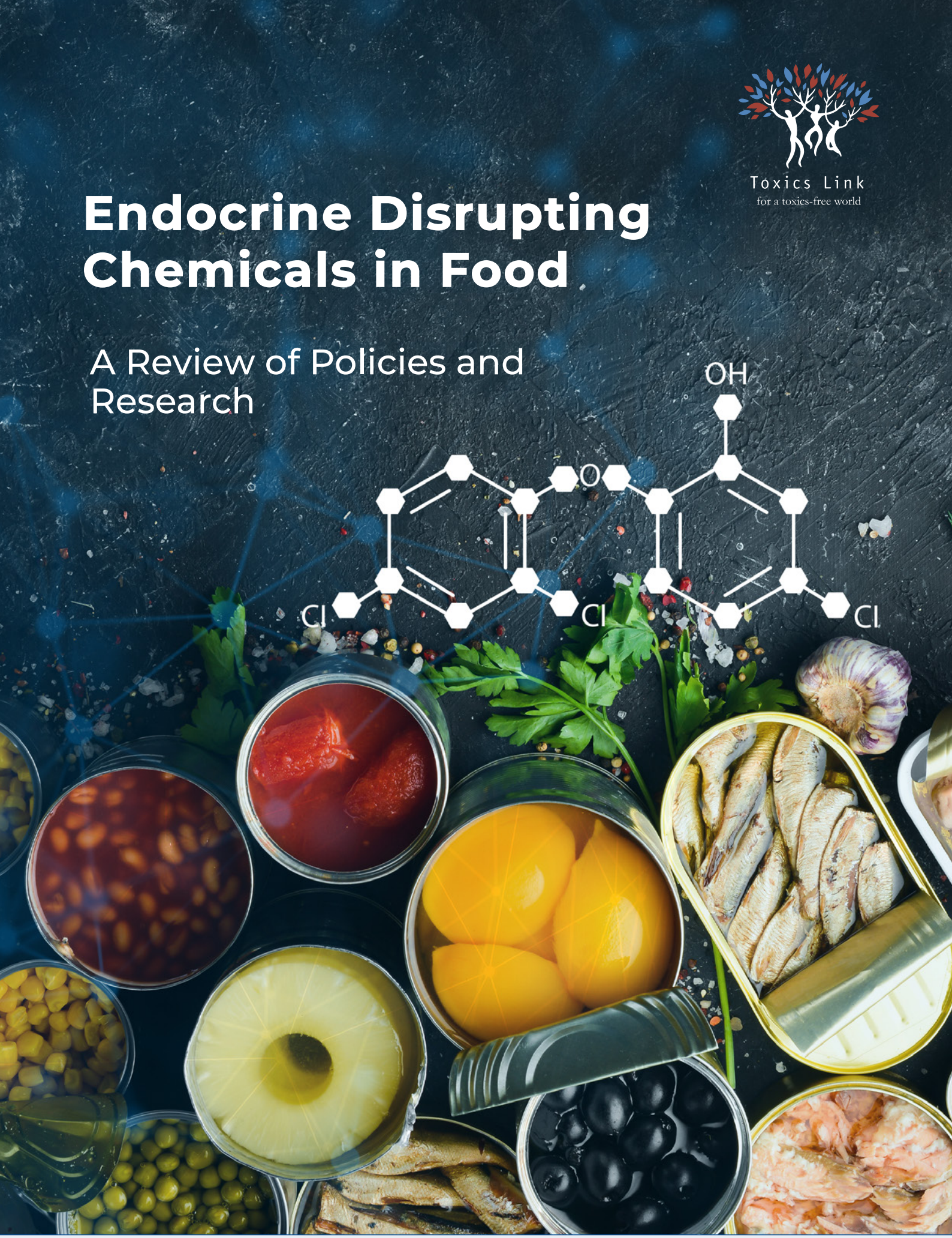
Toxics Link
for a toxics-free world

Endocrine Disrupting Chemicals in Food

A Review of Policies and Research



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About Toxics Link

Toxics Link is an Indian environmental research and advocacy organization set up in 1996, engaged in disseminating information to help strengthen the campaign against toxics pollution, provide cleaner alternatives and bring together groups and people affected by this problem. Toxics Link's Mission Statement - "Working together for environmental justice and freedom from toxics. We have taken upon ourselves to collect and share both information about the sources and the dangers of poisons in our environment and bodies, and information about clean and sustainable alternatives for India and the rest of the world." Toxics Link has unique expertise in areas of hazardous, medical, and municipal wastes, international waste trade, and the emerging issues of pesticides, Persistent Organic Pollutants (POPs), hazardous heavy metal contamination, etc. from the environment and public health point of view. We have successfully implemented various best practices and have brought in policy changes in the aforementioned areas apart from creating awareness among several stakeholder groups.

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About this report

Endocrine Disrupting Chemicals (EDCs) are a group of complex chemicals that are emerging as serious environmental pollutants and threats to public health globally. EDCs are considered highly toxic due to their persistent properties and ability to cause serious and long-term impacts on various critical endocrine functions such as adverse developmental, reproductive, neurological and immune effects in both humans and wildlife.

There are several global research reports which address various aspects of EDCs including the sources & exposure to EDCs and the possible impacts on human health. However, the information on EDCS is very limited in the Indian context for the concerned stakeholders and the general public.

Toxics Link has developed this report as a part of the collaborative project on "Endocrine Disrupting Chemicals (EDCs) in Food in India" along with its international partner, The Norwegian Institute for Water Research (NIVA), as food is found to be an important source of exposure to EDCS. The report has been derived from the most published research studies and data from India and across the globe and has highlighted the gaps and challenges on the issues of EDCs in food in India. It aims to get an overview of the status of EDCs in food and food products in India from the regulatory and policy perspective as well as attempts to incorporate the global regulatory developments on EDCs in food.

The report has covered three major sources of exposure of EDCs -EDCs in industrial applications and consumer products, organo-chlorine pesticides and environmental by-products. It is expected to benefit the policymakers to frame new policies on EDCS in food, catalyze new research studies, and will help in alerting the consumers with new information on EDCs and get access to safe food.

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Abbreviations

µg	Microgram
ABS	Acrylonitrile-butadiene-styrene
AEB	Department of Animal and Environmental Biology
ADI	Average Daily Intake
ARfD	Acute Reference Dose
ATSDR	Agency for Toxic Substances and Disease Registry
BBP	Benzyl butyl phthalate
BDL	below the detection limit
BHC	benzene hexachloride
BIS	Bureau of Indian Standard
BPA	Bisphenol A
Bw	Body weight
CDC	Centers for Disease Control and Prevention
CFIA	Canadian Food Inspection Agency
CFIA	The Canadian Food Inspection Agency
CXLs	Codex Maximum Residual limits
CMES	Center for Marine Environmental Studies
COP	Conference of Parties
CPSC	Consumer Product Safety Commission
DBP	Dibutyl phthalate
DDT	Dichlorodiphenyltrichloroethane
Deca-BDE	Deca Bromodiphenyl Ether
DEHP	Bis (2-ethylhexyl) phthalate
DIDP	Diisodecyl phthalate
DNOP	Di-n-octyl phthalate
ECHA	European Chemicals Agency
EDCs	Endocrine Disrupting Chemicals
EDS	Endocrine Disrupting Substance
EFSA	European Food Safety Authority
EU-RL	European Union Reference Laboratory
FDA	Food and Drug Administration
FEHD	The Centre for Food Safety of the Food and Environmental Hygiene Department
FSANZ	Food Standards Australia New Zealand
FSSAI	Food Safety Standards Authority of India
G	Gram
GC-MS	Gas chromatography-Mass spectrophotometer
HBCDs	Hexabromocyclododecane
HbGV	Health based guidance values
Hg	Mercury
IMS	Infants Milk Substitutes
IPCS	International Program on Chemical Safety
IPEN	International POPs Elimination Network
IS	Indian Standards
Kg	Kilograms

Lbs	Pounds
LOAEL	Lowest-observed-adverse-effect level
LOQ	Limit of quantification
MAC	Maximum Authorized Concentration
MeHg	Methyl Mercury
Mg	Milligram
MN	membranous nephropathy
MRL	Maximum residue level
NFA	National Food Administration
ng	Nano gram
NGO	Non-government organization
NOAEL	Non-observed adverse effect level
NSF	National Science Foundation
OCP	Organochlorine Pesticides
Octa-BDE	Octa Bromodiphenyl Ether
PBT	Polypropropylenes,
PCB	Polychlorinated biphenyl
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo-p-dioxins
PEIs	Poly-etherimides
PentaBDE	Penta Bromodiphenyl Ether
PET	Polyethylene teraphthalates
PFA	Prevention of Food Adulteration
Pg	Picogram
POD	Point of departure
POPRC	Persistent Organic Pollutants Review Committee
POPs	Persistent Organic Pollutants
Ppb	Parts per billion
Ppm	Parts per million
PS	Polysulfone
PVC	Polyvinyl chloride
RfD	Reference dose
SAICM	Strategic Approach to International Chemical Management
SD	Standard deviation
SPME-GC/MS	Solid phase microextraction-gas chromatography/mass spectrometry
TCDDs	Tetrachlorodibenzo-paradioxins
TCS	Triclosan
TDI	Tolerable daily intake
TEQ	Toxic equivalent
U.S.EPA	United State Environmental Protection Agency
UFs	Uncertainty factors
UK	United Kingdome
USFDA	United States Food and Drug Administration
WHO	World Health Organization
Ww	Wet weight

