IJPSR (2024), Volume 15, Issue 2 **(Review Article)**

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 30 April 2023; received in revised form, 09 August 2023; accepted, 22 November 2023; published 01 February 2024

BRIEF OVERVIEW STUDIES ON ENDOCRINE DISRUPTORS POLYCYCLIC AROMATIC HYDROCARBONS WITH SPECIAL REFERENCE TO NEWSPAPER INK

Anita Singh Purvia * and Vinoy Kumar Srivastava

Laboratory of Endocrinology, Department of Bioscience, Barkatullah University, Bhopal - 462026, Madhya Pradesh, India.

Keywords:

Food materials, Endocrine disruptors, Polycyclic aromatic hydrocarbons, Newspaper ink

Correspondence to Author:
Ms. Anita Singh Purvia

Research Scholar,
Department of Bioscience,
Barkatullah University, Bhopal - 462026, Madhya Pradesh, India.

E-mail: anitasnehi@gmail.com

ABSTRACT: Now a day's food materials are packaged and wrapped in paper that is the dangerous practice of wrapping, covering or processing foods with newspaper and printed recycled paper materials remains commonplace worldwide, as seen in the plethora of photographs in advertisements online or in magazines showing newspaper wrapped foods. The health hazard of ink contamination to foods and long-term contact with complex chemicals should always be considered because of the potentially diverse array of biological and toxicological effects. Polycyclic aromatic hydrocarbons inhibit the function of thyroid, adrenal and male reproductive system, like secreted hormonal imbalance due to this several disorders occurs in human body. However, proposed studies will be helpful to human health especially to thyroid, adrenal and male reproductive system deficiency caused by polycyclic aromatic hydrocarbons because we have avoided ink-based newspaper wrapped food materials to minimize the endocrine glands diseases. We will initiate systematic campaigns for generating awareness among all the stakeholders to discourage the use of newspapers for packing, serving and storing food items. Therefore, this proposed study is useful to generate knowledge in the peoples to avoid the wrapped and covering process of food materials by paper inks and also avoid adulterate food materials for betterment of health.

INTRODUCTION: Endocrine glands are glands of the endocrine system that secrete their products, hormones, directly into the blood rather than through a duct. Endocrine disruptors are chemicals that interfere with human and animal hormone systems, and are capable of altering hormone balance and embryo development, with the risk of adverse effects on the health of organisms and their offspring.

QUICK RESPONSE CODE

DOI:
10.13040/IJPSR.0975-8232.15(2).302-10

This article can be accessed online on
www.ijpsr.com

DOI link: https://doi.org/10.13040/IJPSR.0975-8232.15(2).302-10

The term endocrine disruptor chemical (EDC) was coined some 50 years later, in 1991, during the Wingspread Conference, when a group of endocrinologists, toxicologists, epidemiologists, and other health experts met to assess harmful effects on humans. Food as a basic need for all people must be wholesome and safe.

Food adulteration is a major public hazard which affects the quality of life of people. The packaging and processing of food materials mostly are by paper. Paper is a versatile material with many uses, including writing, printing, packaging, cleaning, decorating and a number of industrial and construction processes. In India the peoples consuming food in printed papers served by street vendors and small hotels as there is a higher risk of

contracting cancers at an early age. Foods contaminated by newspaper ink raise specific health concerns since the ink contains multiple bioactive materials with known negative health effects. Polycyclic aromatic hydrocarbons are hydrocarbons-organic compounds containing only carbon and hydrogen that are composed of multiple aromatic rings. Phthalates are industrial chemicals that are extensively used as plasticizers in a variety of consumer products like food. For instance, Di-(2-ethylhexyl) phthalate (DEHP) is usually used for polyvinyl chloride material, food packaging and medical and diethyl phthalate (DEP) [1]. Several researchers have been reported that Endocrine disruptors are chemicals that interfere with human and animal hormone systems, and are capable of altering hormone balance and embryo development, with the risk of adverse effects on the health of organisms and their offspring. The Food Safety and Standards Authority of India (FSSAI) has banned the use of newspapers and other printed papers, still several hotels and eateries are using it without knowing the consequences. Hence, the proposed study is essential for Endocrine Glands disorders and hormones deficiency related to consumption of adulterated food in human diet through preservatives, chemicals and paper inks especially polycyclic aromatic hydrocarbons.

