 2) are the acute aquatic toxicity, chronic aquatic toxicity and persistence in the environment. Among the health hazards, eye irritation, dermal irritation, skin sensitisation, reproductive effects and developmental effects are the most frequent properties assigned a high hazard or classified in the two highest EU categories. Twelve of 19 alternatives are bisphenols and several recent studies have shown that other bisphenols have properties and effects similar to BPA.

The US EPA assessments and/or EU classifications for the three alternative substances that were confirmed to be used in thermal paper receipts indicate the following:

- The two phenol-free alternatives i.e. Pergafast and UU are very persistent in the environment;
- Pergafast is toxic to aquatic life with long lasting effects and has been assigned a moderate hazard for reproductive and developmental effects and repeated dose effects;
- For UU data are very scarce, and
- Bisphenol S is noted to cause serious eye irritation and to be harmful to aquatic life with long lasting effects, and has been assigned a high hazard regarding repeated dose toxicity, and a moderate hazard for reproductive and developmental effects, and mutagenicity/genotoxicity.

Thermal paper receipt samples with confirmed content of BPA, bispenol S and Pergafast were obtained from one manufacturer. These were subject to the analytical experiments performed in this project.

Analyses of the contents showed that the total content of Pergafast in thermal paper receipts was detected to be comparable to BPA (around 1% w/w) while the amount of bisphenol S detected was slightly higher (around 1.2% w/w). This slightly higher bisphenol S concentration is in line with information found in literature.

The migration of Pergafast was generally much lower than for both BPA and bisphenol S, except in the case of migration to sweaty fingers where the migration was comparable to BPA and much higher than for bisphenol S. The migration of bisphenol S was generally slightly lower than for BPA, except in the case of migration to sweat where the migration was slightly higher than for BPA. The results for BPA migration to fingers are generally comparable to the trends seen in other studies (Lassen et al., 2011 and Biedermann et al., 2010), although differences in methodology and paper type has resulted in a lower migration in the Biedermann et al. (2010) study.

The results should be considered indicative rather than representative since analyses were performed on only one sample of paper per substance tested. The results however do confirm what is expected based on theoretical considerations, i.e. that bisphenol S generally migrates similar to BPA while the migration of Pergafast in most cases is hindered, probably due to its larger molecular size. However, migration of Pergafast to sweaty fingers was found to be high, a finding which was unexpected given the molecular size and since the migration to sweat directly was very low.

No data on dermal absorption have been identified for Bisphenol S and Pergafast, but based on professional judgement, dermal absorption of Bisphenol S is expected to be comparable to that of BPA, whereas that of Pergafast is expected to be considerably lower.

As indicated above, bisphenol S and Pergafast have known or suspected unwanted environmental and health properties, but are not as well studied as BPA.

Bisphenol S might possess health properties similar to those of BPA and seems to have similar migration and dermal absorption ability. Overall, current evidence is therefore too scarce to distinguish between thermal paper with respectively BPA and bisphenol S from a health and environmental perspective.

Despite unexpected findings of migration of Pergafast to sweaty fingers, Pergafast is generally found and expected to migrate and absorb through the skin to a lower extent than BPA. Although scarce, also hazard data indicate that Pergafast might be less inherently toxic to human health and thus could be expected to cause less health risks. On the other hand, Pergafast is assessed to be persistent and toxic to the environment. Thus, overall, based on the activities in this project, it is difficult to judge whether Pergafast would be preferable to BPA from a health and environmental point of view.

Overall, it should be stressed that generally few hazard data are available for alternative substances and that the few migration tests performed in this study should not be over-interpreted.

Alternative substances which are preferable to BPA from an environmental and health perspective cannot be identified based on this survey. As there are no well-known safe alternatives, one solution could be to stimulate substitution to other technologies than the thermal printing technologies. Alternative technologies are described and assessed in the subsequent chapter.

5. Survey of alternative technologies to thermal printing receipts

5.1 Overview of identified alternative technologies

There are several advantages in using direct thermal printing for receipts:

- No additional inks or chemicals are needed, the only consumable item is the paper
- Printing is fast (up to 406 mm per second)
- The resolution (up to 400 dpi) is appropriate for the application
- The printers have few moving parts (which makes them reliable and relatively durable)
- The printers are quiet, light weight and can be small (US EPA, 2012).

But there are also several disadvantages of the use of thermal printing. BPA, the most frequently used developer in thermal paper, is suspected to have endocrine disrupting properties and thus there is a growing concern regarding BPA exposure. As shown in the previous chapter, also alternatives to BPA have drawbacks. From a functional perspective, thermal paper rolls are sensitive to heat, prolonged sunlight, water, exposure to chemicals and friction, and are therefore only suited for short term data storage. There are ways to increase durability (e.g. top and back coating, choice of developer, thickness of paper) (US EPA, 2012), but another alternative is to look for an entirely different technology to accommodate the purpose of the thermal paper receipt.

Alternative technologies that may have the potential to replace the traditional BPA-containing thermal paper receipts/tickets or at least reduce human exposure to BPA are outlined in Table 10 and described briefly in the following paragraphs. Many of the identified technologies are developed either in order to simplify or make certain tasks more time-efficient, or as part of the transition to a cashless society. The reduction in the need/use of printed receipts or tickets is assessed to be an indirect effect of these alternative technologies rather than a driver for developing these.

Most of the identified technologies can be used on their own, but are in many cases combined to provide the consumers with a payment and receipt solution consisting of more than one technology, giving the customer a range of options according to preferences. Therefore, some overlap in the description and discussion of technologies is unavoidable but has been minimised as far as possible to avoid confusion.

In the following paragraphs, the alternative technologies will be described shortly with the intention of keeping the aspect of “documentation of purchase” (i.e. the function of the paper receipts being substituted) in mind rather than simply describing the purchase function in itself.

Based on an initial evaluation of the identified technologies’ potential to replace thermal paper receipts or reduce human exposure to BPA, as well as their time to market, a number of the technologies were selected for further study in agreement with the Danish EPA. These will subsequently be treated in greater detail with respect to cost of introduction, estimated current market share, trends in use and development, technological barriers and experience, as well as barriers for and experience with consumer accept. Barrier mitigation approaches will also be addressed.

TABLE 10
OVERVIEW OF ALTERNATIVE TECHNOLOGIES TO TRADITIONAL BPA-CONTAINING THERMAL PAPER RECEIPTS

Technology	Trend/market share	Suppliers / examples (users)	Technological challenges	Barriers for consumer accept
Mobile banking & payment **(SMS text, direct mobile billing, custom apps, Quick Response (QR) codes, mobile web payments (using wireless application protocol (WAP)), contactless near field communication (NFC) technology)**	Strong increase. Global mobile payment volume reached 200 billion USD in 2012 and it is expected to reach 1 trillion by end of 2015. The number of users was almost 500 million by end 2012 and is expected to double by end 2015 (PortioResearch, 2013).	App examples: DSB billet Movia Mobilbilletter Kino.dk EasyPark ParkMan MobilePay (>0.65 million downloads (Danske Bank, n.d. B)).	Requirement for distribution and device costs to be absorbed, some security concerns. Online shopping may transfer the issues of BPA exposure from receipts to labels for packaging	Potentially high initiation complexity for the user. This is a barrier in particular for the older segment. Mobile payments can be performed with or without a PIN-code - decision is based on a weighing of convenience versus security.
Contactless smart card payment **(contactless radio-frequency identification (RFID) technology)**	Strong increase, especially within transportation. The global market for smart cards used in the public transportation sector is expected to reach 1.1 billion unit shipments in 2013 (Mathis, 2013).	Rejsekort, Denmark (0.6 million cards issued, 32.7 million travels (Rejsekort, n.d.). Upass, South Korea. Octopus card, Hong Kong. The Oyster Card, London. OV-chipkaart, Netherlands.	Existing technology, replacing more old-fashioned technology within the transportation sector. Contactless payment cards *per se* do not eliminate paper receipts.	Resistance towards habitual changes. The system is simple to use and replaces many different tickets, however, figuring out price and discounts can be complex. Security issues can be a barrier. For contactless payment cards, the use closely mimics the currently used payment situation. The main difference is an increased security against fraud.