Definition of EDCs

(International Program on Chemical Safety: 2002)

> **An endocrine disruptor is an exogenous substance or mixture that alters function(s) of the endocrine system and consequently causes adverse health effects in an intact organism, or its progeny, or (sub) populations. ”**

I Introduction

i About Endocrine Disrupting Chemicals

Endocrine disrupting chemicals are a group of chemicals generally known to interfere with hormone action by altering the endocrine system that will have an adverse impact on human and wild life. After carefully analyzing the scientific research conducted across the globe, the International Program on Chemical Safety (IPCS), a joint program of WHO, UNEP, and International Labor Organization developed the definition of EDC: "**Endocrine disruptor as an exogenous substance or mixture that can alter the functions of the endocrine system and consequently causes adverse health effects in an intact organism or its progeny or population**".[1] The EDCs have been accepted as a global concern. Therefore the global plan of action has been warranted in the Strategic Approach to International Chemical Management (SAICM) to minimize the adverse impact on human health and the environment from these chemicals.[2]

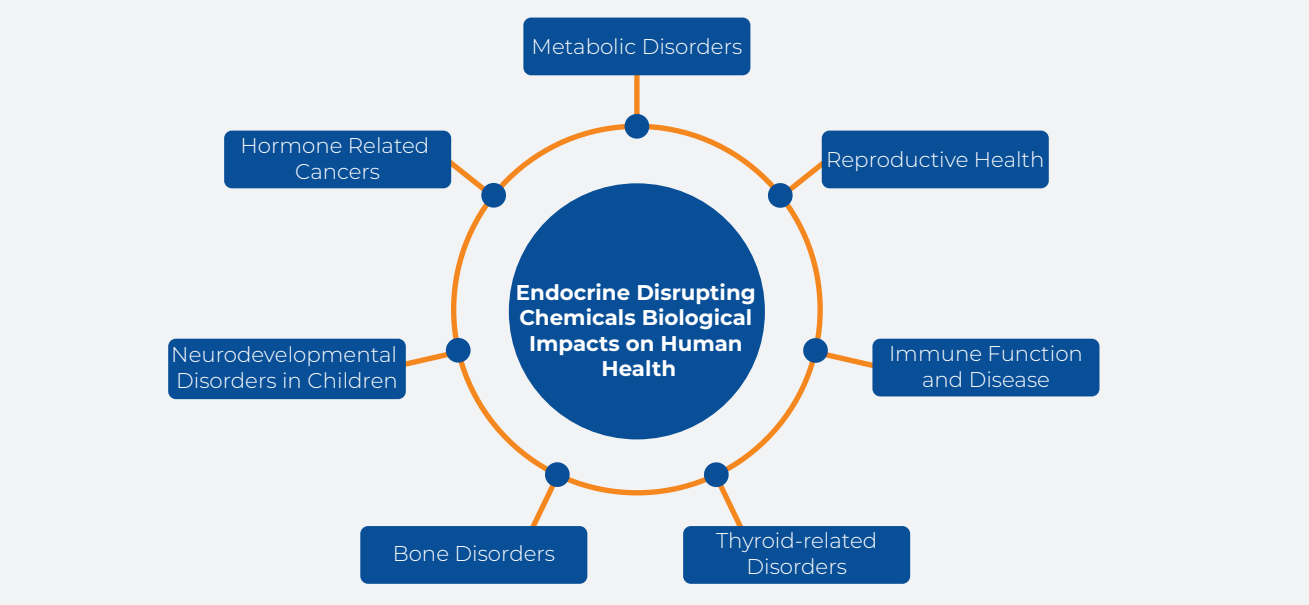
ii EDCs and Human health

It has been estimated that, globally, 24%[3] of human diseases and disorders are attributable to environmental factors and that the environment plays a critical role in 80% of the deadly diseases, including cancer, respiratory and cardiovascular diseases.[4] Because perturbation of the endocrine system is fundamental to the most prevalent of these diseases, the endocrine disrupting chemicals may be primary contributors to these processes. There are scientific studies which indicate that endocrine-associated diseases such as pediatric disorders, male reproductive problems (cryptorchidism, hypospadias, and testicular cancer), early female puberty, leukemia, brain cancer, and neurobehavioral disorders, all risen rapidly over the past 20 years.[5]

It is estimated that, **globally, 24%** of **human diseases and disorders** are attributable to **environmental** factors and the environment plays a critical role in **80% of the deadly diseases**, including **cancer, respiratory and cardio-vascular diseases**.

1 https://apps.who.int/iris/bitstream/handle/10665/78102/WHO_HSE_PHE_IHE_2013.1_eng.pdf;jsessionid=9F31EBB0EA9786CD89A49252D7AEEDF6?sequence=1
2 http://toxicslink.org/docs/Endocrine-Disruptive-Chemicals-REPORT-2016.pdf
3 Fingerhut M, Nelson DI, Driscoll T, Concha-Barrientos M, Steenland K, Punnett L, Pruss-Ustun A, Leigh J, Corvalan C, Eijkemans G, Takala J. The contribution of occupational risks to the global burden of disease: summary and next steps. La Medicina del lavoro 2006; 97:313-321.
4 World Health Organization. 2006. Preventing disease through healthy environments- towards an estimate of the environmental burden of disease. Geneva: World Health Organization.
5 Andrea C. Gore,David Crews,Loretta L. Doan, Michele La Merrill, Heather Patisaul, Ami Zota, 2014 Introduction to endocrine disrupting chemicals (edcs)- a guide for public interest organizations and policy-makers.

Figure 1: **Potential Biological Impacts of EDCS on human health**[6]



iii Endocrine Disrupting Chemicals in Foods

The endocrine disrupting chemicals are generally toxic chemicals known for disrupting the endocrine system in human being. Research studies have confirmed various sources of exposure of these endocrine chemicals in the air we breathe and the food we eat. Food is one of the most critical pathways of EDC exposure of human beings. As many of these chemicals have a longer half-life, they may either not be metabolized, or be metabolized and broken down into more toxic compounds than the parent molecule. These chemicals bioaccumulate by passing through the food chain and get deposited in the fat, resulting in irreversible damage to human health. Furthermore, many of the EDCs can bio-accumulate up in the food chain and lead to biomagnifications of the chemicals, thereby posing health risks to future generations.

Diet is the preferential exposure pathway for humans, whereas lactation is an important pathway for elimination. This process, however, results in a transfer of the toxic load to the newly-born

iv Sources of EDCs

The endocrine disrupting chemicals are largely synthesized. There are also some chemicals that are released unintentionally due to anthropogenic activities as well as natural sources. The EDCs have been generally categorized based on their industrial application, their use in consumer products, organochlorine pesticides (OCPs) and, as environmental bi-products. Though there are several identified chemicals that can be linked with the EDCs, however the ones discussed in this document have been chosen from the list of EU Category 1 of potential endocrine disruptors[7] and are categorized as: (A) Industrial applications and consumer products; (B) Organochlorine Pesticides; and (C) Environmental bi-products. The EDCs under each category are elaborated below:

6 State of the Science of Endocrine Disrup ng Chemicals- 2012 Inter-Organiza on Programme for the Sound Management of Chemicals
7 https://eng.mst.dk/chemicals/chemicals-in-products/endocrine-disruptors/the-eu-list-of-potential-endocrine-disruptors/

A. Industrial Applications and consumer products

- Bisphenol -A,
- Triclosan,
- Phthalates,
- Mercury
- Polychlorinated biphenyls (PCBs),
- Deca BDE
- Penta BDE
- Octa BDE

B. Organochlorine pesticides (OCPs)

- Lindane
- Methoxychlor,
- Chlorpyrifos,
- Dichlorodiphenyltrichloroethane (DDT) and
- Endosulfan

C. Environmental bi-products

- Dioxins
- Furans

A. Industrial Applications and Consumer Products

Chemicals are essential ingredients of industrial applications and consumer products. It is impossible to think of any products which can be manufactured or produced without the use of chemicals. However, in due course, the scientific evidences have surfaced regarding the toxic effect of some of these chemicals on the environment and human health. Globally efforts are being made to reduce its use or phase out these chemicals in order to minimize the impacts on the environment and human health.