Food Adulteration and Endocrine Glands: Food adulteration is a major public hazard that affects the quality of life of people [2]. The nature of food adulteration and contamination may vary from place to place or there could be newer adulterants, as a result of changing environmental factors, like non-seasonal rains or improved production/ cultivation practices and also reported that some of the adulterants which are used for malpractices including starch, stones, chips, saw dust, urea, caustic soda, kesaridal, mineral oil, argemone oil, synthetic colours asbestos, mycotoxins and aflatoxins

Endocrine glands are glands that secretes a substance (a hormone) into the bloodstream. They include the hypothalamus, pituitary gland, pineal gland, thyroid, parathyroid glands, heart, the stomach and intestines, islets of Langerhans in the pancreas, the adrenal glands, the kidney, fat cells and the testes, the ovarian follicle (estrogens) and the corpus luteum in the ovary. Hormones produce their effects on target tissues by binding to specific proteins called hormone receptors located in the target tissues only. Each receptor is specific to one hormone only and hence receptors are specific and formed hormone-receptor complex that leads to certain biochemical changes in the target tissue. Hormones are regulated physiological and metabolic function on target tissue. On the basis of their chemical nature, hormones can be divided into groups:

- Peptide, polypeptide, protein hormones (Pituitary hormones, Insulin, glucagon, hypothalamic hormones, *etc*.).
- Steroids (Cortisol, progesterone estradiol and testosterone).
- Iodo-thyronines (thyroid hormones).
- Amino-acid derivatives (Epinephrine).

Hormones that interact with membrane-bound receptors normally do not enter the target cell, but generate second messengers (e.g., cyclic AMP, IP3, Ca++ *etc*) which in turn regulate cellular metabolism.

Modes of Action of Endocrine Disruptor Chemicals (EDCs): From a toxicological perspective, endocrine disruptor chemical (EDCs) can be classified according to their sources or their modes of action. The first classification of EDCs proposed by scientists are Natural (Phytoestrogen: genistein and coumestrol) and Synthetic (Polychlorinated biphenyls (PCBs), polybrominated biphenyls (PBBs), dioxins; dichlorodiphenyltrichloroethane (DDT), diethylstilbestrol (DES), vinclozolin, BPA and Phthalates [3, 4]. The second classification of EDCs [5, 6] was already reported based on EDCs that affect the central nervous system; thyroid; pancreas; reproductive system; and affect other systems.

Several scientific institutions including European Commission, European Environmental Agency and Endocrine Society, WHO/UNEP, IARC have shown interest for the association between EDCs and cancer affecting testis, prostate, thyroid and breast for suggesting that the exposure to some EDCs may be a risk factor in the development of these tumours as reported by number of pioneer

researchers [7, 8, 9]. Fungicides, pesticides, PDBE, organochlorides, PCB, DDT, dichloro diphenyl dichloroethylene (DDE), arsenic and cadmium are played roles in important roles in food adulteration and may be cause testicular cancer with etiopathogenetic role in the onset of TDS.

PCB also reported forms of dioxins, cadmium, phytoestrogens, DES, furans, ethylene oxide may also contribute to the field of food adulteration and may also cause breast cancer. Finally arsenic, cadmium, PCB, and pesticides seem to contribute importantly to prostate carcinogenesis [10].

Every endocrine axis may be a target for each EDCs and their action is not limited to a single axis or organ but it is now quite clear that hypothalamus-pituitary gland-thyroid (HPT), hypothalamus-pituitary gland-gonads (HPG) and hypothalamus-pituitary gland-adrenal (HPA) represent the main targets of EDCs. Nevertheless, evidence also shows that some EDCs may affect the central nervous system (CNS) impairing hypothalamic and pituitary functions [8, 11]. The report EDCs disrupt the proper actions of peripheral glands reported by some researchers [8, 10, 11]. Recent evidence has reported that EDCs may disrupt energy metabolic homeostasis altering adipose tissue that may increase in number and size of adipose cells, impairing endocrine regulation of adipose tissue, adipocytokine production, reducing basal metabolic rate and changing the regulation of appetite and satiety [12, 13].

Effect of Paper ink in Human Endocrine Glands and other Disorders: The use of newspapers to wrap, pack or serve food is quite common in India. Indian populations are huge fan to street food like chatpata golgappa, chaats, samosa bhel puri, pakoras, batata paos, posa jalebi *etc*. The Safety and Standard Authority of India (FSSAI) found in recent investigations that most street vendors, small hotels, and homes also serving food in the newspaper. FSSAI advises and share that wrapping food items in newspapers is bad for our health as the ink used in printing has multiple bioactive materials with known negative health effects. "Printing inks may also contain harmful colors, pigments, binders, additives and preservatives. Some reports have been reported that contamination of foods by newspaper ink raises specific health concerns and the ink contains multiple bioactive materials with known negative health effects [14, 15]. Naphthylamine and aromatic hydrocarbons are the major concerns and have reported endocrine disruptors are defined as exogenous substances that alter functions of the endocrine system and consequently cause adverse health effects in an intact organism, or its [16].

The ink and dye industry is an increased risk of lung cancer among newspaper printing workers who have been exposed to ink mist containing these chemicals. Bladder cancer is another notable disease found to be associated with ink and dye [17]. The exposure to Naphthylamine, Benzidine, and 4-Aminobiphenyl has long been established as the major risk factor for bladder cancer with this risk being proportional to the length of exposure [18, 19, 20].