Technology	Trend/market share	Suppliers / examples (users)	Technological challenges	Barriers for consumer accept
Electronic receipts	More shops are offering electronic receipts, e-receipt companies are emerging	e-receipt companies: eKvittering (17 shops/chain stores (eKvittering, n.d.) kvittering.dk dSAFE.no (>2300 merchants (dSAFE, n.d.) Xpenser.com, US eReceipts, UK (>9.6 million receipts sent (eReceipts, n.d.)	The time from purchase to delivery of e-receipt may be many hours.	The concept demands a minimum of change in behaviour for the consumer as the system is based on the use of the traditional debit/payment card. The lag time from purchase to receipt of e-receipt and the cost of subscription may limit the spread of use. Security issues and trust in electronic storage can be barriers.
Receipt handling options **(self-service check-out, printer placement so customer handles receipts, choice to opt-out receipt)**	Depending on type; self-service check-out has been tested and abandoned by some Danish merchants	Self-service used in e.g. IKEA, Bilka, Føtex.	Generally, these alternatives are low-tech but may impose some implementation costs.	Depending on type of solution and commodity. A receipt is required for documentation/complaints/return of purchase whereas a grocery receipt may not be necessary
Receipt top-coating	Top-coating is not used in order to protect humans towards BPA exposure. Low market share. The trend is going towards thinner thermal paper in order to reduce paper consumption, cost of transportation/storage and time of paper roll replacement		Increased paper thickness requires more frequent replacement of paper roll. Increased production cost. Barrier effect unknown: Evaluation of the properties of the coating material with respect to BPA migration control and toxicology is required.	None (but the amount of BPA consumption/waste is not decreased).

Technology	Trend/market share	Suppliers / examples (users)	Technological challenges	Barriers for consumer accept
Alternative printing technologies	Considered out-dated regardless of type.		More moving parts and requirement of ribbon, ink or toner cartridges resulting in higher maintenance cost relative to thermal printing.	Typically slower than thermal paper printing and will thus increase the time of payment transaction.

5.2 Description of identified alternative technologies

A short description of each of the identified alternative technologies with a potential for replacing BPA containing thermal paper receipts or reducing human exposure to BPA will be given in the paragraphs below. Focus will be on how each technology works and how it might have a potential for serving as an alternative to thermal paper receipts.

In a Danish project named “Fremtidens penge” (The Future of Money), a number of mobile payment technologies were tested in various settings with emphasis on how the technologies were used, perceived and evaluated by test users (Fremtidens Penge, n.d.). The 30 test users represented the general Danish population (in terms of age, occupation etc.) and five test scenarios were explored (Retail, Cinema, Parking, Event and Social). When relevant, observations and conclusions from this project are referred to in the following.

5.2.1 Mobile banking and payment

The term mobile banking and payment covers a broad category of money transfer technologies that can be employed by using a mobile device such as a mobile phone or a smartphone. Mobile banking and payment is a fast growing area and the number of users globally is expected to double to one billion by the end of 2015 from almost 500 million by the end of 2012. These numbers correspond to an estimated global mobile payment volume reaching one trillion USD by end of 2015 from 200 billion USD in 2012 (PortioResearch, 2013).

Using mobile payment, a consumer can pay for a wide range of services and digital or hard goods (using a mobile device) by a range of technologies that includes:

- Short Message Service (SMS) based transactional payments (also known as direct mobile billing);
- quick response (QR) codes;
- custom applications (apps);
- mobile web payments (using WAP), and
- contactless near field communication (NFC).

For mobile payments, the proof of purchase is also typically received electronically and an increase in mobile payment options is, therefore, expected to lead to a reduction in the use of thermal paper for receipts and tickets.

SMS payment is the most well-known mobile payment technology and is mostly used for low-value purchases such as buying music, ring tones and games for the mobile phone. It is also used for charity donations and some shops also accept payment for food and drinks via SMS (e.g. in Danish cafés (Hansen, 2012)). SMS payment has also been introduced as a means for paying for services such as parking. Originally, the payment was made via the phone bill and proof of purchase would be in the form of an SMS confirming the purchase. More recently, SMS purchases can be charged directly from a bank account (Mobilpenge, n.d. A). SMS payment is a simple but very efficient payment technology as all mobile phones can send and receive text messages. It is, however, not the quickest of the mobile payment technologies as a number of text messages need to be send back and forth (including requirement of purchase, price response, confirmation of purchase, and final documentation of purchase).

QR codes are matrix codes or bar codes that can be scanned by using a smartphone. So far, most people most likely associate the black modules arranged in a square grid on a white background with commercial or information purposes. However, QR codes also enable individuals and businesses to make and receive payments via the QR smartphone applications (QR Pay, n.d.). For instance, Kuapay (US and EU) (Kuapay, n.d.) and LevelUp (US) (LevelUp, n.d.) offer a simple QR code payment solution. Users can add their credit card information and receive a personal QR code that can be scanned at the POS register of participating merchants. This mobile payment solution in itself does not necessarily replace the printed paper receipt. However, the technology can be employed in a number of ways and documentation for purchase of tickets and other purchases may be obtained as a QR code. Additionally, QR codes may be used directly for generation of an electronic receipt (see section 5.2.3) (Ho et al., 2013). Test users of various mobile payment technologies in the project "Fremtidens penge" expressed a worry that the use of QR codes for buying e.g. cinema tickets and snacks would not decrease queuing, merely shift the queuing from the payment situation to entrance and hand-out of snacks (Stefánsdóttir et al., n.d. A).

Custom apps are self-contained programs or pieces of software that can be installed on mobile devices. They are designed to fulfil a particular purpose and the technology is emerging on the Danish market, specifically within the transport sector. Other types of tickets such as for the cinema are also starting to become available for mobile purchase. Via these apps, the phone number and payment card details are typically registered before the first purchase and subsequent payments require the use of a personal code only. Proof of purchase is typically documented directly in the app and will be stored there for future use. So far, mobile app payments have primarily included purchases of small value.

The Danish bank, Danske Bank, launched an app in May 2013 called MobilePay, which can be used to transfer money from one mobile phone to another without the use of internet banking or exchange of bank account numbers. Within the first six months, more than 650,000 people have downloaded the app (Danske Bank, n.d. B). Today, there are maximum limits to the amount of transfer on a daily and an annual basis of 1,500 DKK and 50,000 DKK, respectively (October 2013). A technology similar to MobilePay named Swipp was introduced in June 2013 by a group of collaborating Danish banks including Nordea, Nykredit, Arbejdernes Landsbank, Spar Nord, Sydbank, Jyske Bank and a number of local banks (Swipp, n.d.).

Mobile payment using custom apps covers a very broad range of solutions, including the electronic payment solution provided by iZettle, which is aimed at small shops or stores as a simple and cheap alternative to conventional payment terminals. The iZettle solution replaces traditional credit card payment terminals by a mobile unit such as an iPad, iPhone or android with iZettle's app installed, thus allowing payment via credit cards (iZettle, n.d.; Olesen, 2012). Authorisation of the payment takes place via signature, no PIN code is required. Card details can be entered into the system manually or by use of a plug-in card reader for the mobile unit, which contains the global standard for authentication of debit and credit card transactions. The first iZettle service was launched in Sweden in 2011 and is now available to individuals and small businesses in nine countries including the Nordic countries. The receipt is typically e-mailed to the customer (see also section 5.2.3 on electronic-receipts below) and the payment solution will thus reduce the number of printed receipts. A printing unit may, however, also be combined with the iZettle technology.

Mobile web payments is a mean to connect to the internet and then pay by entering credit card details on the company website, or pay using an online payment method such as PayPal (PayPal, n.d.) or an electronic wallet (NETELLER, n.d.; Google Wallet, n.d.). The technology uses the Wireless Application Protocol (WAP) facility to access the internet. Online shopping is increasing globally, and today virtually all commodities can be purchased online. This type of shopping inherently employs electronic receipts that are typically sent to the customer via e-mail or to a registered account that is available via login. It should be emphasized, however, that while online shopping eliminates the issue with BPA-containing receipts, it may transfer the problem to BPA-containing labels used for tracking and shipping of the purchased items (communication with reference group). Some of the labelling may be performed automatically and the consumer exposure to BPA may be reduced, but the environmental and occupational exposure to BPA may still be an issue. Technological alternatives to labelling applications of thermal paper is considered outside the scope of this project and proof of purchase for online shopping will be categorized as electronic receipts in the context of this project.