01 Bisphenol-A (BPA)

It is a carbon-based synthetic compound that belongs to the group of di-phenyl methane derivatives and Bisphenols. BPA is primarily used as a monomer in the manufacturing of polycarbonates, a high performance transparent, rigid plastic. BPA is also used in flame retardants, unsaturated polyester resins, polysulfone (PS) resins and polyetherimides resins (PEIs), and other consumer products such as polycarbonate tableware, food storage containers, water bottles, and baby bottles. BPA is also being used in the lining of packaged food containers to avoid contact between food items and containers.[8]

1.1 Uses

- As a lining of food and drink packages
- Reusable water and infant bottles
- Impact-resistant safety equipment (Metal products, Food & beverages cans, Bottle tops, Water supply pipes)
- Dental sealants and composites
- Receipt papers at grocery store and restaurants
- The precursor of flame-retardant tetra-bromo bisphenol A
- Car safety seats
- Water coolers
- Medical devices
- Compact Discs (CDs), credit cards, cell phones, and computers
- Sports equipment
- Household electronics
- Electrical laminates

1.2 Potential Health Impacts of BPA

- Heart diseases,
- Liver toxicity
- Metabolic syndrome (diabetes obesity).[9]
- Anxiety
- Hyperactivity.[10]
- Miscarriage of fetus
- Disruptive effects in androgen or estrogen responsive tissues, within the immune system, thyroid, and the developing nervous system.[11-12]
- In animals, change in prostate growth and development, mammary gland organization, sexually dimorphic behavior, onset of oestrus cyclicity, early puberty, body weight, genital malformations syndrome.[13-14]

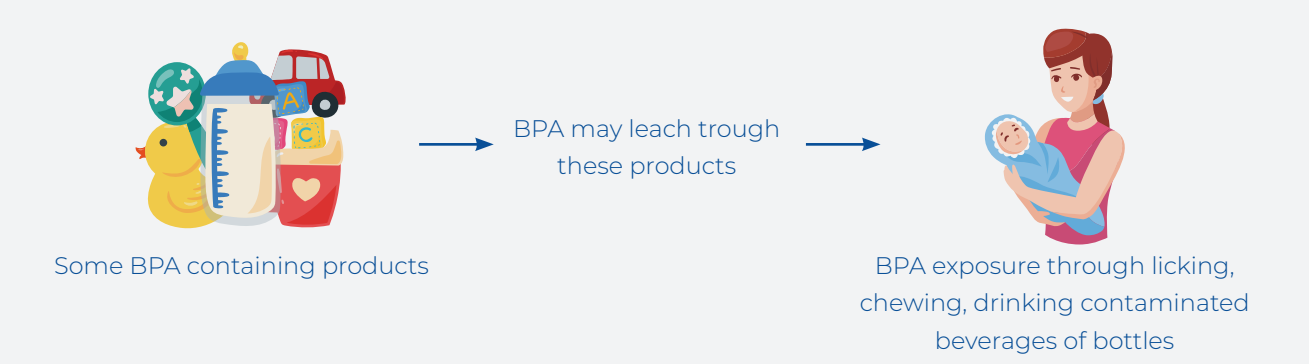
8 http://toxicslink.org/docs/BPA%20study%20report.pdf
9 Newbold RR, Padilla-Banks E, Jefferson WN, 2009 a.Environmental estrogens andobesity. Mol Cell Endocrinol, 304(1-2): 84-9.
10 BPA Exposure in Pregnancy May Affect Behavior in Girls – TIME.com". Time. 24October 2011.
11 Richter CA, Taylor, Ruhlen RL, Welshons WV, vomSaal FS, 2007. Estradiol and Bisphenol A stimulate androgen receptor and estrogen receptor gene expression in fetal mouse prostate mesenchyme cells. Environ Health Persp, 115 (6).
12 Vandenberg LN, Chahoud I, Heindel JJ, Padmanabhan V, Paumgartten FJR, Schoenfelder G,2010. Urinary, circulating, and tissue biomonitoring studies indicate widespreadexposure to Bisphenol A. Environ Health Persp, 118 (8).
13 Richter C, Birnbaum LS, Farabollini F, Newbold RR, Rubin BS, Talsness CE, Vandenbergh JG, Walser-Kuntz DR, vomSaal FS, 2007. In vivo effects of Bisphenol A in laboratory rodent studies. Reprod Toxicol, 24: 199–224.
14 Wetherill YB, Akingbemi BT, Kanno J, McLachlan JA, Nadal A, Sonnenschein C, Watson CS, Zoeller RT, Belcher SM, 2007. In vitro molecular mechanisms of Bisphenol action. Reprod Toxicol, 24(2): 178-98.

1.3 Research Studies on BPA in Foods

BPA has been widely used for various products. There are many sources of human exposure to BPA, such as through dietary intake, environmental exposure as well as consumer products. The exposure through diet includes release and migration from food packaging and repeat-use polycarbonate containers such as baby bottles. The exposure through environmental media is from ambient air, indoor air, drinking water, soil and dust. The exposure is also from the use of some of the consumer products. However, research studies indicate that dietary exposure is the major source of BPA exposure and that makes it very important to monitor levels of BPA contamination in food. The wide use of BPA in products may also indicate a broad spectrum of exposure routes, although certain product types such as baby feeding bottles and cash receipts may be more prevalent for babies and cashiers, respectively.[15],[16]

There are several research studies showing the presence of BPA in different samples. A group of researchers found it in thanksgiving canned food. Another group of research studies have found the presence of BPA in pastas/soups, vegetables, infant formula samples, juices/beverages, ready-to-consume energy/sports/soft drinks, fruit products, pie fillings, coconut milk, curry products, etc. These details are presented in Table-1.

Figure 2: Sources and route of exposure to BPA



1.3.1 International studies

Table 1: International studies on BPA

Year	Authors	Institute	Title	Important Findings
2019	Adebola A. Adeyi & Babafemi A. Babalola[17]	University of Ibadan	Bisphenol-A (BPA) in Foods commonly consumed in Southwest Nigeria and its Human Health Risk	• Eight diferent food categories were selected for this study • Vegetable oil had the highest BPA concentration (28.4ng/g). This was followed by aquatic canned fish (26.3ng/g), canned beef (21.3ng/g) and crayfish (17.5ng/g). • The adult population had an average dietary intake of 30.4ng/kg bw/day.

15 Huang YQ, et al, Bisphenol A (BPA) in China: A review of sources, environmental levels, and potential human health impacts, Environ Int (2011), doi:10.1016/j.envint.2011.04.010
16 http://toxicslink.org/docs/Factsheet-46-on-BPA.pdf
17 Adebola A. Adeyi & Babafemi A. Babalola. Bisphenol-A (BPA) in Foods commonly consumed in Southwest Nigeria and its Human Health Risk. Sci Rep 9, 17458 (2019).

Year	Authors	Institute	Title	Important Findings
2016	Leena Omer, Hassn Ahmed and Abdalla Elbashir[18]	University of Khartoum	Determination of Bisphenol- A in exposed bottled water samples to direct sun light using multi walled carbon nanotubes as solid phase extraction sorbent	• Trace amounts of BPA was detected in 10 different brands of bottled water samples from Khartoum supermarkets • The mean concentration of BPA in 10 bottled water brands was 4.28 ng/ml for those stored at room temperature (25°C) and 11.81 ng/ml for those exposed to direct sunlight (40°C) • The concentration of BPA in bottled water exposed to direct sun light was significantly higher than those stored at room temperature
2014	-	An independent research organization (Breast Cancer Funds)[19]	BPA in Thanksgiving Canned Food	• 23 of the 28 samples were found BPA between 2 and 221 ppb. • As per their view, single 120 g serving of a food with a BPA concentration at or above 11 ppb would lead to exposures comparable to those that lab studies have associated with disruptions to in utero brain development.[20-21] • Twelve of the food cans that they tested would lead to exposures at those levels in a woman of average weight (65.4 kg or 144 lbs.).[22]
2014	-	Consumer Group Choice[23]	BPA in canned food	• 33 out of the 38 products they tested contained BPA • Just one serving of 29 of them delivered a dose that exceeded a safe daily level of exposure for a 70kg adult.
2013-2014	-	Canadian Food Inspection Agency (CFIA)[24]	-	• 391 Samples tested which included 93 pastas/soups, 70 vegetables, 55 infant formula samples, 54 juices/beverages, 43 ready-to-consume energy/sports/soft drinks, 38 fruit products, 20 pie fillings, 13 coconut milk, and 5 curry products. • BPA was detected in 65.5% of the surveyed samples. • The level of detection for all samples ranged from 0.001 ppm (found in a tropical fruit salad sample) to 0.565 ppm (detected in a single corn sample).

18 Leena Omer, Hassn Ahmed and Abdalla Elbashir. Determination of bisphenol A in exposed bottled water samples to direct sun light using multi walled carbon nanotubes as solid phase extraction sorbent. Journal of Environmental Chemistry and Ecotoxicology. Vol. 8(7), pp. 51-57, July, 2016

19 https://d124kohvtzl951.cloudfront.net/wp-content/uploads/2017/03/02025221/Report_BPA-in-Thanksgiving-Canned-Food_November-2011.pdf

20 Nishizawa H, Imanishi S, Manabe N (2005). Effects of exposure in utero to bisphenol A on the expression of aryl hydrocarbon receptor, related factors, and xenobiotic metabolizing enzymes in murine embryos. J Reprod Develop, 51(3):593-605.

