The dark side of thermal printed paper

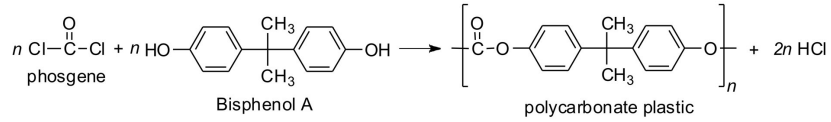
There is a lot more pandemonium about human health risks of an estrogen-like chemical being found in everything from baby bottles, some beverages, to the epoxy linings of food and beverage cans as well as in dental products – known as bisphenol A (BPA) (4,4′-(propane-2,2-diyl)diphenol). BPA is the building block of polycarbonate plastics (Scheme 1).

The exposure of BPA to human beings is nearly universal and a study has reported that the urine samples from 92.6% of the population in USA contain this nephrotoxin[1]. With dubious observations over its effects, some researchers have found BPA to have estrogenic and anti-androgenic effects in both *in vivo* and *in vitro* studies, while others reject any such tendency in their animal model studies. These findings related to the effects of BPA are being challenged by the scientific community, and it has been a subject of debate and controversy in many academic and research institutes[2–11]. Further reports, however, by the National Toxicology Program and the National Institute of Environmental Health and Safety (both in USA) nullifies the effect of BPA as a suspected human endocrine disruptor[7,12,13]. Meanwhile studies have found a link between BPA, cardiovascular diseases and diabetes in humans and its mimicking propensity to disrupt hormone signalling in animals. Other significant effects of BPA on the model laboratory animals include disruption of spermatogenesis and seminiferous epithelium and reduction in free-plasma testosterone and 17β-oestradiol levels[14]. Following the epidemiological studies which demonstrate the link between BPA and health disorders in humans, the Canadian administration took the initiative to ban BPA (potent xenoestrogen) in baby products. Similar initiatives were taken by the Malaysian Health Ministry[14,15].

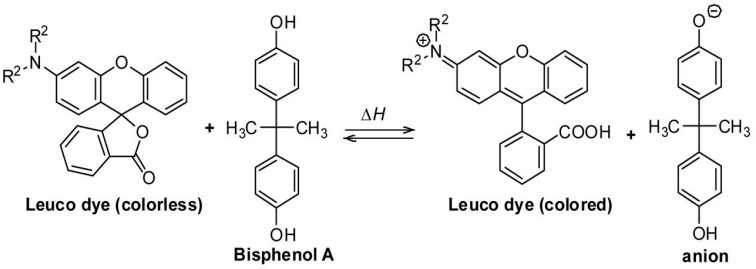
In recent times, one prominent source of BPA is the thermal paper which works on the principle of thermochroism. This is a phenomenon as a result of which the coating on the thermal paper undergoes a colour change in the areas where it is heated by a laser beam producing an image (Scheme 2). With high efficiency and accessibility, BPA has received wide exploitation in thermal paper printing technology as a colour developer. Thus, the possibility of human exposure is explicitly ubiquitous. Thermal paper printing technology is reported to have first developed in the late 1960s, and its popularity grew in the 1980s and 1990s as it became cost-effective and versatile. Nowadays, BPA is preferentially used in commercial point-of-sale (POS) receipts, luggage tags, faxes and labels, tickets and print-outs from recording devices. POS receipts include sales receipts from cash registers, ATMs and banks.

The presence of free monomers of BPA in thermal papers facilitates its transdermal movement through human skin to finally get absorbed and metabolized within. Hand contact while casual handling of thermal paper is the most common exposure to BPA, which eventually gets deposited on the skin. Dermal acquaintances contribute maximum BPA exposure to humans. Paper receipt has been documented as a major source of BPA exposure, but little research has been done to explicate the potential health risk to the common people. Lu *et al.* have reported that supermarket receipts in Shenzhen, China contain BPA at concentrations ranging from 2.58 to 14.7 mg g^{-1}, and the amount is more or less thousand times that found in the epoxy lining of food cans[16]. Moreover, the transfer of BPA to paper currencies does take place from thermal paper receipts when currencies are kept along with receipts for more than 24 h in wallets/bags. Thus, paper currencies do masquerade as a threat because of the thermal paper receipts[17]. BPA exposure affects the hormonal system, in particular, the pathway involving estrogen; its effects have been studied on cells, tissues and whole organisms. It was also observed that the abnormal sperm production and reduced fertility in BPA-treated adult male mice was reversed when exposure was stopped. In another human epidemiological study, a relationship between BPA exposure and repeated miscarriage was revealed[18,19]. Thus, the workers involved in the production of thermal papers are more prone to infertility. The manufacturing workers are exposed to BPA with the worst case of direct inhalation exposure at an estimated 100 mg/kg body weight/day[20].