Near Field Communication (NFC) is a technologically more advanced mobile payment form currently receiving a lot of attention. NFC employs a set of standards for smartphones and similar devices to establish communication based on radio-frequency electromagnetic fields between two endpoints by bringing them into close proximity. Today, the technology allows two-way communication between the devices and the technology can be used for contactless transactions and data exchange. This can be utilised in a way so that a mobile payment can be performed by holding the NFC device, such as a mobile phone, close to another device which functions as a cash register. Communication is also possible between a NFC device and an unpowered NFC chip, a so-called "tag". For instance, an NFC-scanner integrated in a POS enables communication between a smartphone or similar devices containing a NFC chip, thus facilitating electronic payment and receiving of receipt.

In the Danish project named "Fremtidens penge", the test users could do grocery shopping in a supermarket set-up using a mobile phone with NFC-technology to scan prices displayed as bar codes and then proceed to a self-service POS terminal with an integrated NFC-scanner and a touch screen providing guidance (Stefánsdóttir et al., n.d. C). The scanner would instantly read the consumption and the customer was charged via the mobile phone. Most of the test users found the NFC-based payment form faster and simpler than traditional payment using credit card or cash. Importantly, however, in two other test scenarios (cinema and parking) where payment options included SMS, QR code and NFC technology, most test users chose the more well-known SMS payment as a first solution, or alternatively the QR code solution. Some even had to be persuaded to try using the NFC-based payment form. By the end of the test, however, more than 90% of the test users actually preferred the NFC solution (Stefánsdóttir et al., n.d. A; Stefánsdóttir et al., n.d. B). This indicates a consumer barrier that needs to be addressed in order for the NFC technology to gain a wide acceptance. Regarding safety, most test users preferred using a PIN code as this is known from credit card payments and is thus perceived safe and a "necessary evil" while at the same time most preferred as few steps as possible for increased flow during payment. A majority of the test users found that a central feature of the payment form is the potential for helping the user to keep track of receipts and expenses. Collecting and storing printed receipts is generally regarded as a constant source of frustration (Stefánsdóttir et al., n.d. C).

One limitation for the spread of NFC-based payments today is the lack of built-in NFC technology in Apple's iPhone. However, developments to overcome this limitation have started to dawn (Dyer, 2013; Gottipati, 2013).

5.2.2 Contactless smart card payment

Contactless smart card payment is based on a wireless non-contact data transfer using radio-frequency electromagnetic fields for communication between a card reader and a chip embedded in a so-called smart card. The radio-frequency identification (RFID) technology is often the technology employed by contactless smart card communication and is used globally as a payment technology for "ticketless travel". In Denmark, users of public transportation can travel without a paper ticket by use of the Rejsekort, which was introduced on the market in 2008/09. The travel fare is deducted from a prepaid account, which can be followed via the internet, and the account status is also displayed on the card reader by the end of the journey. The number of Rejsekort issued in Denmark today is around 0.6 million and it has been used for a total of 32.7 million travels (by September 2013) (Rejsekort, n.d.). The ticketless travel technology was initially introduced in South Korea in 1995 (Upass), followed by Hong Kong in 1997 (Octopus card). In Europe, The Oyster Card was introduced in London in 2003 and the OV-chipkaart in the Netherlands in 2005. Today, the Octopus card – in addition to payment for transportation – can be used also for payment of parking, at retail outlets, self-service machines, leisure facilities and schools, as well as for online purchases (Octupus, n.d.). The RFID technology is well-established and considered an off-the-shelf product. The basic functionality of the Rejsekort is rather simple and the system replaces a number of different tickets, simplifying travel with various public transportation means. However, difficulties in obtaining an overview of the price and discounts plus delay in registration of online money transfer make the Rejsekort less user-friendly (Sørensen, 2013A; Sørensen, 2013B). Additionally, the use of the Rejsekort also requires some change in habits as the user must remember to check in at each change of transportation means and not the least remember to check out by the end of the journey. For some elderly people and people without a technological outlook, the use of smart card payments may be viewed as difficult and may require some barrier mitigation efforts.

It is possible to spread the technology to include other sectors besides transportation, as it has been done in Hong Kong with the Octopus card (Octupus, n.d.). However, the technology is expected to face high implementation and developmental costs, a long time to market for new sectors and high consumer barriers. Consumer barriers will vary depending on sector but include uncertainty for the consumer due to complexity and lack of transparency of pricing (e.g. no user interface to see discounts), and change of consumer habits. Due to the complexity of the system, several approaches may be required in order to mitigate barriers, for instance information campaigns for consumers (e.g. to offer introduction and training in using the card), consulting and sharing experience with other countries (or sectors) where the system is already in use, and specific discounts (e.g. applied by the Rejsekort). The technology is interesting as a payments means that could act as a substitute for paper receipts/tickets. However, in a Danish context with e.g. an existing well-integrated national payment form such as the Dankort, the mobile payment technologies are considered of primary interest and contactless smart card technology as secondary.

One card to cover several sectors would be preferable and contactless smart card solutions are now becoming available across Europe from payment card companies such as Visa Europe (PayWave, introduced in 2007), MasterCard (PayPass, introduced in 2005) and American Express (ExpressPay, introduced in 2005) (PayWave, 2013; PayPass, 2012; ExpressPay, n.d.). Today these contactless smart cards are used as the conventional payment cards at a physical terminal and with proof of purchase as a paper receipt thus having no direct influence on the use of thermal paper receipts. The option of electronically stored receipts could however become available in the future.

5.2.3 Electronic receipts

E-receipts are basically electronic receipts sent from the store directly to a customer's e-mail address or to a password-protected web-site. The technology can be managed by a merchant himself simply by asking the customer for an e-mail address (see also the iZettle mobile payment solution described in section 5.2.1). However, e-receipt companies (with point-of-sale partners and payment solution partners) are also emerging all over the world that offer to manage the system for shops and customers that sign up. When a customer signs up, he/she adds debit and credit card details and when purchasing from stores signed in for the service, the receipt is automatically sent to the customer in digital form. The technology is well established in and outside of Denmark and it does not require a habitual change for the consumer as the payment is based on the traditional payment card. On the down side, there is currently a lag time from purchase to receiving the e-receipt, which may be between 5 min and 12 hours depending on the store and the system employed (personal communication). This, in addition to the cost of subscription to some features of the service, may limit the spread of use. Furthermore, (mis-)use of e-mail addresses by merchants to send promotional e-mails is a potential nuisance for the consumers and for the merchant/shops and the system demands continuous updating when customers' e-mail addresses change. The systems provided by e-receipt companies cannot be used for cash payment and the necessity for sharing credit card details on registration with e-receipt companies may also be of concern to some users.

5.2.4 Receipt handling options

A number of means to minimize the handling of receipts have been implemented (or are being tested) in various shops, in particular with the aim of reducing the exposure to BPA of the employee working at the cash register. Alternative technologies within receipt handling options include:

- Placing the receipt printer so that customer picks up the receipt
- Self- service check-out registers
- Giving the customer and/or cash register attendant a choice of not printing out the receipt

Placing the receipt printer so that it directly faces the customer has been implemented in some grocery shops in Denmark. Generally, a physical solution like this is rather low-tech but may impose some implementation costs. The solution will reduce the contact with BPA-containing receipts for the most exposed (e.g. the cash register attendant at the supermarket), while the exposure for the consumer may be unchanged. Also, the environmental exposure to BPA may not be affected by this solution as the receipt in many cases is automatically printed even if the customer does not wish a receipt.

Self-service check-out registers have become available in some supermarkets, chain stores and do-it-yourself timber and hardware shops in Denmark. These reduce either the need for a printed receipt or the daily handling of a multitude of receipt for employees. Implementation and maintenance costs may theoretically be balanced by a faster customer service and fewer employees working at the cash register. The solution will reduce the handling of BPA-containing receipts for the most exposed (the cash register attendant), while the exposure for the consumer may be unchanged since a paper receipt is still printed at most self-service terminals. However, the latter could eventually be optional if such registers are provided with a customer choice option regarding print of the receipt.