21 Nishizawa H, Morita M, Sugimoto M, Imanishis S, Manabe N (2005). Effects of in utero exposure to bisphenol A on mRNA expression of arylhydrocarbon and retinorid receptors in murine embryos. J Reprod Develop, 51(5):315-24.

22 EPA (1997). 1997 Exposure Factors Handbook, National Center for Environmental Assessment, Office of Research and Development, Volume 1 – General Factors, Chapter 7 – Body Weight Studies. Washington, DC. oaspub.epa.gov/eims/eimscomm.getfile?p_download_ id=50344

23 https://www.choice.com.au/food-and-drink/food-warnings-and-safety/plastic/articles/bpa-in-canned-foods

24 http://www.inspection.gc.ca/food/chemical-residues-microbiology/food-safety-testing-bulletins/2016-11-10/bisphenol-a-in-canned-foods/eng/1478624666677/1478624721121

Year	Authors	Institute	Title	Important Findings
2010	-	National Workgroup for Safe Markets,(a coalition of U.S. public health- and environmental health-focused NGOs)	No Silver Lining An -Investigation into Bisphenol A in Canned Foods[25]	• 92% of the canned food samples collected from USA and Canada. • The highest level of BPA detected was 1,140 (ppb).
2010	Ren J and Jiang SJ.[26]	Not observed	An investigation on pollution situation of 4-Nonylphenol and Bisphenol A in some vegetable products in Haikou city	• Results indicated that Bisphenol A were detected in whole five species vegetable samples, and it was detected especially in all Chinese cabbage and rapeseed plant samples, the average contents was 0.43-5.31 µg/kg • It was concluded that BPA and their downstream products are used in China widely, there may have caused pollution of some vegetables

1.3.2 Indian studies

As of now only one study in the Indian context was found which showed that BPA was present in various powdered, fruit based and milk-based baby food. This study was published at a conference. The details of the finding are presented below.

Table 2: Indian studies on BPA

Year	Authors	Institute	Title	Important Findings
2017	Meeta Rakesh, &Jayashree Parker[27]	Department of Chemistry, GN Khalsa College, Mumbai, India	Determination of BPA in commercial baby foods in India, using QuEChERS extraction, one pot derivatization and GC-MS analysis.	• The concentration of BPA found in various powdered, fruit based and milk-based baby foods ranged from < 1.04 to 26.19 ng g-1. • It was concluded that the dietary intakes of BPA from baby foods present in the Indian market are of grave concern to children's health.

1.4 Regulations of BPA in Food

There are a number of research studies which have established the characteristic of BPA as EDCs, and hence efforts have been made to restrict the presence of the chemicals in various products. There are many countries that have phased out BPA in baby feeding bottles, teether, thermal paper etc. Generally, BPA is not added intentionally or a constituent in any of the food products, so there is no legal mandate by any countries to ban BPA in food. However, BPA is being used in consumer products as well as in food contact materials, therefore, many countries have regulations in place to restrict BPA based food packaging or dispensing products.

25 https://www.cleanwaterfund.org/files/publications/mn/no_silver_lining_report_bpa.pdf
26 Ren J, Jiang SJ. An investigation on pollution situation of 4-Nonylphenol and Bisphenol A in some vegetable products in Haikou city. Mod Prev Med 2010;37:451–5.
27 Rakesh, Meeta & Parker, jayashree. (2017).Determination of BPA in commercial baby foods in India, using QuEChERS extraction, one pot derivatization and GC-MS analysis.

1.4.1 International regulations

Table 3: Tolerable daily intake (TDI) limits for BPA and health-based guideline values of some countries

Country/Organization	TDI (µg/kg bw/day)
European Food Safety Authority (EFSA)	4
Australia	50
China	50
Korean Food Safety Authority	50
India	No standards

Table 4: BPA health-based guidance values of international organizations

Organization[28]	Endpoint	Point of departure (POD)	Uncertainty Factors(UFs)	Health based guidance values(HbGV)
EFSA	Reduced body weight and liver toxicity	NOAEL 5 mg/kg bw/day	100	TDI 0.05 mg/kg bw/day
Health Canada	Reduced body weight	LOAEL 25 mg/kg bw/day	1,000	pTDI 0.025 mg/kg bw/day
U.S.EPA	Reduced body weight	LOAEL 50 mg/kg bw/day	1,000	RfD 0.05 mg/kg bw/day
NSF International	Reduced body weight and liver toxicity	NOAEL 5 mg/kg bw/day	300	RfD 0.016 mg/kg bw/day
NSF International- National Science Foundation, NOAEL- Non-Observed Adverse Effect Level, LOAEL- Lowest-Observed-Adverse-Effect Level, RfD- reference dose				

1.4.2 Indian regulations

In India, there is no specific regulation meant for BPA in food items nor is any TDI limit prescribed for the food. However, feeding bottles are regulated by the Infant Milk Substitutes, Feeding Bottles, and Infant Foods (Regulation of Production, Supply, and Distribution) Act, 1992 as Amended in 2003 (IMS Act). The act mandates that all the baby feeding bottles to be sold in India will be subjected to checking based on standard IS-14625 specified by the Bureau of Indian Standards (BIS).

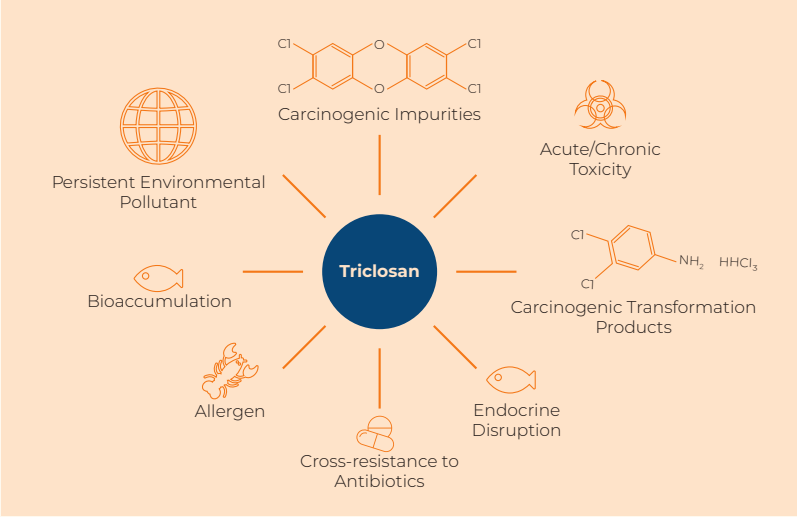
The Bureau of Indian Standard (BIS) has revised the standard for baby feeding bottles in 2015 and the notification has stated that BPA will not be used in baby feeding bottles. In addition to this, it was also suggested by the concerned ministry to phase out BPA from cup, spout, and straw with the possible amendment into the definition of feeding bottle in the IMS act. The revised definition will be "Any bottle or receptacle used for the purpose of feeding infant milk substitute through a teat or drinking accessory attached or capable of being attached to such bottle or receptacle".

28 https://www.researchgate.net/profile/Myung_Sil_Hwang/publication/258924888_Establishment_of_the_Korean_Tolerable_Daily_Intake_of_Bisphenol_A_Based_on_Risk_Assessments_by_an_Expert_Committee/links/55a44f6e08aef604aa03d712/Establishment-of-the-Korean-Tolerable-Daily-Intake-of-Bisphenol-A-Based-on-Risk-Assessments-by-an-Expert-Committee.pdf?origin=publication_detail

02 Triclosan

Triclosan [5-chloro-2-(2, 4-dichlorophenoxy) phenol] is a chlorinated aromatic chemical having antimicrobial and antifungal properties.[29] However, the antimicrobial properties of Triclosan vary as at low doses it is bacteriostatic in nature and at higher doses it becomes bactericidal.[30] Due to these antibiocidal and antibacterial properties, Triclosan has been used as a preservative and antibacterial agent in personal care products, soaps, and veterinary uses, industrial and household products. Triclosan has also been categorized as a halogenated aromatic hydrocarbon having phenolic, diphenyl ether and polychlorinated biphenyl (PCB) substructures. Hence, they are related to many toxic compounds such as PCBs, polybrominated biphenyl ethers, Bisphenol-A, and dioxins.[31-32]

Figure 3: Effects of Triclosan[33]



2.1 Uses

As a preservative and antibacterial agent in personal care products, soaps, veterinary uses, industrial, and household products such as:

- Antiseptic soaps,
- Cosmetics,
- Deodorant,
- Detergents,
- Toothpaste,
- Mouthwash,
- Hair products, etc.