Research has also shown health concerns regarding exposure to some other specific ink chemicals (example 2-Naphthylamine induced rat bladder cancer) [21]. The arylamines have reported exposure (cigarette smokers, hairdressers, and workers of dye and textile industries) has been linked to a significantly higher risk for bladder cancer in men [22]. In addition to the above-mentioned carcinogenic effects of printing ink, other research shows that newspapers and newspaper ink contain agonists for the AhR [23]. The AhR pathway is a ligand-dependent, basic helix-loop-helix, Per-Arnt-Sim-containing transcription factor that mediates a diverse array of biological and toxicological effects in a variety of species [24].

Some evidence indicates that chronic exposure to relatively high doses of a metabolically labile polycyclic aromatic hydrocarbon (PAH) AhR agonist, *i.e.* b-Naphthoflavone can be as effective at producing AhR-dependent toxicity as a single exposure to those that are metabolically persistent have reported time to time [25, 26, 23].

After that other researchers have reported and indicated that when a PAH metabolizing enzyme, such as CYP1A (cytochrome P450, family 1, subfamily A) is either chemically inhibited or knocked down, metabolically labile AhR ligands will produce AhR-dependent toxic effects [27, 28]. Some researchers showed that the direct contact between the greasy food and the newspaper

increases the risk of newspaper ink and chemicals being absorbed by the food through the cooking oil (lipid), which acts as a good medium for the transfer of ink ingredients [29].

The majority of printing inks are based on mineral oils (MOs) which contain complex mixtures of saturated and aromatic hydrocarbons. Consumer exposure to these oils occurs either through direct skin contact or, more frequently, as a result of MO migration into the contents of food packaging that was made from recycled newspaper. Despite this ubiquitous and frequent exposure little is known about the potential toxicological effects, particularly with regard to the aromatic MO fractions [30].

The inks used can be categorized into water-based, solvent-based and mineral oil (MO)-based. With more than 420,000 ton used in 2012 the latter on majority of inks used for printing in institute of Europe and world-wide as reported by EuPIA. Some scientists proposed some applications comprising, amongst others, newspaper printing as well as the labeling and decoration of food packaging [31]. Hence it comes as little surprise that residues of MOs are detectable in cardboard packages for food. Without further barriers the respective MOs can migrate into the packaged foodstuffs and compounds from mineral oils have indeed been detected in dry foods such as rice and noodles in concentrations as high as tens to hundreds of mg/kg have reported [32, 33].

The naphthenes, n-alkanes and iso-alkanes isolated by LC-GC analysis of the aromatics in a mineral oil fraction and batching oil for jute bags, whereas the latter contains highly alkylated monoand polycyclic aromatic hydrocarbons (PAHs) [34, 35].

In an investigation found that the most of the newspapers are printed with soy-based inks and rest of the papers are printed with vegetable oils (cooking oils) and is still most widely used raw material in the ink industry. Furthermore, they have explained both the direct contact and relatively long contact time (more than 24 hours) increase the level of the food been contaminated by the ink. Polycyclic aromatic hydrocarbons (PAHs), such as benzo[*a*]pyrene (BP), are detectable in certain consumer products, including newspapers [14].

In one studies of PAHs BP which were able to migrate from newspaper inks and to penetrate into deeper and viable layers of the skin. In addition it could be shown that the molecular weight of the PAHs is strongly influencing its cutaneous migration. Human skin cells and 3D skin models were proven to be capable of metabolizing BP toward a range of phenols, diols, quinones and the hydrolysis product of the ultimate carcinogenic intermediate (BPDE), that is, the 7,8,9,10-tetraol. They have alternatives of bisphenol A (BPA) which is more being used in thermal paper receipts for getting an overview of the situation in Switzerland [36].

A substitution of BPA by BPF and BPS should be thus considered with caution and exhibits almost a similar endocrine activity as BPA. D-8 and Pergafast®- 201 could be alternatives to replace BPA, however further analyses are needed to better characterize their effects on the hormonal system [37].

The thermal paper contains potentially toxic additives, such as bisphenol A (BPA), as a common color developer has reported, because of its known endocrine disrupting effects, structural analogues to bisphenol A (BPA), such as bisphenol S (BPS), D-8 and Pergafast 201, which have been used as alternatives [38]. A study suggested some epidemiological evidence for several groups of common contaminants, including PCBs, brominated flame retardants, phthalates, BPA and perfluorinated chemicals, are associated with reduced serum thyroid hormone levels in humans. Moreover, a much longer list of chemicals has caused a reduction in circulating levels of thyroid hormones or interfered directly with thyroid hormone action in experimental animals. Severe thyroid hormone deficiency causes severe brain damage, such that universal screening of thyroid hormone levels in serum occurs all over the world [16].

Phthalates reported as one of the industrial chemicals that is extensively used as plasticizers in a variety of consumer products. For instance, diethyl phthalate (DEP) and di-n-butyl phthalate (DBP) are used for personal care and pharmaceutical products [1].

Di-(2-ethylhexyl) phthalate (DEHP) reported that it is usually used for polyvinyl chloride material, food packaging and medical device [39, 40, 41]. The EDCs is represented by its ability to bind endocrine nuclear receptors acting as total, partial, or inverted agonist proposed the most documented mechanism [42, 43, 10, 8].