Giving the customer and/or cash register attendant a choice of not printing out the receipt is another option. Today, Danish costumers are regularly faced with the question if he/she wants a receipt. Often the receipt is printed regardless of the answer, but technological solutions are available where receipts are only printed if desired by the customer. For everyday necessities or small purchases, a receipt may not be required, but for many types of purchases, the receipt functions as a warranty that is required for later return or complaints (In some countries, e.g. to avoid VAT fraud, it is required by law that a physical receipt is provided, even for a cup of coffee.). Further, in supermarkets, people tend to ask for a receipt in order to validate that the number and price of purchased items are correct and that any discounts have been deducted/registered. Hence the choice of no receipt will only be acceptable in some situations, but may in these cases reduce the contact with BPA-containing receipts for both cash register attendants and the consumer. Also, the environmental exposure to BPA may be reduced by this solution since less BPA containing thermal paper will be used.

5.2.5 Receipt top coating

Thermal paper can be produced with the addition of a top coat applied on top of the thermal coat creating a physical barrier between the chemical substances in the thermal coat (e.g. BPA or bisphenol S) and the consumer/cash attendant, see Figure 1. The function of the top coat is to extend the quality/durability of the print by making the thermal paper more resistant to mechanical, chemical and environmental influences (as described in section 3). Potentially, a top coat may also reduce the direct human exposure to BPA/Bisphenol S during thermal paper handling and is therefore considered as a technology with a potential for reduction of human exposure to BPA or other alternative chemical substances used in thermal paper. However, the migration barrier properties of a top coat should be investigated as well as potential toxicological issues relating to the top coating material itself. In addition, top coating increases the price of thermal paper and the increase in paper thickness results in a need to replace paper rolls more frequently, which makes this potential solution less attractive. In fact, the trend is going towards thinner thermal paper in order to reduce paper consumption, cost of storage/transportation and paper roll replacement. In addition, the environmental exposure to BPA is also not reduced by addition of a top coat as a potential means of reducing human exposure to BPA. To the best of our knowledge, top coating is not being used with the intention of reducing the human exposure to BPA and as mentioned earlier, top coated thermal paper is not, according to the thermal paper manufacturers, commonly used for POS receipts today (see Chapter 3).

5.2.6 Alternative printing technologies

Alternative printing technologies may include thermal transfer printing, impact printing and laser printing. They all require either ribbons, ink or toner cartridges and have more moving parts, and are thus slower and more service demanding, generally making these technologies less attractive alternatives to thermal paper printing (US EPA, 2012). The Imaging and Printing Association (I&P Europe) also confirms that alternative printing technologies that could replace the use of thermal paper are not a focus area for their members (Personal communication). Similarly, it was also the common opinion amongst the members of the reference group of this project that these technologies are historical rather than future options. Consequently, it was agreed that these technologies will not be addressed further in this report.

5.2.7 Selection of alternative technologies for further study

Some of the identified technologies are expected to have a great potential for growth in the coming years while others are either out-dated or seen as too immature, too demanding from a technological point of view, or have too high a barrier for immediate and broad consumer accept to gain any significant market share within the next few years.

Technologies that will not be treated any further are:

- **Contactless smart cards**. Although a promising technology, it is considered to be of limited use outside of the transportation sector in Denmark, partly due to existing payment methods and due to high cost and complexity of implementation as well as an expected long time to market.
- **Top-coating of thermal paper**, since the intended purpose of this technology is not the formation of a barrier in order to reduce migration of chemical substances. No literature is available on the barrier properties of the surface coatings used today and the market share of top coated thermal paper for receipts is assessed to be very low (due to price and a trend towards thinner paper)
- **Alternative printing technologies**, since these are considered out-dated.

The technologies considered to be of high potential interest with respect to the scope of this project will be evaluated further in the following section. The selected technologies will be described in greater detail and information regarding criteria such as cost, estimated current market share, trends in use and development, technological barriers and experience as well as barriers for and experience with consumer accept. The technologies selected for further study are:

- **Mobile payment solutions, specifically the use of apps**. Many Danes are already well acquainted with apps in general and inclusion of a payment step in some apps may seem as a natural next step to some consumers. Thus, payment via apps appears to be a technology with potential for fast market establishment and with a broad market potential. The often simple user-interface makes proof of purchase easily available for the consumer depending on the design of the app. The app technology may provide the fastest mobile payment solution that will reduce the use of paper receipts, at least until other more complex mobile payment methods like NFC reach maturity. Certain aspects of the NFC technology and its potential uses in the context of this project will be mentioned in connection with other technologies.

- **E-receipts**, since it is a simple means of directly substituting paper receipts. The technology can be rather simple and it does not require that the consumer is technologically adept. Also, it is built on the traditional credit card payment system, thus not requiring a huge change in consumer habits. The technology already exists on the Danish market (as well as on the global scene) and could, therefore, rather quickly be able to replace paper receipts if certain technological barriers and consumers barriers are overcome.

- **Handling options** including self-service registers and different approaches to reducing the physical handling of thermal paper receipts by employees and consumers, since they are relatively inexpensive, low tech, short-term solutions that will reduce human exposure to BPA from thermal receipts, at least for cash register attendants that are the most exposed. However, contrary to the two other selected technologies, some of the alternative solutions in this category may not have an effect on the environmental exposure to BPA from paper receipts.

5.3 Further evaluation of prioritised alternative technologies

The prioritised/selected technologies (mobile payment, electronic receipts and receipt handling options) represent solutions with the potential of replacing the paper receipt or at least the human exposure to BPA. They range from low to high tech solutions and they are at different stages in development and commercial use, with cost of development and implementation also reflecting this. Their usability also covers different shop requirements in terms of size and market sector. As a whole, the various solutions may be seen as a patch-work of solutions satisfying various needs on the market. Some of them can be implemented already today while others within a few years. Some may serve as temporary solutions that can be implemented in order to aid in the process of eliminating thermal paper receipts while others represent more long-term solutions. In this section, cost and maturity, market share and trends, and barrier and barrier mitigation is described for mobile payment via custom applications, electronic receipts and the different handling options, respectively.

5.3.1 Mobile payment via custom applications

Mobile payment technologies as such display a strong growth globally. The technology reduces the human as well as the environmental exposure to BPA through a reduction in the need for thermal paper receipts since proof of payment in almost all cases will be in electronic form. Some of the technological solutions are fully developed and well integrated already such as payment by SMS and this technology is of relative low cost and with few barriers for consumer accept. However, this payment form used to be limited to low-value purchases as the cost could only be charged over the phone bill. Today, SMS purchases of goods and services may also be charged directly from an account associated with the mobile phone via “Mobilpenge” (Mobile money) and using this solution, a maximum daily expenditure of 1,500 DKK is possible (Mobilpenge, n.d. B). Payments by use of QR codes or via apps are more recent phenomena. The app technology is quite developed in particular with regard to in-app payment and thus some consumer experience and acceptance are already gained. The NFC technology shows great potential but is the most technologically demanding and also seems to be the most immature of the mobile payment technologies. The cost of development and introduction of the technology is relatively high and the consumer may have barriers towards the technology due to its technical complexity and (a sense of) potential security issues. The issue of security is a general concern for most if not all mobile payment technologies and they may need to be addressed in order to overcome barriers for a wider consumer acceptance. Payment via apps appears to be a technology with potential for fast growth and with a broad market potential and focus will be on this particular area of mobile payment in the following.

MobilePay

After downloading the app MobilePay, the user has to state name and credit/debit card details (including safety digits) and choose a four digit code that must be used every time the app is accessed.

A transaction using MobilePay requires only a few steps:

1. Open the app using your personal four digit security code
2. State amount to be transferred and the mobile phone number of the recipient
3. Check that the recipient's name and phone number is correct and accept the transfer

5.3.1.1 Market share and trend – custom apps

Apps are well-known to most smartphone users for instance to check time schedules for transportation, check up on news or the weather forecast, playing games, find opening hours of a store, finding food recipes and much more. Apps are also emerging as payment solutions, in some cases as an obvious next step to the existing apps for instance within the transportation sector (apps such as DSB Billet, Movia Mobilbilletter, Easypark and Mols-linien) or for buying tickets within the entertainment sector (apps such as those available for several cinemas or for music events supplied by ebillet (e-tickets)). A range of other single in-app payment solutions are appearing on the Danish market: Click A Taxi (Dilling, 2013), MobilPorto (mobile stamps) (Post Danmark, n.d.) and Zerved (Zerved, n.d.) (for ordering and payment of food and drinks).