29 Courtney, K.D.; Moore, J.A. Teratology studies with 2,4,5-trichlorophenoxyacetic acid and 2,3,7,8-tetrachlorodibenzo-P-dioxin. Toxicol. Appl. Pharmacol. 1971, 20, 396–403

30 Yazdankhah, S. P., A. A. Scheie, E. A. HØiby, B.-T. Lunestad, E. Heir, T. Ø. Fotland, K. Naterstad & H. Kruse: Triclosan and antimicrobial resistance in bacteria: an overview. Microbial Drug Resistance 2006, 12, 83-90.

31 Ahn, K.C.; Zhao, B.; Chen, J.; Cherednichenko, G.; Sanmarti, E.; Denison, M.S.; Lasley, B.; Pessah, I.N.; Kültz, D.; Chang, D.P.Y.; et al. In vitro biologic activities of the antimicrobials triclocarban, its analogs, and triclosan in bioassay screens: Receptor-based bioassay screens. Environ. Health Persp. 2008, 116, 1203–1210, doi:10.1289/ehp.1120

32 Allmyr, M.; Harden, F.; Toms, L.M.L.; Mueller, J.F.; McLachlan, M.S.; Adolfsson-Erici, M.; Sandborgh-Englund, G. The infl uence of age and gender on triclosan concentrations in Australian human blood serum. Sci. Total Environ. 2008, 393, 162–167, doi:10.1016/j.scitotenv.2007.12.006

33 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3974611/

2.2 Potential Health Impacts

- Skin irritation,
- Hormone disruption,
- Interference with muscle function,
- Contribution to antibacterial resistance,
- Detrimental effects on the central nervous system,
- Possibly linked to allergies and asthma

2.3 Research Studies on Triclosan

Triclosan (TCS) is a multi-purpose antimicrobial agent used as a common ingredient in everyday household personal care and consumer products. The physico-chemical properties indicate the bioaccumulation and persistence potential of TCS in the environment. The bioaccumulation and slow conversion of methyl TCS in lower level consumers could serve as potential carriers of Triclosan from the environment to higher level consumers in the food chain. Hence, there is an increasing concern about the presence of TCS in the environment and its potential negative effects on human and animal health.[34]

Oral exposure from Triclosan can also occur from the use of products in and around the mouth, as well as from hand-to-mouth contact such as toothpaste, soap, moisturizer, etc. Children have higher exposures to Triclosan because of their hand-to-mouth activities. As Triclosan is fat-soluble, it does not get rapidly flushed out of the body, but rather is stored in fat and bioaccumulates in the food chain.[35]. Research studies have confirmed the presence of Triclosan in food samples, and human milk.[36]

2.3.1 International studies

A few research studies that have confirmed the presence of Triclosan in human milk samples and food chain are presented in Table 5.

Table 5: International studies on Triclosan

Year	Authors	Institute	Title	Important Findings
2011	-	Food & Water Watch organization, Washington DC	Triclosan: What the Research Shows, 2008-2010	• The studies have found food chain contamination from Triclosan that spread in agriculture field from both the sludge and wastewater by absorption of the root system of the crops. The migration could be observed in the other parts of the plant, including the fruits/beans.[37]
2011	Toms LM, Allmyr M, Mueller JF, Adolfsson-Erici M, McLachlan M, Murby J, Harden FA.[38]	National Research Centre for Environmental Toxicology (Entox), The University of Queensland, Brisbane, Australia.	Triclosan in individual human milk samples from Australia.	• Triclosan was detected in individual human milk samples (n=151) collected between 2002 and 2005 from primiparous Australian mothers. • The distribution of Triclosan concentration was 7.2% of the samples below the Limit of Quantification (LOQ), 66% with a concentration of less than or equal to 1 ng/g fresh weight and the remaining samples above 1 ng/g reaching a maximum concentration of 19 ng/g fresh weight.

34 Gurpreet Singh Dhillon, Surinder Kaur, Rama Pulicharla, Satinder Kaur Brar, Maximiliano Cledón, Mausam Verma, Rao Y. Surampalli. Int J Environ Res Public Health. 2015 May; 12(5): 5657–5684. PDF is available on https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4454990/
35 http://toxicslink.org/docs/Triclosan.pdf
36 https://pdfs.semanticscholar.org/e3ca/ff729db2870f069a147264fd201f1e690fbd.pdf
37 https://www.foodandwaterwatch.org/sites/default/files/triclosan_research_2008-2010_fs_feb_2011.pdf
38 https://www.ncbi.nlm.nih.gov/pubmed/22000243

2.3.2 Indian studies

In India, the studies involved analysis of river water, sediment, and fishes of River Gomati and Kaveri and have found traces of Triclosan in sediment. The study on River Kaveri has established bioaccumulation of Triclosan in freshwater fish. In India, there are no standards for Triclosan content in food or food products but Maximum Authorized Concentration (MAC) of Triclosan as preservatives in cosmetics are defined as 0.3%. The details of the research studies on Triclosan in India are as presented in Table-6.

Table 6: Indian studies on Triclosan

Year	Authors	Institute	Title	Important Findings
2018	Nag S. K., Das Sarkar S., Manna S. K.[39]	Fishery Resource and Environmental Management Division, ICAR-CIFRI, Kolkata	Triclosan - an antibacterial compound in water, sediment and fish of River Gomati, India.	• Triclosan was detected in the range of 1.1-9.65 µg/L while in sediments the level was 5.11-50.36 µg/kg. It was also found in fishes of different species in concentrations ranging from 13 to 1040 µg/kg on wet weight basis.
2011	Govindaraj Shanmugam, Karthik Ramasamy, Krishna Kumar Selvaraj, Srimurali Sampath, and Babu Rajendran Ramaswamy,	Bharathidasan University, Tiruchirappalli, Tamil Nadu	Triclosan in Fresh Water Fish Gibelion Catla from the Kaveri River, India, and Its Consumption Risk Assessment	• Found 0.73–50ng/g wet weight (ww) of Triclosan in Gibelion Catla collected from the Kaveri River, India. • The authors claim that this investigation is the first to report the bioaccumulation of Triclosan in freshwater fish from India.40

2.4 Regulations of Triclosan in food

2.4.1 International regulations

- Triclosan is generally not added intentionally in the food products so globally there is no regulation in place for the food products. However, some of the countries have the regulation in place on the use of Triclosan in food contact particles and in cosmetics/ personal care products. In US (USFDA, USEPA), European Union, Japan and Germany, the use of Triclosan in food contact plastics is banned since September 2009. Furthermore, there is a complete prohibition of Triclosan as food preservatives.
- In 2016, the U.S. Food and Drug Administration (FDA) banned nineteen antimicrobial ingredients, including Triclosan and Triclocarban, in over-the-counter consumer antiseptic wash products based on insufficient evidence demonstrating their safety for long-term daily use and that they reduce the spread of illness and infection.[41]
- In Europe Triclosan is not approved as a food preservative.[42]
- The use of Triclosan is governed by different regulations in countries such as Canada, Brazil, China, Japan, and Australia.[43]
- The European Commission restricted Triclosan to a maximum concentration of 0.2% in mouthwashes and 0.3% in other cosmetic products such as toothpaste, hand soaps and face powders. However, some of the EU countries have banned Triclosan completely.

39 Nag S. K., Das Sarkar S., Manna S. K. (2018) Triclosan- an antibacterial compound in water, sediment and fish of River Gomti, India. Int J Environ Health Res. 2018 Oct;28(5):461-470. doi: 10.1080/09603123.2018.1487044.
40 Govindaraj Shanmugam, Karthik Ramasamy, Krishna Kumar Selvaraj, Srimurali Sampath, and Babu Rajendran Ramaswamy, (2014) Triclosan in Fresh Water Fish Gibelion Catla from the Kaveri River, India, and Its Consumption Risk Assessment, Environmental Forensics, 15:207–212,
41 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5644973/
42 https://copublications.greenfacts.org/en/triclosan/l-2/2-uses-cosmetics-disinfectant.htm
43 http://triclosan.basf.com/general-information-about-triclosan-/regulatory

- The European Union announced in June 2015 that the anti-bacterial pesticide, Triclosan, is toxic and bio-accumulative and will be phased-out from products used for hygiene purposes and replaced by more suitable alternatives. According to the European Chemicals Agency (ECHA), "No safe use could be demonstrated for the proposed use of Triclosan." The ECHA opinion states that "Risk was identified for both surface water and for the non-compartment specific effects relevant to the food chain (secondary poisoning)".
- Minnesota is the first state in USA that has banned the use of Triclosan in most retail consumer hygiene products.
- In Australia, the maximum permissible limit of Triclosan in cosmetics is 0.3%.
- In Japan, Triclosan is included in the Standards for Cosmetics (as established by the Pharmaceutical Affairs Law, 1960), which sets a maximum allowable concentration of 0.1% in cosmetic products (Ministry of Health and Welfare Notification No. 331, 2000).