The effect of endocrine disrupters (EDCs) reported earlier that EDCs can bind to activate various hormone receptors including androgen receptor, estrogen receptor, aryl hydrocarbon receptor, pregnane X receptor, constitutive androstane receptor, estrogen-related receptor, glucocorticoid receptor, thyroid hormone receptor, retinoid X receptor-AR, ER, AhR, PXR, CAR, ERR, GR, TR and RXR) that mimic the action of natural hormone's [42, 43, 44, 45].

Effect of Endocrine Disrupters on Thyroid Glands: Thyroid is essentially a gland that produces stores and releases two important hormones, which are Tri-iodothyronine (T3) and Thyroxine (T4). The amount of thyroid hormones secreted is controlled by another hormone, called thyroid stimulating hormone (TSH), which is released from the pituitary gland in your brain.

Thyroid hormones as Triiodothyronine (T3) and Thyroxine (T4), basically are important regulators for differentiation, growth and metabolism of virtually all tissues and organs of human body including the ovaries and endometrium [46]. Researchers have noticed and defined the proper thyroid function is essential to have a healthy and normal reproduction, therefore, the female reproduction is inhibited by both hyperthyroidism and hypothyroidism [47, 48]. Some report highlighted that the hypothyroidism is the leading cause of impaired female fertility as it causes ovulatory dysfunction and most of the women who have polycystic ovarian syndrome (PCOS) which is one of the most common endocrinopathy, in women of reproductive age, seem to be concomitantly affected by thyroid dysfunction [49].

In India, hypothyroidism was usually categorized under the cluster of iodine deficient disorders (IDDs), which were represented in terms of total goiter rates and urinary iodine concentrations, typically assessed in school-aged children and it is also prevalence of iodine deficiency disorders in adolescents [50, 51, 52].

The researcher reported that ever since India adopted the universal salt iodization program in 1983, there has been a decline in goiter prevalence in several parts of the country, which were previously endemic [53, 54, 55].

Phthalates are industrial chemicals like diethyl phthalate (DEP) and di-n-butyl phthalate (DBP), Di- (2-ethylhexyl) phthalate (DEHP) is usually used for polyvinyl chloride material, food packaging and medical device that's are effects on endocrine glands [39, 40, 41]. Thyroid disease, as a chronic illness which is affecting approximately 200 million people worldwide [56]. The prevalence of thyroid disease is much higher among women than among men [57].

Phthalates may have antagonistic effect on the thyroid function both *in vivo* and *in vitro* through a variety of mechanisms, such as down-regulation of the human sodium/iodide symporter (NIS) promoter [58, 59, 60, 61, 62, 63, 64]. Ice cream is adultered by pepper oil, ethylacetate, butraldehyde, acetate, nitrate, washing powder etc. Pepper oil is used as a pesticide and ethyl acetate causes terribble diseases affecting lungs, kidneys and heart due to hormonal imbalance reported earlier [65].

Effect of Endocrine Disrupting Chemicals on Pituitary Gland: The pituitary gland secretes two gonadotropic (gonad-stimulating) hormones that control ovarian functions: follicle-stimulating hormone (FSH) and luteinizing hormone (LH). Growth of the ovarian follicles is regulated by FSH, whereas both LH and FSH are necessary for estrogen synthesis (the major estrogen is estradiol). LH also stimulates progesterone and androgen synthesis in the ovary. The androgen is a precursor for estrogen synthesis and this step is regulated by FSH. In addition, LH is responsible for ovulation. Release of LH and FSH from the pituitary is regulated by a single hypothalamic hormone called gonadotropin-releasing hormone (GnRH; formerly called luteinizing hormone-releasing hormone, or LHRH). Several EDCs which act on the pituitary gland, for influencing the different endocrine axes, as a result, a wide spectrum of clinical manifestations were found to be has been

associated with exposure to pollutants, such as precocious/delayed puberty and circadian disruption as reported [66, 67].

Effect of Endocrine Disrupting Chemicals on Reproductive System: The chemical structure of most of EDCs mimics sex gonadal hormones showed the ability to bind to endocrine receptors interfering with hormonal signals, reproductive system represents the most vulnerable endocrine axis to EDCs actions have been reported [44]. The US EPA described five classes of EDCs endowed with anti-androgenic properties and, simultaneously, with weak estrogenic activity:

1. Drugs or synthetic estrogens (17 b estradiol, diethylstilbestrol).
2. Phytoestrogens (Isoflavonoids, cumestans, lignans, stilbens).
3. Pesticides (Organophosphates, carbamates, organochlorines, synthetic pyrethroids).
4. Plasticizers and chemicals produced by incomplete combustion of polyvinyl chloride (PVC), paper and putrescible substances (dioxin).

Researcher have isolated some industrial substances and their by-products (i.e. Phenols, dioxins, heavy metals, perfluorooctanoic acid, flames retardants) [68, 69].