In May 2013, the app Mobilepay from the Danish bank, Danske Bank, was introduced as part of a transition towards the cashless society, allowing easy and fast money transfer between people (see fact box) (Danske Bank, n.d. A). Using the app, a transaction can be made simply by knowing the phone number of the recipient, i.e. it does not require exchange of account numbers. The transfer of money is apparent to both parties immediately; the receipt for transfer appears in the app as soon as it is made. It is expected that the next MobilePay developmental step will include mobile payment in shops (Thiemann, 2013). A small-scale usability test of the app for payment of low-value purchases such as coffee, fast-food and taxi fares was initiated in October 2013 (Andersen, 2013). Later this year, the app is expected to cover general shop purchases in shops that sign-in to offer the technology (Danske Bank, n.d. A). The app will thus aid to eliminate the requirement for printed receipts. The MobilePay app appears to satisfy the expressed wish for an app combining the payment process for a number (of related) purchases (Fremtidens Penge, n.d.).

The introduction of MobilePay also revealed a huge interest in mobile payment technology in Denmark: approximately 650,000 people have downloaded MobilePay within the first six months of its introduction (of which 57% are not customers in Danske Bank), more than 12,000 transactions are performed on a daily basis, and the total sum of transactions amount to more than 150 million DKK. At introduction, approximately two thirds of the down-loads were performed by males whereas today, the users are almost equally distributed between genders (54% male and 46% female users). The oldest user is 94 years old (Danske Bank, n.d. B).

Today, the app is free of charge, but from 2016, a fee will be charged for users that are not costumers in Danske Bank. In June 2013, a number of banks in Denmark have joined forces and introduced a similar mobile payment system, Swipp, specifically for their customers (Swipp, n.d.).

5.3.1.2 Cost and maturity – custom apps

Mobile payments are at quite an advanced stage in Denmark compared to many other countries due to a high number of smartphone users (Kielstrup, 2013). The willingness of Danes to embrace new payment technologies was also confirmed by the project “Fremtidens penge” (Fremtidens Penge, n.d.). However, as the existing payment systems are generally quite well-functioning, cover most needs and are considered safe, there is less of an incentive to change to other payment technologies (Skou, 2011). Thus, the test users of different mobile payment technologies (SMS or app-based QR codes or NFC) in various test scenarios (e.g. payment for groceries, cinema tickets, or parking) generally expect “something extra” in order to change to new payment forms. This could be saving time or money, avoid queuing up or getting extra services. The test users specified that the use of new technology definitely cannot leave the users worse off compared to users of traditional payment forms, for instance in relation to cancellation of tickets and time of money refund (Stefánsdóttir et al., n.d. A).

There will be costs associated with each new app to be developed. Requirements for the functionality and the design of the app are essential for the cost and the price range for developing a customised app is therefore broad. The price range could be anything from DKK 20,000 (approx. EUR 3,000) for a very simple app to several hundred thousand DKK for a more complex app with many complex in-app functions (Bytelab A/S, 2012).

5.3.1.3 Barriers and barrier mitigation – custom apps

Generally, users appear quite positive towards in-app payments due to a typically well-known and simple user-interface plus a sense of flow, speed, simplicity of payment and easy accessible proof of purchase. In-app payment solutions also give a sense of spontaneity to users, since purchases can be made anywhere and anytime via smartphones and other devices (Fremtidens Penge, n.d.). Concerning barriers for consumer acceptance issues such as safety and return of tickets/purchase can be mentioned. Additionally, test users of mobile payment technologies in the project “Fremtidens penge” also feared that they would end up with too many unique apps (e.g. one for every single cinema). There appeared to be a request for apps with a broader coverage, and a common user interface for a number of similar purchases (Fremtidens Penge, n.d.). The newly introduced app, Mobilepay, from Danske Bank may partially serve these needs.

The test users of various mobile payment technologies in the project “Fremtidens penge” generally expected some type of reward when using a new technology instead of the conventional payment methods. It was also clear in the consumer’s minds, that new technology should perform at least as good as the traditional payment forms regarding services such as money refunds and cancellations.

The issue of safety is also a general concern amongst the test users, in particular when the app requires storage of credit/debit card details. Most prefer the use of a personal security code such as the PIN code known from traditional credit card transactions or a log-in with password – or even both - in order to accept the payment. The request for a PIN code is also regarded as a nice reminder that the user is about to perform a money transfer and not simply browsing various options via the app. The test users also point out that the requirement of a PIN code will reduce the risk of misuse of payment apps if a phone is stolen – or if children are playing with a phone. One common drawback mentioned regarding PIN codes is the break of flow in the payment process, increasing the time of payment. The general lack of knowledge about the technology behind mobile payments adds to the feeling of the technology being unsafe (Fremtidens Penge, n.d.).

For the elderly, the internet/mobile apps are often regarded as unsafe, although this is beginning to change with more elderly users embracing new technologies (Personal communication). Learning how to use the new technology generally takes more time for this group of users and some cannot be bothered to get acquainted with new technology if they will only use it rarely, such as a cinema app (Stefánsdóttir et al., n.d. A). In order to mitigate this type of barrier a personal introduction to the technology could be offered. This approach is used in the introduction of many new technologies (e.g. self-check-in counters in the airport, self-service registers in supermarkets).

Another general barrier for acceptance of mobile payment technologies by consumers is a worry of how to deal with an interruption or lack of network connection, in particular if the connection is lost during a transaction (did the transaction go through, was documentation received). Similarly, the phone may run out of battery which is a highly relevant concern both with respect to an inability to perform a purchase as well as to prove a purchase of e.g. tickets (Fremtidens Penge, n.d.).

Barriers towards mobile payment technologies may also exist among merchants/shop owners. One respondent of our questionnaires replied that consumer interaction was an important aspect for them and high-tech solutions for the payment situation did not fit with their segment of consumers (personal communication). Thus, some shops may not wish to be first movers and might implement new payment technologies only when it is well-established among most consumers - or at least the majority of consumers within the relevant segment. A cost issue may also form a barrier for merchants/shop owners, since development of an app can be a costly affair depending on the requirements to functionalities and design.

A number of steps can be taken in order to mitigate consumer barriers when it comes to mobile payments. To overcome barriers for consumer acceptance, the knowledge of the user segments and its preferences will be essential because the best approach to barrier mitigation will depend on the type of app and the target group in question. Typically, a detailed knowledge of the expected consumer group will be helpful in balancing criteria such as easy of flow and convenience against safety and the feeling of security when using in-app payment. Also, a simple and user-friendly interface is preferable, but the design may be challenged if the purpose of the app calls for a multitude of functionalities (including more than just a new way of paying).

5.3.2 Electronic receipts

Electronic receipts sent from the store directly to a customer's e-mail address or to a password-protected web-site can be managed by a merchant himself or via e-receipt companies. Today, an electronic receipt is a natural part of on-line shopping but it has also become available for purchases done in physical shops around Denmark (e.g. receipt solutions supplied by e.g. "e-kvittering" and "kvittering.dk").

The introduction of electronic receipts as replacement for paper receipts should reduce both the human and environmental exposure to BPA from thermal paper since the paper receipts, at least in theory, becomes obsolete.

5.3.2.1 Market share and trend – e-receipts

The market share is potentially quite big as keeping track of paper receipts appears to be a constant source of distress to many people (Fremtidens Penge, n.d.). Typically, the e-receipt companies work on a national basis with players such as e.g. Xpenser.com in the US (since 2008) and eReceipts in the UK, the latter displaying a receipt counter reading of more than 9.5 million receipts (eReceipts, n.d.). In Norway, dSafe.no has more than 2300 merchants signed up (dSafe, n.d.). In Denmark the market is not yet as advanced, but companies such as kvittering.dk and eKvittering.dk exist, the latter offering electronic receipts to customers shopping in 17 different shops or chain stores (eKvittering, n.d.).