2.4.2 Indian regulations

- As per the Bureau of Indian Standards on the classification of cosmetics raw materials and adjuncts, the Maximum Authorized Concentration (MAC) of Triclosan as preservatives in cosmetics is 0.3%. Though Triclosan has not been forbidden from use in these products, there are products available in the markets that have been clearly labeled as "No Triclosan". However, there is no standard on triclosan in food contact materials or food preservatives.

03 Phthalates

Phthalates or phthalate esters are esters of Phthalic acid (1, 2-benzene dicarboxylic acid), and are mainly used as plasticizers. These are substances added to plastics to increase their flexibility, transparency, durability, and longevity. Phthalates are commonly used in personal care products as skin moisturizers, skin softeners, skin penetration enhancers, stabilizers, dispersants and lubricants, binders, emulsifying agents, solvents, and suspending agents. Phthalates are also used as anti-brittleness and anti-cracking agents in nail polishes and sealants, as anti-foaming agents in aerosols[44-45].

3.1 Uses

- Fragrances
- Shampoo
- Hairspray
- Shaving creams and lotions
- Cosmetics

3.2 Potential Health Impacts

- Phthalates are hormone-disrupting chemicals that pose a serious threat to the health of pregnant women and children.
- Studies have linked prenatal exposure to phthalates to abnormal development and function of the brain and reproductive system, male reproductive health (lowering of sperm count, less mobile sperm, birth defects, etc.).
- Phthalates are also associated with obesity, diabetes, and irregularities of thyroid.[46]
- Phthalates and their metabolites have been found potentially harmful for human and environment due to their hepatotoxic, teratogenic, and carcinogenic characteristics.[47]
- Topical exposure to Phthalate esters in cosmetic products may contribute to the observed urinary levels of mono-esters (metabolites of phthalate esters) in humans.[48]
- Phthalates have potentially toxic effects to the developing endocrine and reproductive systems.
- High doses have been shown to change hormone levels and cause birth defects.[49]
- Phthalate also can cause anti-androgenicity in adult men.[50]

44 H. J. Koo and B. M. Lee, Es mated exposure to phthalates in cosmetics and risk assessment, J. Toxicol. Env. Health A, 67, 1901–1914 (2004).
45 Cosmetic ingredient review, Annual review of cosmetic ingredient safety assessments 2002/2003, Int. J. Toxicol., 24(suppl. 1),1–102 (2005).
46 http://kleanupkraft.org/data-summary.pdf
47 Matsumoto M, Hirata-Koizumi M, Ema M (2008) Potential adverse effects of phthalic acid esters on human health: a reviewof recent studies on reproduction. Regul Toxicol Pharm 50:37–49
48 National Toxicology Program, Center for the Evaluation of Risks to Human Reproduction, NPT-CERHR Expert Panel Report onDi-n-Butyl Phthalate, October 2000.
49 Third National Report on Human Exposure to Environmental Chemicals, (PDF) U.S. CDC, July 2005.
50 Albert, O.; Jegou, B. (2013). "A critical assessment of the endocrine susceptibility of the human testis to phthalates from fetal life to adulthood". Human Reproduction Update 20 (2): 231. doi:10.1093/humupd/dmt050. PMID 24077978

3.3 Research Studies on Phthalates

The key characteristics of the Phthalate are its durability, flexibility, weather resistance, and ability to withstand high temperature.[51-52] Because of its characteristic, it is being used in various products but researchers have conducted detailed research and confirmed the presence of phthalates in food, food packaging material, etc. In one study, the Phthalates (DBP, BBP & DEHP), and Nonylphenol were found to be migrating from PVC packaging in UK supermarket foods.

3.3.1 International studies

Phthalates are soluble in fat and therefore are commonly found in fat-containing foods.[53-54] Phthalates can also migrate into foods (particularly fatty foods such as cheese and meat) from plastic food wrappings and possibly printing inks used in wrappers.[55-56]It can also enter into the food items during its processing, quite often due to the use of PVC in food production and processing systems.[57-58] A number of studies of fat-containing food items have suggested that the presence of Phthalates in food is due to general contamination of the environment and food chain[59-60]. Hence, ingestion of phthalates in food can occur irrespective of the packaging and/or processing involved. Many researchers have estimated the different levels of phthalates in packaged food, milk products, baby food, etc. Detailed findings of the studies are presented in Table 7.

Table 7: International studies on Phthalates

Year	Authors	Institute	Title	Important Findings
2020	Wei Xiang , Qin Gong, Jian Xu, Kailong Li, Fengxiang Yu, Ting Chen, Si Qin, Can Li, Fangbin Wang[61]	Crop Research Institute, Hunan Academy of Agricultural Science, Changsha, China	Cumulative risk assessment of phthalates in edible vegetable oil consumed by Chinese residents	• total of 1016 samples of four major edible vegetable oil sources: an edible oil blend, soybean oil, peanut oil and rapeseed oil were analysed for DEHP and DBP • The phthalate with the highest detection rate was DBP (13.48%), followed by DEHP (7.78%). • Contamination levels of phthalates in the soils where oil crops are cultivated have a great influence on the phthalate concentrations in edible vegetable oils.
2018	-	The Centre for Safety of the Food and Environmental Hygiene Department (FEHD), Government of the Hong Kong[62]	-	• A total of 317 samples in 16 food groups were tested for 7 Phthalates and observed that the vast majority of them (310 samples or 98%) found at least one phthalate at quantifiable levels and only 7 samples (2.2%) were found free from the seven Phthalates tested. • Among the seven Phthalates examined, DEHP was the most commonly detected Phthalate compound, followed by DINP, BBP, DBP, DIDP, DEP and DNOP.

51 https://www.cdc.gov/biomonitoring/phthalates_factsheet.html
52 https://phthalates.americanchemistry.com/Consumers/Uses-and-Applications/
53 MAFF (Ministry of Agriculture Fisheries and Food), UK (1998). Food Surveillance Information Sheet, Number 168. Phthalates in infant formulae- Follow-up survey
54 Sharman, M., Read, W.A., Castle, L. and Gilbert, J. (1994) Levels of di-(2-ethylhexyl)phthalate and total phthalate esters in milk, cream, butter and cheese. Food Addit Contam., 11, pp375-385
55 Schettler T. (2006). Human exposure to phthalates via consumer products. Int J Androl., 29(1), pp134-9
56 Greenpeace UK (2004). The determination of additives in food products. http://www.greenpeace.org.uk/MultimediaFiles/Live/FullReport/6120.pdf
57 Tsumura Y, Ishimitsu S, Kaihara A, Yoshii K, Nakamura Y, Tonogai Y. (2001a). Di(2-ethylhexyl) phthalate contamination of retail packed lunches caused by PVC gloves used in the preparation of foods. Food Addit Contam., 18(6), pp569-79
58 Tsumura Y, Ishimitsu S, Saito I, Sakai H, Kobayashi Y, Tonogai Y. (2001b). Eleven phthalate esters and di(2-ethylhexyl) adipate in one-week duplicate diet samples obtained from hospitals and their estimated daily intake. Food Addit Contam., 18(5)
59 MAFF (Ministry of Agriculture Fisheries and Food), UK (1998). Food Surveillance Information Sheet, Number 168. Phthalates in infant formulae- Follow-up survey
60 MAFF (Ministry of Agriculture Fisheries and Food) UK (1996). Food Surveillance Information Sheet, Number 82. Phthalates in food
61 Xiang et al. Cumulative risk assessment of phthalates in edible vegetable oil consumed by Chinese residents. J Sci Food Agric. 2020 Feb;100(3):1124-1131
62 https://www.cfs.gov.hk/english/programme/programme_rafs/files/Phthalates_in_Food_e.pdf

Year	Authors	Institute	Title	Important Findings
2016	Long-Kai, S.; Ming-Ming, Z.; Yu-Lan, L[63]	-	Concentration and survey of phthalic acid esters in edible vegetable oils and oilseeds by gas chromatography-mass spectrometry in China	• PAE concentrations in thirty-four edible oils and twenty-eight oilseeds were evaluated. • Five and thirteen oil samples exceeded the upper limits 1.5 and 0.3 mg/kg set for di(2-ethtlhexyl) phthalate and dibutyl phthalate in China, respectively.
2016	Jarošová A., Bogdanovičová S.[64]	Mendel University, Brno	Phthalates in meat products in dependence on the fat content	• leaching of DEHP and DBP from a package into food was 2 - 21 times higher in samples with 50% of fat than in samples with 10% of fat.
2014	Ihsan Ustun, Sana Sungur, Ramazan Okur, Ahmet Taner Sumbul, Suleyman Oktar, Nigar Yilmaz & Cumali Gokce[65]	Endocrinology Division, School of Medicine, Mustafa Kemal University, Turkey	Determination of Phthalates Migrating from Plastic Containers into Beverages	• The mean phthalate concentrations were determined to be between 0.095 and 0.633 mg/L in soda, 0.018 and 1.219 mg/L in lemonade, 0.019 and 1.123 mg/L in cola, and 0.085 and 0.312 mg/L in mineral water • (DEHP) showed the highest level of migration into beverages
2013	Francisco Bono-Blay 1, Albert Guart, Boris de la Fuente, Marta Pedemonte, Maria Cinta Pastor, Antonio Borrell, Silvia Lacorte[66]	Department of Environmental Chemistry, IDAEA-CSIC, Barcelona, Spain	Survey of phthalates, alkylphenols, bisphenol A and herbicides in Spanish source waters intended for bottling	• Out of twelve samples phthalates were detected in two samples with 0.0018 µg/L as limitation of quantification.
2012	T Fierens, K Servaes, M Van Holderbeke, L Geerts, S De Henauw, I Sioen, G Vanermen	An independent VITO (Flemish Institute for Technological Research), Belgium	Analysis of Phthalates in food products and packaging materials sold on the Belgian market	• Tested thirteen ortho-Phthalates in 30 cheese products and Phthalates were detected in nearly every cheese product that tested (29 of 30 varieties). • The most widely restricted Phthalate was found more often and at a much higher average concentration than any other Phthalate, among all the cheese products tested.67