Phthalates, diethylstilbestrol, bisphenol A (BPA), TCCD that are involved in the onset of endometriosis occurring in 10% of fertile women, causing infertility in 50% of affected subjects reported [70]. Study carried out on female infertility are endocrine disruptors and observe some changes histopathology of ovary that seems to be related to the exposure to: PCB, phtalates, atrazine, genistein, BPA, TCDD, parabens, triclosan, dichlorodiphenyltrichloroethane (DDT) and metoxychloride (MXC) [71, 72]. Males, reproductive function may affected by pollutants and EDCs, but evidence is scarce; EDCs, such as phthalates, bisphenol A, biphenyls, and vinclozolin, widespread use of therapeutic drugs, obesity and sedentary life-style may play a crucial role in this supposed decrease of male fertility studied reported [73, 74].

CONCLUSION: On the basis of above mentioned reviews it can be concluded that food adulteration is a major public hazard which affects the quality of life of people. It is also well known fact that in present scenario human being are depend on fast food products which are being preserved by the manufacturing companies to preserve for longest duration and for the improvement of tastes therefore, manufactures are adding some toxic substances/chemical substances including polycyclic aromatic hydrocarbons, nitrate, nitrate, SCN and phthalates which are causing several side effects is indicating endocrine glands toxicity. All toxic substances competitively inhibit the function of endocrine glands, like secreted hormonal imbalance due to this several disorders occurs in human body.

Now a day's food materials packaged and wrapped in paper that is the dangerous practice of wrapping, covering or processing foods with newspaper and printed recycled paper materials remains commonplace worldwide, as seen in the plethora of photographs in advertisements online or in magazines showing newspaper wrapped foods. The health hazard of ink contamination to foods and long-term contact with complex chemicals should always be considered because of the potentially diverse array of biological and toxicological effects.

Present study, reveals that chemicals are a serious health hazard and important cause of morbidity and mortality in developing countries. The study also showed that the increased incidence of contaminated food by paper inks and others chemicals like polycyclic aromatic hydrocarbons effect on endocrine glands and causes several disorders in humans body. We will initiate systematic campaigns for generating awareness among all the stakeholders to discourage the use of newspapers for packing, serving and storing food items. Therefore this study is useful to generate knowledge in the peoples to avoid the wrapped and covering process of food materials by paper inks and also avoid adulterate food materials for betterment of health.

ACKNOWLEDGEMENTS: The Authors would like to thank the Vice Chancellor for supporting and providing the research facilities.

CONFLICTS OF INTEREST: The Authors declared no conflict of interest.

REFERENCES:

1. Schettler T: Human exposure to phthalates *via* consumer products. International Journal of Endocrinology 2006; 29: 134-139
2. Sudershan RV, Prtima Rao and Kalpagam Polasa: Food Safety Research in India; a review. The Asian Journal of Food and Agro-Industry 2013; 2 (03): 412-433.
3. Zawatski W and Lee MM: Male pubertal development: Are endocrine-disrupting compounds shifting the norms? Journal of Endocrinology 2013; 218: 1-12.
4. Tavares RS, Escada-Rebelo S, Correia M, Mota PC and Ramalho-Santos J: The non-genomic effects of endocrine-disrupting chemicals on mammalian sperm. Reproduction 2016; 151: 1–13.
5. Whaley DA, Keyes D and Khorrami B: Incorporation of endocrine disruption into chemical hazard scoring for pollution prevention and current list of endocrine disrupting chemicals. Drug Chemical Toxicology 2001; 24: 359-420.
6. Lee HR, Jeung EB, Cho MH, Kim TH, Leung PC and Choi KC: Molecular mechanism(s) of endocrine-disrupting chemicals and their potent oestrogenicity in diverse cells and tissues that express oestrogen receptors. Journal of Cellular Molecular Medicine 2013; 17: 1-11.
7. Lamb JC IV, Boffetta P, Foster WG, Goodman JE, Hentz KL and Rhomberg LR: Critical comments on theWHO-UNEP State of the Science of Endocrine Disrupting Chemicals-2012. Regulatory Toxicology Pharmacology 2014; 69: 22-40.
8. Gore AC, Chappell VA, Fenton SE, Flaws JA, Nadal A and Prins GS: EDC-2: The Endocrine Society's second scientific statement on endocrine-disrupting chemicals. Endocrinology Review 2015; 36: 1-150.
9. Trasande L, Zoeller RT, Hass U, Kortenkamp A, Grandjean P and Myers JP: Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis. Andrology 2016; 4:565–72. doi: 10.1111/andr.12178.
10. De Coster S and van Larebeke N: Endocrine-disrupting chemicals: associated disorders and mechanisms of action. J. Environ. Public. Health 2012; 71: 36-96.
11. Kabir ER, Rahman MS and Rahman I: A review on endocrine disruptors andtheir possible impacts on human health. Environmental Toxicology Pharmacology 2015; 40: 241–58.
12. Street ME and Angelini S: Current knowledge on Endocrine Disrupting Chemicals (EDCs) from animal biology to humans, from pregnancy to adulthood: highlights from a National Italian Meeting. International Journal of Molecular Sciences 2018; 19: 1647.
13. Lauretta R, Sansone A, Sansone M, Romanelli F and Appetecchia M: Endocrine Disrupting Chemicals: Effects on Endocrine Glands. Frontier in Endocrinology 2019; 10: 178.
14. Leach RH, Pierce RJ, Hickman EP, Mackenzie MJ and Smith HG: The printing ink manual 1993; Springer (India) Pvt. Ltd.
15. Zhou R and Stanley R: Food risks associated with newspaper ink and contaminated recycled fibre materials. Journal of Hygiene Science 2011; 7: 10.
16. Bergman AK, Heindel JJ, Jobling S, Kidd KA and Zoeller RT: The State of the Science of Endocrine Disrupting Chemicals. World Health Organization 2012.
17. Leon DA, Thomas P and Hutchings S: Lung cancer among newspaper Printers exposed to ink mist: a study of trade union members in Manchester, England. Occupational and Environmental Medicine 1994; 51: 87-94.
18. Hendry WF, Blandy JP, Glashan RW, Hall RR, Wallace DMA, Baxter PJ, Couch JA, Finch WM, Howe DW, Parkes DHG and Westbrook MB: Occupational Bladder Cancer: A Guide for Clinicians: The Baus Subcommiuee On Industrial Bladder Cancer. British Journal of Urology 1988; 61: 183- 191.
19. Konety BR and Carroll PR: Urothelial carcinoma: cancers of the bladder, ureter, & renal pelvis. Smith's General Urology. 17thed. New York: Mc Graw-Hill Companies 2008; 308-327.
20. Ruder AM, Carreon T, Ward EM, Schulte PA and Halperin W: Bladder Cancer. In: Textbook of clinical occupational and environmental medicine. Rosenstock L, Cullen MR, Brodkin CA, Redlich CA (Eds.) 2005; 757.
21. Hicks RM, Wright R and Wakefield JSJ: The induction of rat bladder cancer by 2-naphthylamine. British Journal of Cancer 1982; 46: 646-661, https://doi.org/10.1038/bjc.1982.250.
22. Al-Zoughool M, Succop P, Desai P, Vietas J and Talaska G: Effect of N-glucuronidation on urinary bladder genotoxicity of 4-aminobiphenyl in male and female mice. Environmental Toxicology and Pharmacology 2006; 22(2): 153-159.
23. Bohonowych JES, Zhao B, Timme-Laragy A, Jung D, Di Giulio RT and Denison MS: Newspapers and Newspaper Ink Contain Agonists for the Ah Receptor. Toxicological Sciences 2008; 102: 278-290, doi.org/10.1093/toxsci/kfn011.
24. Woods S, Farrall A, Procko C and Whitelaw ML: The bHLH/Per-Arnt-Sim transcription factor SIM2 regulates muscle transcript myomesin2 via a novel, non-canonical E-box sequence. Nucleic Acids Res 2008; 36: 3716-3727. doi.org/10.1093/nar/gkn247.
25. Grady AW, Fabacher DL, Frame G and Steadman BL: Morphological Deformities in Brown Bullheads Administered Dietary β-Naphthoflavone. Journal of Aquatic Animal Health 1992; 4: 7-16.
26. Navas JM, Zanuy S, Segner H and Carrillo M: β-Naphthoflavone alters normal plasma levels of vitellogenin, 17β-estradiol and luteinizing hormone in sea bass broodstock. Aquatic Toxicology 2004; 67: 337-345. doi.org/10.1016/j.aquatox.2004.01.016.
27. Wassenberg Deena M and Di Giulio Richard T: Synergistic Embryotoxicity of Polycyclic Aromatic Hydrocarbon Aryl Hydrocarbon Receptor Agonists with Cytochrome P4501A Inhibitors in *Fundulus heteroclitus*. Environmental Health Perspectives 2004; 112: 1658-1664. doi.org/10.1289/ehp.7168.
28. Billiard SM, Timme-Laragy AR, Wassenberg DM, Cockman C and Di Giulio RT: The Role of the Aryl Hydrocarbon Receptor Pathway in Mediating Synergistic Developmental Toxicity of Polycyclic Aromatic Hydrocarbons to Zebrafish. Toxicological Sciences 2006; 92:526-536. doi.org/10.1093/toxsci/kfl011.
29. Richard XZ, Stanley R and Le M: Contamination of food with newspaper ink: An evidence-informed decision making (EIDM) case study of homemade dessert. Environmental Health Review 2012; 55(2): 63-69.
30. Tarnow P, Hutzler C, Grabiger S, Schön K, Tralau T and Luch A: Estrogenic Activity of Mineral Oil Aromatic Hydrocarbons Used in Printing Inks. PLoS ONE 2016; 11 (1): 0147239.