Electronic receipts are also generated by the payment service provided by iZettle. iZettle offers a simple and relatively cheap solution for accepting credit card payment to small shops or individuals by use of an app installed on a mobile device. The device is simple to use and is operated by the shop keeper and will not put high demands on the technological skills of the consumer. However, the bill is sent to the consumer's mobile device, and he/she must therefore be able to access the internet via the mobile device in order to confirm the payment. The receipt will typically be sent as an SMS or by e-mail but a printer may also be coupled to the iZettle payment service. (iZettle, n.d.)

In addition to the solutions that already exist on the Danish market, some new ideas that specifically aim at providing customers with e-receipts directly on their smartphone also needs mentioning. These include generation of an e-receipt at check-out by 1) scanning a 2D bar code that is generated on a POS screen facing the customer, to directly pick up the receipt data or 2) NFC-transfer of receipt information contained in an NFC tag which the user touches with the smartphone. Once the receipt has been received by either method, the digital receipt indicates on the smartphone which products have been bought, in what quantity and for what price. In addition, extra value can be contained in this type of electronic e-receipt such as information of purchased goods (e.g. description, nutritional information, related product recommendation etc.). The idea is that the added value of this type of electronic receipts will drive adoption of the mobile payment technologies (Ho et al., 2013). As described previously, the pay function itself may also be performed by the use of either QR code or NFC technology.

5.3.2.2 Cost and maturity – e-receipts

Digital or electronic receipts (e-receipts) have gained a wide acceptance since Apple introduced the concept in its retail stores in 2005 and the market is increasing (Koch, 2012).

The existing e-receipt solutions are generally not amongst the most expensive alternatives in terms of development, implementation and use. E-receipt companies charge shops that sign in for the service. Consumers may have the option of free access to basic functionalities of the electronically stored receipts, whereas they may be charged a fee in order to obtain full functionality of the service, including organizational and search functions. Challenges with integration of the new technology with existing payment systems have been dealt with and development continues. One technological obstacle, however, is the lag time from purchase of goods to access of the e-receipt, which, depending on the set-up, may be rather high (from 5 minutes to 12 hours). According to an e-receipt company, the lag time is due to the nature of the cash register system in the shops that sign-in for the service (personal communication). These lag times need to be dramatically shortened for this technology to replace paper receipts in situations where the receipt is required (e.g. to check the price and deduction of discounts) in particular when purchasing many items such as when doing grocery shopping.

In the case of iZettle, the new app is developed as a payment terminal for use by small shop owners, temporary stalls on festivals or similar entities where payment is needed. The implementation costs are quite low since the solution basically only requires a mobile unit as point-of-sale and registration at iZettle who then charges a fixed fee for every transaction being made.

The generation of an e-receipt at check-out by means of QR code/NFC scanning will require some initial implementation costs for the shops. This solution will require implementation of a device which can either display the QR code or communicate using NFC in order to transfer the receipt to the customer via their smartphone. If the consumer owns a smartphone, the technology should be free of charge to the consumer. No specific examples of the technology being used in Denmark have been found during this survey.

The (initial) expenses for shop owners that wish to employ an e-receipt technology would often, at least to a certain extent, be balanced by reduced expenses for purchasing paper rolls for receipts.

5.3.2.3 Barriers and barrier mitigation – e-receipts

Automatic delivery of an electronic receipt by e-receipt companies such as e-kvittering and kvittering.dk after purchases using a conventional credit card (e.g. Dankort) is a very simple solution for the consumer. When the card details are given, the purchases can be performed exactly as before and no other change in consumer behaviour is needed. However, barriers for consumer accept may include the dislike of giving credit/debit card details to e-receipt companies. Also, users may fear what happens to their proof of purchase if the company closes. The issues of keeping receipts in a safe place for long-term storage is also relevant for the QR code/NFC scanning solution as a mobile phone may be lost or stolen or stop functioning. Thus, this solution might require the option of sending the generated e-receipts to an electronic storage space. Still, the question is if consumers have trust in that documentation cannot be lost from various electronic storage places.

The lag time from purchase of goods to possible access of the e-receipt from e-receipt companies, may be another barrier for broad consumer acceptance. The problem of lag time does not exist with the POS scanning of a QR code/NFC tag, where receipt information is transferred directly to a mobile device.

5.3.3 Receipt handling options

As a part of this project, questionnaires were sent to a number of major stores and chain stores in Denmark, including questions on which (if any) alternative technologies were in use that would decrease the human exposure to BPA. From the responses, three handling solutions were in use today: Placing the receipt printer so that customers pick it up, self-service registers, and giving the customer the choice of saying “no thank you” to the receipt. The first two solutions will primarily decrease the exposure of the cash register attendant to BPA, whereas the third solution may have the potential to reduce all human as well as environmental exposure to BPA. The options can be regarded as low-tech technologies and are more or less ready for implementation on the marked. The three options covered differ in many aspects.

5.3.3.1 Market share and trend – receipt handling options

In at least two major grocery store chains in Denmark, a physical change has recently been made so that the receipt is printed next to the costumer, thus eliminating the need for the check-out assistant to handle the receipt.

In some supermarkets, chain stores and do-it-yourself timber and hardware shops in Denmark, self-service check-out registers have become available. These reduce the daily handling of a multitude of receipt for employees. Self-service check-out was introduced in the grocery chain Netto a number of years ago in order to make the payment process faster and more efficient, but was removed again after a couple of years. Costumers requested a serviced register next to the self-service systems and it was concluded that the market was not yet mature for this type of technology. Also, the price per transaction was found to be much higher for the self-service check-out compared to traditional serviced check-out (Andersen, 2012). The market potential for this solution in other types of shops might be limited as one respondent of our questionnaires replied that consumer interaction was an important aspect for them, and self-service check-out would, therefore, not be an option (Personal communication).

The choice of opting out of a printed receipt is given quite often in Danish shops today. However, in many cases the receipt is being printed in any case and in that case only the consumer will be less exposed to BPA but this is not the case for the cash register attendant and the environment.

5.3.3.2 Cost and maturity – receipt handling options

There will be a cost of implementation, but for most of the handling options covered here, the technologies are considered off-the-shelf/low-tech solutions and much simpler technologies than e.g. most mobile payment technologies.

Placing the printer towards the consumer may require investment in new technology and may also require a physical change in the location of equipment used today that can be associated with a cost.

Self-service registers will require space, cost of implementation and a change of habits for the consumer.

Cash registers today are most often set-up to automatically print the receipts. Changes to the underlying system behind the cash register may be required in order for it not to print or a new cash register and/or system might be needed. Only very few examples are seen on the choice of not printing the receipt at all.

5.3.3.3 Barriers and barrier mitigation – receipt handling options

Placing the receipt printer towards the consumer only requires a minimum of change for the consumer and very low consumer barrier is anticipated for this solution.

Self-service registers are considered a much larger change for the consumer. To some consumers, an added benefit in return for the reduction in service is expected, for instance a faster check-out time, discounts or additional information on products or prices (Fremtidens Penge, n.d.). To some consumers, especially the elderly, new technology can be intimidating and measures such as personal introduction and support can be included in the implementations strategy to accommodate this group of consumers.

The option of not getting a receipt is only acceptable to some consumers and in some situations. For instance, many people like to check the receipt after grocery shopping for number and price of items and correct deduction of discounts. In other situations, the receipt is important as documentation or proof of purchase and must be presented to the shop in case of return of goods or repair within the warranty period.

5.4 Discussion/Summary

Table 11 shows an overview of the identified alternative technologies. The table lists the pros, cons and possible ways to mitigate barriers associated with each of the technologies. The primary driving force for development of most of the identified alternative technologies is not the intention to reduce the use of BPA or to reduce of paper receipts in general. The development of most technologies is rather a consequence of a transition to a cashless society, where more and more purchases are done electronically and without the exchange of actual money. The reduction or elimination of the paper receipt is only a side-effect of this transition.