63 Long-Kai, S.; Ming-Ming, Z.; Yu-Lan, L. Concentration and survey of phthalic acid esters in edible vegetable oils and oilseeds by gas chromatography-mass spectrometry in China. Food Control. 2016, 68, 118–123

64 https://doi.org/10.5219/621

65 https://link.springer.com/article/10.1007/s12161-014-9896-5

66 https://pubmed.ncbi.nlm.nih.gov/22421799/

67 Fierens, Tine & Servaes, Kelly & Van Holderbeke, Mirja & Geerts, Lieve & De Henauw, Stefaan & Sioen, Isabelle & Vanermen, Guido. (2012). Analysis of phthalates in food products and packaging materials sold on the Belgian market. Food and chemical toxicology : an international journal published for the British Industrial Biological Research Association. 50. 2575-83. 10.1016/j.fct.2012.04.029. Pdf available on-http://kleanupkraft.org/data-summary.pdf

3.3.2 Indian studies

In India, studies have reported the migration of DEHP from packaging into fatty foods. The details of the finding are presented in Table 8.

Table 8: Indian studies on Phthalates

Year	Authors	Institute	Title	Important Findings
2016	Srinivasan K., Kumaravel S. and Singaravadivel K.[68]	Department of Food Safety & Quality Testing, INDIA	Phthalate leachate in selected plastic packed food Products - A GC-MS Study	• Food products (tea, sambar, alcohol) were tested • The study revealed the fact that the Phthalates are highly soluble in oily food products. • DEHP, a plasticizer can migrate from packaging into fatty foods
2016	Selvaraj K.K., Mubarakali H., Rathinam M., Harikumar L., Sampath S., Shanmugam G., & Ramaswamy B.R.	Department of Environmental Biotechnology, School of Environmental Sciences, Bharathidasan University,India	Cumulative exposure and dietary risk assessment of phthalates in bottled water and bovine milk samples: A preliminary case study in Tamil Nadu, India	• Total phthalates in bottled water and milk were in the range of 39–7820 ng/L and 56–686 ng/g, respectively, with the highest contribution from diethylhexyl phthalate (DEHP).

3.4 Regulations of Phthalates in food

3.4.1 International regulations

- European Union restricted the articles to be placed in the market, intended for use indoors and articles that may come into direct contact with the skin or mucous membranes, which contain one or more of the four Phthalates in a concentration greater than 0.1 % by weight of any plasticized material. The four phthalates are: DEHP (bis (2-ethylhexyl) phthalate; DBP (dibutyl phthalate; BBP (benzyl butyl phthalate and DIBP (diisobutyl phthalate).[69]
  Currently, the international acceptance criteria for the daily maximum consumption of Phthalates range from 0.6-30 mg for a 60 kg adult, depending on the Phthalate compound
- Taiwan has established a standard of 1 ppm for six phthalates (DEHP, DIDP, DINP, BBP, DBP, and DNOP) and China has established standards of DBP 0.3 ppm; DINP 9 ppm; and DEHP 1.5 ppm.
- The Canadian Food Inspection Agency (CFIA) issued an advisory about the DEHP problem in Taiwan, followed by an alert two days later, and recalled multiple products imported from Taiwan throughout June 2018.

68 Srinivasan K., Kumaravel S. and Singaravadivel K., (2016) Phthalate Leachates in Selected Plastic Packed Food, Products- A GC-MS Study., International Journal of Research in Chemistry and Environment, Vol. 6 Issue 1 (18-20)

69 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014XC0809(01)&from=EN

Table 9: Overview table of critical toxic effects and Tolerable Daily Intakes (TDI)[70]

Phthalate	TDI (in mg/kg body wt / day	Critical Toxics Effects on
DEPH	0.5	Reproduction
BBP	0.5	Reproduction and development
DBP	0.01	
DINP	0.15	Liver
DIDP	--	-
DNOP	No TDI available	Liver and Thyroid
DIBP	--	Reproduction and Development

3.4.2 Indian regulations

- The Bureau of Indian Standards (BIS) has updated its requirements for Phthalates in toys to align with the Phthalate limit that are currently in place in more than 30 countries, including the United States, Canada and member-states of the EU. India's new limit on Phthalates will now align with guidelines set forth by the U.S. Consumer Product Safety Commission (CPSC), which stipulates that toys and childcare articles may not contain more than 0.1% of each banned Phthalate.
- Previously, BIS had limited the level of Phthalates in toys to 0.1%; however, the limit was for the total of three Phthalates (DEHP, DDP and DBP or DINP, DIDP, and DNOP) and not for each of these.
- In India, there are no such regulations meant for Phthalates in food items/ingredients.
- The Bureau of Indian Standards (BIS), proposed to restrict the use of Phthalates (and other three chemicals viz., toluene, titanium, acetylacetonate) in the printing of packaging materials used for food products. The above-mentioned materials will be included in the existing exclusion list in the current standard (IS 15495).

70 https://www.sgs.com/en/news/2011/10/phthalates-contamination-in-food-products

04 Mercury

Mercury (chemically named Hg) is a naturally occurring substance in the earth's crust and is usually found as cinnabar which is mined and refined to obtain pure mercury. It is the most toxic heavy metal which is liquid at room temperature and evaporates easily. However, mercury has a wide application in product manufacturing and industrial processes. Naturally occurring mercury is often found in very small amounts in oceans, rocks and soils, which become airborne when rocks erode, volcanoes erupt and, soil decomposes. Moreover, anthropogenic source accounts for 30% of the total amount of mercury entering the atmosphere each year. The main industrial sources of atmospheric mercury are coal burning, mining, industrial activities that process ores to produce various metals or process other raw materials to produce cement. Further the mercury also released from the mercury added products like lamps, health care instruments and measuring devices.[71]

4.1 Uses

Mercury is used in various products and processes, which includes:

- Healthcare instruments,
- Dental amalgam,
- Batteries,
- CFL and other lighting equipment,
- Paints
- Cosmetics,
- Traditional Ayurveda, Siddha medicines and cultural products.

The various processes where mercury is used include Chlor-alkali process, vinyl chloride monomer, etc.

4.2 Potential Health Impacts

- Mercury is a naturally occurring substance, which contains neuro and nephrotoxins and can damage kidney and central nervous system
- Mercury bio-accumulates and bio-magnifies, which makes it unmanageable
- Mercury can pass through skin, blood-brain & placental barrier and can cause devastating effects on the function and growth of the brain and the growing fetus
- The ability of trans-continental or trans-boundary movement beyond one country to other makes mercury an issue of global concern

71 Satish Sinha, Kankana Das, 2014, Mercury free India- Right Choices. Toxics Link

4.3 Research Studies on Mercury in Foods

Mercury is a toxic heavy metal that is widely dispersed in nature. Most human exposure results from fish consumption or dental amalgam. The levels of mercury and methyl mercury in fish has been studied extensively by researchers world wide. Some research studies focus on particular geographical locations suspected to have mercury or methyl mercury such as coal-fired power plants in China.

4.3.1 International studies

Many researchers have estimated the levels of mercury and methyl mercury in fish, grains etc. Some of the recent research studies are presented in Table 10.