31. Biedermann M, Uematsu Y and Grob K: Mineral Oil Contents in Paper and Board Recycled to Paperboard for Food Packaging. Packag Technology and Science 2011; 24 (2): 61–73.
32. Vollmer A, Biedermann M, Grundbock F, Ingenhoff JE, Biedermann-Brem S and Altkofer W: Migration of mineral oil from printed paperboard into dry foods: survey of the German market. European Food Research Technology 201l; 232(1): 175–182.
33. Lorenzini R, Biedermann M, Grob K, Garbini D, Barbanera M and Braschi I: Migration kinetics of mineral oil hydrocarbons from recycled paperboard to dry food: monitoring of two real cases. Food additives & contaminants Part A, Chemistry, analysis, control, exposure & risk assessment 2013; 30(4): 760-70.
34. Grob K, Biedermann M, Caramaschi A and Pacciarelli B: LC-GC analysis of the aromatics in a mineral oil fraction: Batching oil for jute bags. Journal of High Resolution Chromatography 1991; 14(1) :33-9.
35. Biedermann M and Grob K: On-line coupled high performance liquid chromatography–gas chromatography for the analysis of contamination by mineral oil. Part 1: Method of analysis Journal of Chromatography 2012; 1255: 56–75.
36. Paschke M, Hutzler C, Brinkmann J, Henkler F and Luch A: Polycyclic Aromatic Hydrocarbons in Newspaper Inks: Migration, Metabolism, and Genotoxicity in Human Skin. Polycyclic Aromatic Compound 2014; 35(1): 32-40.
37. Daniels PH and Cabrera A: Plasticizer compatibility testing: Dynamic mechanical analysis and glass transition temperatures. Journal of Vinyl and Additive Technology 2015; 21(1): 7– 11.
38. Björnsdotter MK, Jonker W, Legradi J, Kool J and Ballesteros-Gómez A: Bisphenol A alternatives in thermal paper from the Netherlands, Spain, Sweden and Norway. Screening and potential toxicity Science Total Environment 2017; 601-602: 210-221.
39. Calafat AM, Silva MJ, Reidy JA, Earl Gray L, Samandar E, Preau JL, Herbert AR and Needham LL: Mono - (3-carboxypropyl) phthalate, a metabolite of di-n-octyl phthalate. Journal of Toxicology Environmental Health 2006; 69: 215–227.
40. Philippat C, Mortamais M, Chevrier C, Petit C, Calafat AM, Ye X, Silva MJ, Brambilla C, Pin I, Charles MA, Cordier S and Slama R: Exposure to Phthalates and Phenols during Pregnancy and offspring Size at Birth. Environmental Health Perspective 2012; 120: 464–470.doi: 10.1289/ehp.1103634.
41. Gao L, Zou J, Liu H, Zeng J, Wang Y and Chen X: Determination of bisphenol A in thermal printing papers treated by alkaline aqueous solution using the combination of single-drop microextraction and HPLC. Journal of Separation Science 2013; 36(7): 1298–1303.
42. Mnif W, Hassine AI, Bouaziz A, Bartegi A, Thomas O and Roig B: Effect of endocrine disruptor pesticides: a review. International Journal of Environmental Research Public Health 2011; 8: 2265-303.
43. Schug TT, Janesick A, Blumberg B and Heindel JJ: Endocrine disrupting chemicals and disease susceptibility. J of Steroid Bioch and Mol Biology 2011; 127: 204-15.
44. Monneret C: What is an endocrine disruptor? Comptes Rendus Biologies 2017; 340: 403–5. doi.org.10.1016/j.crvi.2017.07.004.
45. Balaguer P, Delfosse V, Grimaldi M and Bourguet W: Structural and functional evidences for the interactions between nuclear hormone receptors and endocrine disruptors at low doses. CR Biology 2017; 340: 414–20.
46. Krassas GE, Poppe K and Glinoer D: Thyroid function and human reproductive health. Endocrinology Review 2010; 31: 702-755.
47. Muderris II, Boztosun A, Oner G and Bayram F: Effect of thyroid hormone replacement therapy on ovarian volume and androgen hormones in patients with untreated primary hypothyroidism. Annual Saudi Medicine 2011; 31: 145-151.
48. Kang JH, Kueck AS, Stevens R, Curhan G and De Vivo I: A large cohort study of hypothyroidism and hyperthyroidism in relation to gynecologic cancers. Obstetrics and Gynecology International 2013; 743-721.
49. Sinha U, Sinharay K, Saha S, Longkumer TA and Baul SN: Thyroid disorders in polycystic ovarian syndrome subjects: A tertiary hospital based cross-sectional study from Eastern India. Indian Journal of Endocrinology and Metabolism 2013; 17: 304-309.
50. Sood A, Pandav CS, Anand K, Sankar R and Karmarkar MG: Relevance and importance of universal salt iodization in India. National Medical Journal of India 1997; 10: 290-293.
51. Kapil U, Saxena N, Ramachandran S, Balamurugan A, Nayar D and Prakash S: Assessment of iodine deficiency disorders using the30 cluster approach in the National Capital Territory of Delhi. Indian Pediatrics 1996; 33: 1013-7.
52. Dodd NS and Godhia ML: Prevalence of iodine deficiency disorders in adolescents. Indian Journal of Pediatrics 1992; 59: 585-91.
53. Tiwari BK, Ray I and Malhotra RL: Government of India New Delhi: Policy Guidelines on National Iodine Deficiency Disorders Control Programme-Nutrition and IDD Cell. Directorate of Health Services, Ministry of Health and Family Welfare 2006; 1-22.
54. Toteja GS, Singh P, Dhillon BS and Saxena BN: Iodine deficiency disorders in 15 districts of India. Indian J Pediatr 2004; 71: 25-8.
55. Marwaha RK, Tandon N, Gupta N, Karak AK, Verma K and Kochupillai N: Residual goitre in the postiodization phase: Iodine status, thiocyanate exposure and autoimmunity. Clinical Endocrinology 2003; 59: 672–81.
56. Rajoria S, Suriano R, Shanmugam A, Wilson YL, Schantz SP, Geliebter J and Tiwari RK: Metastatic phenotype is regulated by estrogen in thyroid cells. Thyroid 2010; 20(1): 33-41.
57. Cassidy F, Ahearn EP and Carroll BJ: Thyroid function in mixed and pure manic episodes. Bipolar Disorder 2002; 4: 393–397.
58. Breous E, Wenzel A and Loos U: The promoter of the human sodium/iodide symporter responds to certain phthalate plasticisers. Molecular Cell Endocrinology 2005; 244: 75–78.
59. Hinton RH: Effects of phthalic acid esters on the liver and thyroid. Environment Health Perspectives 1986; 70: 195-210.
60. Sugiyama S, Shimada N, Miyoshi H and Yamauchi K: Detection of thyroid system-disrupting chemicals using *in-vitro* and *in-vivo* screening assays in *Xenopus laevis*. Toxicology Science 2005; 88: 367-374.
61. Huang PC, Kuo PL, Guo YL, Liao PC and Lee CC: Associations between urinary phthalate monoesters and thyroid hormones in pregnant women. Human Reproduction 2007; 22: 2715-2722.
62. Pereira C, Mapuskar K and Rao CV: A two-generation chronic mixture toxicity study of Clophen A60 and diethyl phthalate on histology of adrenal cortex and thyroid of rats. Acta Histochemica 2007; 109: 29-36.