TABLE 11
SUMMARY OF PROS AND CONS OF ALTERNATIVE TECHNOLOGIES TO THERMAL PRINTING

Technology	Pros	Cons	Possible ways to mitigate disadvantages
Mobile payment			
SMS text	Strong global increase Can be used on all mobile phones Simple, well known and well established technology Relatively low consumer barrier and cost	Primarily low value purchases accepted Slow process since messages back and forth is required to get price, accept purchase and get receipt Feeling of low security when using new technology	Reduce number of sms'es per purchase (but also reduces security) More promotion activities Provide training / help
Custom apps	Strong global increase, apps are popular and the app market booming Can be used on any mobile device (smart phone, tablets etc.) Often a very simple interface for purchase and receipts	A need for dedicated (may be expensive) development for each new app Typically apps only cover one type of purchase (e.g. cinema ticket or parking ticket) and a range of apps are needed Habitual change considered medium since apps (in some form) are known to most consumers today Feeling of low security when using new technology	Design app to accommodate consumer group preferences Make user interface as simple as possible Promotion activities Provide training / help
NFC technology	Strong global increase NFC technology is built into many smart phones today Contactless, but not over long distances	High requirement for further development Cost of devices for communication Complex technology NFC not currently built in to iPhones No/Low experience in Denmark Feeling of low security when using new technology Habitual change since NFC requires close proximity but no actual contact between devices	Keep it as simple as possible Make it broadly applicable (many sectors) Include PIN code confirmation to increase feeling of security Promotion activities Provide training / help

Technology	Pros	Cons	Possible ways to mitigate disadvantages
Contactless smart card payment	Strong global increase, especially within transportation sector but also with respect to payment cards Established technology but developmental work needed for introduction to new sectors	High requirement for further development Cost of devices for communication Could result in an additional card in the wallet besides traditional payment cards (e.g. Dankort) Low experience in Denmark, but growing in EU Feeling of low security when using new technology Do not always eliminate paper receipts	Keep it as simple as possible Make it broadly applicable (many sectors) Include PIN code confirmation to increase feeling of security Promotion activities Provide training / help Add e-receipt possibility when introducing the technology
Electronic receipts	Technology available on the market today E-receipt companies cover a range of shops Store can maintain their own system of registered customers (also on-line shopping) No change in habits during purchasing is needed (except when checking your receipt)	The lag time for receiving the receipt through the system can be long (not possible to check prices, discounts etc. at the store) Registration of personal information and credit card details is needed Consumer may have to pay for some parts of the service provided (subscribe) Uncertainty regarding the access to receipts in the future (stability of companies)	Reduce lag time by investing in updated systems supporting the new technology Secure storage of receipts in the future Promotion activities Provide training / help

Technology	Pros	Cons	Possible ways to mitigate disadvantages
Receipt handling options			
Self-service check-out	Technology already on the market and in use in Denmark Decreases contact to thermal paper for store employees Simple user interface Most suited for purchasing few items Reduces staff	Habitual change needed Cost on implementation to be expected No extra benefit for the consumer (not even time saved) Feeling of low security when using new technology Do not always eliminate paper receipts	Reduce queuing by implementing a large number of terminals Promotion activities Provide training / help Add e-receipt possibility when introducing the technology
Printer facing customer	Decreases contact to thermal paper for store employees Implemented at many locations today Very little habitual change needed Low/no implementation cost Technologically simple	Cost can be associated with implementation Compared to electronic technologies: no reduction in the amount of thermal paper used Receipt typically still printed, so human and environmental exposure is not eliminated	Promotion activities Provide training
No receipt option	No receipt will reduce contact to thermal paper for customers and in some cases for store employees If no receipt is printed, a reduction in volume of thermal paper use will be possible (resulting in reduced cost etc. in relation to thermal paper use)	Receipt is needed for some purchases (for documentation of warranty or complaints) Implementing a "no printing" option to existing systems can be difficult and costly	Consider no printing option when updating systems Promotion activities Promotion activities Provide training

Technology	Pros	Cons	Possible ways to mitigate disadvantages
Other alternatives			
Receipt topcoating	Potentially a topcoat can form a barrier against migration of the developer in thermal paper, thereby delaying/reducing the human exposure No habitual change required	Increased production and in-use cost due to increased paper thickness, more frequent replacement of roll, added storage/transport Trends is going toward reduced paper thickness to reduce overall paper consumption Unknown effect of existing topcoat as barrier BPA exposure for manufacturers and the environment is not eliminated	Barrier properties of topcoat could be studied by migration tests to evaluate change in BPA exposure and release
Alternative printing technologies	No habitual change required	More moving parts - more maintenance Requires a ribbon, ink or toner cartridges in addition to paper roll Slower printing process Considered out-dated and inconvenient	Not relevant - outdated

Today, the technologies addressed in this project are used alone or in combination, and several of the technologies are provided for the same purpose to accommodate different customer types. The transition to technologies supporting a cashless society has been confirmed during the project. Although the development of such technologies looks strong and some technologies look very promising, the process of phasing out paper receipts entirely may be a slow process and the prospects of each technology is still considered uncertain.

The most promising technologies which are expected to have a significant effect on the reduction of paper receipts and tickets are mobile payments via apps (with in-app purchases and receipt handling) and automated electronic receipts handling systems (e.g. via apps such as offered by eKvittering.dk).

Using electronic payment forms and receipt handling is expected to have a positive effect in reducing the consumption of thermal printing paper, but today some electronic payment is still accompanied by a paper receipt as proof of purchase. Technologies like apps for handling e-receipts automatically exist (e.g. eKvittering), and already have the potential of reducing the amount of thermal paper used for receipts today, if the technology was properly embraced by users and shop owners. This has not yet happened, but the outlook is positive as the wide public becomes more and more familiarised with the use of mobile devices. Technologies like mobile payments via apps have the potential to develop fast and thereby result in a significant reduction in the use of paper receipts in the very near future, and other types of mobile payment might follow soon thereafter.

Solutions at cash registers that reduce the amount of paper used for receipts or that reduce the handling of thermal paper for the most frequently exposed group (the cash register attendants), can be implemented. But due to the rising popularity of the use of mobile devices and the associated technologies these solutions are expected to provide, “cash register solutions” are considered temporary solutions which are therefore less likely to be implemented, although they are expected to be associated with lower cost of introduction as compared with the electronic solutions.

Because the market for alternative technologies for replacing paper receipts is complex, the possibilities of barrier mitigation for the introduction of the new technologies are also diverse. The need for sharing knowledge on new technologies, promoting and training are main issues to be addressed for almost all technologies identified in the project. For mobile payment via apps, a simple design and user interface is important as a means of barrier mitigation, as well as an adequate balance between convenience and security depending on the size of purchase (no PIN/PIN required). For automated receipt handling systems the reduction of the lag time between purchase and delivery of an electronic receipt is a barrier which can be reduced either by choice/updating of the underlying systems or by introducing a means for direct scanning of receipts at the register (QR code or NFC tag). A segment among the elderly might not, or only very slowly, adapt to new technologies.

Danes are generally positive toward new technology and they are frequent owners of smartphones. Therefore, one might expect the growth of the mobile payment solutions to continue and that the consumer will gain knowledge and acceptance over time. A convenient payment system is already in place today (Dankort) and it is trusted and highly functional. This is expected to be one explanation why the growth rate of the alternative payment technologies in Denmark is lagging somewhat behind other European countries, but the trends are strong and this barrier is expected to be overcome within few years.

Phasing out paper receipts by using alternative technological solutions has potential as a strong development towards a cashless society is going on in these years. At present none of the technologies presented in this report can be considered mature enough to fully replace the paper receipt.

Abbreviations

app	Mobile application
BAF	Bioaccumulation factor
BCF	Bioconcentration factor
BPA	Bisphenol A
BTUM	4,4'-bis(N-carbamoyl-4- methylbenzenesulfonamide) diphenylmethane
CLP	Classification, Labelling and Packaging Directive
D-8	4-hydroxyphenyl 4- isoprooxyphenylsulfone
D-90	4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl]phenol
DSB	Danish Railways
EPA	Environmental Protection Agency
ETPA	The European Thermal Paper Association
EU	European Union
HPV	High Production Volume Chemical
I&P Europe	The Imaging & Printing Association
Koc	Soil Adsorption Coefficient
KemI	Swedish Chemicals Agency
MW	Molecular weight
NFC	Near Field Communication
PIN	Personal Identification Number
POS	Point-of-sale
PVA	Polyvinyl alcohol
QR	Quick Response
QSAR	Quantitative structure–activity relationship
RFID	Radio-frequency identification
SMS	Short Message Service
TDI	Tolerable Daily Intake
USD	United States Dollar
UU	Urea urethane compound
UV	Ultra-violet
WAP	Wireless Application Protocol

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NB: Manufacturer, personal communication
Information provided by telephone interviews with manufacturers of thermal paper and thermal paper rolls. The company names are kept confidential upon request from the manufacturers.