It is more or less acceptable that the thermal paper printing technology with BPA is the most rapid and cost-effective; however, these mere factors cannot compensate its ill-effects on the future generation. As the thermochroism reaction between leuco dye and BPA is reversible, the thermal paper prints do not last for long periods, making it unsuitable for long-term preservation. We need to have an alternative, as the global population is exposed to this chemical and it is under biomagnification. Research findings alone cannot put pressure on the behemoth chemical industries funding the replica research with a vested interest in BPA production. Thus it becomes difficult to draw a fine line between the two and the final picture becomes perplexing. The United States Environment Protection Agency (EPA) 2014 final report provided



Scheme 1. Synthesis of bisphenol A (BPA)-polycarbonate by the poly-condensation of BPA and phosgene.



Scheme 2. Reversible-thermal reaction between leuco dye and BPA.

detailed toxicity of BPA taking into consideration the *in vivo* and *in vitro* studies and enlisted some potential chemicals as alternative to BPA. In the report, the EPA's Design for the Environment (DfE) program suggests and encourages innovation and product development, when preferable alternatives are not available. This can incite innovation with design challenges and will give an insight on hazard end-point and its exposure. These efforts will help demarcate safer chemicals for which we can look forward to the field of green chemistry designs[21].

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Outbreak of dengue in Tamil Nadu, India – a rejoinder

I read the research communication by Chandran and Azeez[1]. They have used incorrect data for regression modelling. They have selectively used just two years of actual National Vector Borne Disease Control Programme (NVBDCP) data and wrong (provisional) data for 2012, while up-to-date actual data are available at the NVBDCP website (http://nvbdcp.gov.in/den-cd.html). Considering the fact that the paper was submitted for publication in 2014 to the journal, an up-to-date data should have been used. The dengue data from multiple agencies are extensively used in this paper without proper citation to the data source and date of accessing on-line data.

The authors misquote Brunkard *et al.*[2] to support their statement: 'Earlier studies have reported no specific role for climatic factors in dengue infection'. However, the conclusion of Brunkard *et al.*[2] states that 'Climate and weather factors play a small but significant role in dengue transmission in Matamoros, Mexico…'. The authors arbitrarily state that the earlier studies have reported no specific role for climatic factors, when there are several studies available proving the contrary as has been quoted by the authors themselves. For instance, Johansson *et al.*[3], unambiguously state that 'The associations between temperature, precipitation, and dengue transmission reported here are strong and consistent through time'. Moreover, elsewhere in the paper[1] it is also stated that temperature plays a role in dengue spread citing earlier studies.

The paper[1] also has several mistakes that could have been easily rectified through proper editing. When the authors state that 'Interestingly, every year, until 2011, there was 175% increase in dengue cases', a reader can find it even more 'interesting' to see that the very statement itself is false and the actual increase was around 201%, 188% and 138% as the data in figure 1, clearly show. Again on p. 173, it is stated that 'During the study period while the rainfall deficit increased, the number of reported cases of dengue decreased'. Quite the opposite trend is apparent in figure 5 and the data show that the highest number of dengue cases was reported in 2012, the most rain-deficient year. On p. 171, the paper discusses about three consecutive rain-deficit years (2011, 2012 and 2013) in Tamil Nadu, citing a newspaper article, while figure 5 shows around 25% surplus rain in 2011.

Further, there are self-contradictions at several places. On p. 173, the authors state that 'The rainfall varied significantly (ANOVA $P < 0.05$) across the seasons'; while on p. 175 they state that '…the difference between total rainfall and power supply during the four seasons in a year not being statistically significant ($P < 0.05$)...'. And 'the present study also indicates the failure of the surveillance system in 2012, while it was relatively satisfactory in 2010 and 2011'. The data provided in table 4 show exactly the opposite, with the highest accuracy (28.1%!) of the prediction figures during 2012 and much less in 2010 and 2011.

On p. 174 the authors state that 'When the predicted dengue cases were plotted against the actually reported cases for the respective years, the model exhibited significant correlation between the predicted and the actual number of cases ($r = 0.999$, $P = 0.031$)'. The overall difference between the predicted and actual number of dengue cases was also found insignificant, thereby suggesting the goodness and suitability of this model for dengue case prediction. However, on the very next page the authors state: 'The flaws in the surveillance and reporting system could be a possible, but crucial, reason for the failure of this prediction model. Thus, possibly this model emphasizes the need for accurate IDSP alert reporting through better collection, collation, compilation and validation of data.'

There is false information provided in this paper[1]. For instance, according to