63. Meeker JD and Ferguson KK: Relationship between Urinary Phthalate and Bisphenol A Concentrations and Serum Thyroid Measures in US Adults and Adolescents from the National Health and Nutrition Examination Survey (NHANES) 2007–2008. Environmental Health Perspect 2011; 119: 1396-1402.
64. Kuo FC: Relationship of urinary phthalate metabolites with serum thyroid hormones in pregnant women and their newborns: a prospective birth cohort in Taiwan. PLoS One 2015; 10: 0123884.
65. Laxmi V and Labs RV: Food Adulteration. The International J of Scie Inventi Today 2013; 1(2): 106-113.
66. Sen A and Sellix MT: The circadian timing system and environmental circadian disruption: from follicles to fertility. Endocrinology 2016; 157: 3366–73. Doi.org.10.1210/en.2016-1450.
67. Soriano-Guillén L and Argente J: Central precocious puberty, functional and tumor-related. Best Practices Research Clinical Endocrinology and Metabolism 2019; 33(3): 101262. doi: 10.1016/j.beem. 01.003.
68. Harding AK, Daston GP, Boyd GR, Lucier GW, Safe SH and Stewart J: Endocrine disrupting chemicals research program of the U.S. Environmental Protection Agency: summary of a peer-review report. Environment Health Perspectives 2006; 114: 1276-82.
69. Browne P, Noyes PD, Casey WM and Dix DJ: Application of adverse outcome pathways to U.S. EPA's endocrine disruptor screening program. Environment Health Perspectives 2017; 125: 096-001.
70. Caserta D, Bordi G, Ciardo F, Marci R, La Rocca C and Tait S: The influence of endocrine disruptors in a selected population of infertile women. Gynecological Endocrinology 2013; 29: 444–7.
71. Marques-Pinto A and Carvalho D: Human infertility: are endocrine disruptors to blame?. Endocrine Connections 2013; 2:15–29. 10.1530/EC-13-0036.
72. Minguez-Alarcon L and Gaskins AJ: Female exposure to endocrine disrupting chemicals and fecundity: a review. Current Opinion in Obstetrics and Gynecology 2017; 29: 202–11. Doi.org.10.1097/GCO.0000000000000373.
73. Anawalt BD: The silent spermatozoon: are man-made endocrine disruptors killing male fertility. Asian Journal Endocrinology 2013; 15: 165-8.
74. Handelsman DJ and Cooper TG: Falling sperm counts and global estrogenic pollution: what have we learned over 20 years. Asian Journal of Endocrinology 2013; 15: 159-61.

How to cite this article:
Purvia AS and Srivastava VK: Brief overview studies on endocrine disruptors polycyclic aromatic hydrocarbons with special reference to newspaper ink. Int J Pharm Sci & Res 2024; 15(2): 302-10. doi: 10.13040/IJPSR.0975-8232.15(2).302-10.