Appendix 1: Supporting information on properties of BPA and alternatives

TABLE A

HAZARD DATA FOR BPA AND 19 ALTERNATIVE SUBSTANCES IN THERMAL PATER. ASSESSMENT BY US EPA (2012) AND NOTIFIED OR HARMONISED EU HAZARD CLASSIFICATIONS ACCORDING TO CLP, SORTED BY EFFECTS (MODIFIED FROM US EPA 2012)

Substance	CAS No	Health effects											Environmental end points			
		Acute toxicity	Carcinogenicity	Mutagenicity/ genotoxicity	Reproductive	Developmental	Neurological	Repeated dose	Skin sensitizer	Respiratory sensitiser	Eye irritation	Dermal irritation	Aquatic acute toxicity	Aquatic chronic toxicity	Persistence	Bioaccumu-lation
Bisphenol A	80-05-7	L H302 (4)	M H350 (1B)	L H340 (1B)	H H361f* ** (2)	H	M	M	M H317 (1)	H335 (3)	M H318 (1)	M	H	H H411 (2)	VL	L
Bisphenol F	620-92-8	L	M	L	H^{VLQ}	H^{VLQ}	M	H	L H317 (1)	H335 (3)	VH H319 (2A)	M^{VLQ} H315 (2)	M	H H412 (3)	L	L
Bisphenol C	79-97-0	L^{VLQ} H373 (2)	M	M H341(2)	H^{VLQ}	H^{VLQ}	M	M^{VLQ}	M^{VLQ}	H335 (3)	H^{VLQ} H319 (2A)	M^{VLQ} H315 (2)	H	H	M	M
MBHA	5129-00-0	L^{VLQ}	M	L^{VLQ}	H^{VLQ}	H^{VLQ}	M	M^{VLQ}	L		M^{VLQ}	M^{VLQ}	H	H	M	L
BisOPP-A	24038-68-4	L^{VLQ}	M	L^{VLQ}	H^{VLQ}	H^{VLQ}	M	M^{VLQ}	M^{VLQ}		M^{VLQ} H319 (2A)	M^{VLQ} H315 (2)	L	H	H	M

Substance	CAS No	Health effects											Environmental end points			
		Acute toxicity	Carcinogenicity	Mutagenicity/ genotoxicity	Reproductive	Developmental	Neurological	Repeated dose	Skin sensitizer	Respiratory sensitiser	Eye irritation	Dermal irritation	Aquatic acute toxicity	Aquatic chronic toxicity	Persistence	Bioaccumu-lation
Bisphenol AP	1571-75-1	L^{VLQ}	*M*	L^{VLQ}	H^{VLQ}	H^{VLQ}	*M*	M^{VLQ}	M^{VLQ}		M^{VLQ} *H319 (2A)*	M^{VLQ}	*H* H400 (1)	*H* H410 (1)	*H*	*M*
Substituted phenolic compound, #1	Classified	L^{VLQ}	*M*	L	H^{VLQ}	H^{VLQ}	*M*	M^{VLQ}	M^{VLQ}		M^{VLQ}	M^{VLQ}	*H*	*M*	*M*	*L*
Substituted phenolic compound, #2	Classified	L^{VLQ}	*M*	L^{VLQ}	H^{VLQ}	H^{VLQ}	*M*	M^{VLQ}	M^{VLQ}		M^{VLQ}	M^{VLQ}	*H*	*H*	*H*	*H*
PHBB	94-18-8	L	*M*	*M*	*L*	*M*	*M*	*L*	M^{VLQ}	*H335 (3)*	VL *H319 (2A)*	VL *H315 (2)*	H	*H* *H411 (2)*	L^{VLQ}	*L*
Bisphenol S	80-09-1	L	*M*	M	M	M	*M*	H	L		L *H319 (2A)*	L	M	M *H412 (2)*	M	L
2,4-BPS	5397-34-2	L^{VLQ} *H302 (4)*	*M*	M H341 (2)	M^{VLQ}	M^{VLQ}	*M*	H^{VLQ}	L^{VLQ} *H312 (4)*		L^{VLQ} *H314 (1B)*	L^{VLQ} *H314 (1B)*	*M*	*H*	*M*	*L*

Substance	CAS No	Health effects											Environmental end points			
		Acute toxicity	Carcinogenicity	Mutagenicity/ genotoxicity	Reproductive	Developmental	Neurological	Repeated dose	Skin sensitizer	Respiratory sensitiser	Eye irritation	Dermal irritation	Aquatic acute toxicity	Aquatic chronic toxicity	Persistence	Bioaccumu-lation
		H332 (4)									*H319 (2A)*	*H315 (2)*				
TGSA	41481-66-7	L	*M*	L	M^{VLQ}	M^{VLQ}	*M*	M	H H317 (1)	M	L	VL	H	*H* H411 (2)	*H*	*L*
BPS-MAE	97042-18-7	L *H302 (4)*	M^{VLQ}	M	M^{VLQ}	M^{VLQ}	*M*	L	L	M	L *H319 (2A)*	VL *H312 (4)* *H315 (2)*	H	H	*H*	*L*
BPS-MPE	63134-33-8	L	*M*	M^{VLQ}	M^{VLQ}	M^{VLQ}	*M*	H^{VLQ}	L		L	L	VH	*H*	*H*	*M*
D-8	95235-30-6	L^{VLQ}	*M*	*M*	M^{VLQ}	M^{VLQ}	*M*	H^{VLQ}	L^{VLQ}		L^{VLQ}	L^{VLQ}	*H*	*H* H411 (2)	M^{VLQ}	*L*
D-90	191680-83-8	L	*M*	L	*L*	*L*	*M*	L	L		M	VL	*L*	*L*	*VH*	*H*
DD-70	93589-69-6	*L*	*M*	*L*	*M*	M^{VLQ}	*M*	M^{VLQ}	M^{VLQ}		H^{VLQ}	M^{VLQ}	*H*	*H* H411 (2)	*H*	*L*
Pergafast 201	232938-43-1	L	*M*	L	M	M	*L*	M	L		L	VL	VH	*H* H411 (2)	VH	L

Substance	CAS No	Health effects											Environmental end points			
		Acute toxicity	Carcinogenicity	Mutagenicity/ genotoxicity	Reproductive	Developmental	Neurological	Repeated dose	Skin sensitizer	Respiratory sensitiser	Eye irritation	Dermal irritation	Aquatic acute toxicity	Aquatic chronic toxicity	Persistence	Bioaccumu-lation
BTUM	151882-81-4	L	*M* H351 (2)	L	*L*	*L*	*L*	M	L		L	L	*H*	*H*	*H*	*L*
UU	321860-75-7	L	*M*	L	*L*	*L*	*L*	L	L		L	L	L	*L*¤	VH	L

Text and colour coding for Table A	**US EPA hazards**	**EU classification**
Red colour – very high hazard	VH- very high	Hazard categories 1 - (1, 1B)
Pink colour – high hazard	H - high	Hazard categories 2 - (2, 2A, 2B)
Blue colour – medium hazard	M- medium	Hazard categories 3 - (3)
Upright text - high quality data	Based on empirical data	Harmonised classification
Italicized text - low quality data	*Assigned using values from estimation software and professional judgement*	*Notified classification by industry*
Italicized text and VL Q- very low quality data	*Based on analogy to experimental data for a structurally similar compound*	

Hazard statements for hazard codes, see Table 2

Alternative technologies and substances to bisphenol A (BPA) in thermal paper receipts

The aim of the project is to identify solutions which reduce the exposure to bisphenol A (BPA) from thermal paper receipts. This includes investigating and assessing alternative substances as well as alternative technologies. The most frequently used alternatives to BPA in thermal paper receipts appear to be bisphenol S and Pergafast. Based on: i) migration findings of this study, ii) absorption and exposure considerations and iii) considering readily available information on health and environmental properties, it cannot be concluded that these alternatives cause a lower impact on health and the environment than BPA. Phasing out paper receipts as a result of using alternative technological solutions has potential. However, at present none of the technologies presented in this report can be considered mature enough to fully replace the paper receipt.

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