Table 10: International studies on Mercury

Year	Authors	Institute	Title	Important Findings
2020	McCormick A., Robertson M.D., Brasso R., Midway S.R.[72]	Department of Oceanography and Coastal Sciences, Louisiana State University Department of Oceanography and Coastal Sciences, Louisiana State University	Mercury concentrations in store-bought shrimp	• 159 shrimp from 10 different brands were analyzed for mercury • the mean of mercury concentration for all shrimp sampled was 0.02 ± 0.01 ppm ww. • the lowest fat shrimp (1 g) having significantly more mercury than the highest fat shrimp (2 g)
2017	Renata Kuras, Beata Janasik, Magdalena Stanislawska, Lucyna Kozlowska, and Wojciech Wasowicz[73]	Department of Biological and Environmental Monitoring, Nofer Institute of Occupational Medicine, 8 Teresy St, 91-348 Lodz, Poland	Assessment of Mercury Intake from Fish Meals Based on Intervention Research in the Polish Sub-population	• The average Hg concentration in the analyzed fish ranged from 0.018 ± 0.006 mg/kg wet weight (*Gadus chalcogrammus*) to 0.105 ± 0.015 mg/kg wet weight (*Macruronus magellanicus*).
2017	Rui Li, Han Wu, Jing Ding, Weimin Fu,1 Lijun Gan, and Yi Li[74]	College of Horticulture, Nanjing Agricultural University, Nanjing, 210095, P. R. China	Mercury pollution in vegetables, grains and soils from areas surrounding coal-fired power plants	• Investigates the mercury content of the edible parts of ten types of vegetables and grain crops. • Found varied levels of mercury in lettuce leaves that were positively correlated with the soil sample and negatively correlated with the distances from the site of the power plants. • Similar case observed for amaranth leaves, water spinach leaves, cowpea, and rice grains ($P < 0.01$), and also tomato, eggplant and cucumber fruits. • The mercury contents in 79% of vegetable samples and 67% of grain samples exceeded the maximum contaminant mercury levels defined by the Food Safety Standards in China [10 µg/kg fresh weight (FW) for vegetables and 20 µg/kg FW for grains according to Maximum Levels of Contaminants in Foods, GB 2762-2012

72 https://onlinelibrary.wiley.com/doi/epdf/10.1002/fsn3.1659

73 Renata Kuras, Beata Janasik, Magdalena Stanislawska, Lucyna Kozlowska, and Wojciech Wasowicz (2017) Assessment of Mercury Intake from Fish Meals Based on Intervention Research in the Polish Subpopulation. Biol Trace Elem Res. 2017; 179(1): 23–31.doi: 10.1007/s12011-017-0939-9. Also available on:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5550534/

74 Li, Rui & Han, wu & Ding, Jing & Fu, Weimin & Gan, Lijun & Li, Yi. (2017). Mercury pollution in vegetables, grains and soils from areas surrounding coal-fired power plants. Scientific Reports. 7. 10.1038/srep46545. Full text available on https://www.nature.com/articles/srep46545

Year	Authors	Institute	Title	Important Findings
				• The highest mercury concentrations measured in the vegetable and grain samples were 8.6 and 6.3 times higher than the permissible levels, respectively. • Meanwhile, none of the vegetable and grain samples purchased from a grocery store >55Km away from any coal-fired power plant had mercury content above permissible levels. • The mercury concentrations were also observed in rice and maize samples which were 3.0 and 2.1-fold higher than the maximum permissible mercury level in grains, respectively (Maximum Levels of Contaminants in Foods, GB 2762-2012)
2015	Quratulan Ahmed and Levent Bat[75]	The Marine Reference Collection and Resources Centre, University of Karachi, Karachi, Pakistan	Mercury (Hg) Levels in Indian Mackerel Rastrelliger kanagurta (Scombridae) from Karachi Fish Harbour and its Risk Assessment	• Tested Hg levels in edible tissues of the Indian mackerel *Rastrelliger kanagurta* collected at Karachi Harbour of Pakistan • Hg levels ranged from 0.01 to 0.09 with mean ±SD 0.042±0.023 mg/kg dry wt. The Hg level in R. kanagurta is relatively low when compared to those studied in other parts of the world and the legal standards by EU Commission Regulation and other international food standards • The findings obtained were also compared with established permissible weekly intake values. It is concluded that the Hg levels in the Indian mackerel from Karachi coasts did not exceed the permissible limits (0.5 mg/kg). • The results show that the Indian mackerel appears to be useful bio-indicator due to their accumulation of Hg.
2014	Nurul Izzah Ahmad, Mohd Fairulnizal Mohd Noh, Wan Rozita Wan Mahiyuddin, Hamdan Jaafar, Ismail Ishak & Wan Nurul Farah Wan Azmi, Yuvaneswary Veloo, Mohd Hairulhisam Hairi[76]	Institute for Medical Research, Jalan Pahang, 50588 Kuala Lumpur, Malaysia	Mercury levels of fish in Peninsular Malaysia	• Investigated the concentration of total mercury in the edible portion of 46 species of marine fish (n=297) form Peninsular Malaysia • The results showed that mercury concentrations were found significantly higher and were positively related with fish size (length and weight) in all fish samples • Despite the results, the level of mercury in marine fish did not exceed the permitted levels of Malaysian and JECFA guideline values at 0.5 mg/kg methyl mercury in fish

75 Quratulan Ahmed and Levent Bat (2015) Mercury (Hg) Levels in Indian Mackerel Rastrelliger kanagurta (Scombridae) from Karachi Fish Harbour and its Risk Assessment. Journal of Fisheries Sciences.com 9(1): 356-360 (2015) DOI: 10.3153/jfscom.201444

76 https://www.researchgate.net/publication/270512163_Mercury_levels_of_fish_in_Peninsular_Malaysia

4.3.2 Indian studies

There are several of Indian research studies which have confirmed the presence of mercury and methyl mercury in fish samples, water soil, vegetable, and meat. In a study, the authors (Santanu Chakravarty & Abhay Kumar), observed high level of mercury and methyl mercury above the prescribed regulations under the food safety laws.

Table 11: Indian studies on Mercury

Year	Authors	Institute	Title	Important Findings
2017	Alok Chandra Samal*, Sumalya Chakraborty, Anusaya Mallick & Subhas Chandra Santra[77]	Department of Environmental Science, University of Kalyani, West Bengal, India	Mercury contamination in urban ecosystem – a case study in and around Kolkata metropolis, West Bengal, India	• Studies the total residual mercury in water, soil, plant, vegetables, fish and meat samples and found varied levels of Mercury in it • The residual mercury was 0.94±0.041 ppm
2014	M. Chatterjee, N. Basu and S. K. Sarkar[78]	Divecha center for Climate change, Indian Institute of Science, Bangalore, India	Mercury exposure assessment in fish and humans from Sundarban, Mangrove wetland of India	• Six commonly consumed fishes were tested • Mean total mercury content in edible composites of locally caught fishes was low and ranged from 0.01 to 0.11 microgram per gram mercury, dry weight.
2009	Santanu Chacraverti & Abhay Kumar[79]	NGO Disha, Kolkata and Toxics Link, New Delhi	Fishing Toxics-Mercury contamination of fish in West Bengal	• In market samples, 7 out of 60 samples found mercury levels above Prevention of Food Adulteration (PFA) stipulations. • 24 out of 60 samples have methyl mercury levels above PFA stipulations • In 5 out of 7 cases of excess Hg, Hg levels have exceeded by more than 50% over PFA stipulations and in 2 such cases it has exceeded by more than 100% above PFA stipulations. • In the 24 cases, of methyl mercury excess, 18 cases show MeHg excess of more than 50% above PFA stipulations. • 7 cases show MeHg excess of more than 100% above PFA stipulations • In the fishing locations samples in 45 cases, Hg levels have been exceeded and in 105 cases MeHg levels have been exceeded • Of the 45 cases where Hg levels have been exceeded 35 cases exhibit excess by more than 50% of PFA stipulations and 19 cases show excess by more than 100% of PFA stipulations • Of the 105 cases where MeHg levels have exceeded in 70 cases and exhibit excess by more than 50% of PFA stipulations and 45 cases show excess by more than 100% of PFA stipulations • Moreover, 18 cases showmore than 200% over PFA stipulations for MeHg levels.

77 http://www.iaph.in/wp-content/uploads/2018/02/Int.-J.-Exp.-Res.-Rev.-Vol.-13-38-43-2017.pdf
78 http://nopr.niscair.res.in/bitstream/123456789/28980/3/IJMS%2043%286%29%201101-1107.pdf
79 http://www.dishaearth.org/Fishing_Toxics_Report.pdf

4.4 Regulations of Mercury in food

4.4.1 International regulations

Mercury is a well known neurotoxin, therefore global efforts have been made to minimize the health and environmental risks associated with mercury. Adoption of the Minamata convention is a significant step to get rid of the mercury from the world. However, even before adoption of the Minamata convention stringent regulations have been placed in developed and developing countries including India to prevent mercury presence in food items.

Table 12: Guidance: Mercury Exposure Form Fish Consumption

Country[80]	Food Product	Substance	levels
USA	All fish (fresh/saltwater, finfish, crustaceans, molluscs)	Methyl mercury	1.0 ppm. NOTE: An older FDA requirement had a 0.5 ppm maximum for specific fish, such as tuna. This requirement is still listed in some US State regulations.
	Retail fish (with exceptions)		0.5 ppm
Canada	Exceptions: fresh/frozen tuna, shark, swordfish, escolar, marlin, and orange roughy	Total Mercury (inorganic and organic)	1.0 ppm
	Crustacea, fish and molluscs:	Total Mercury (inorganic and organic)	Mean 0.5 mg/kg
Oceania (Australia & New Zealand)	Gemfish, billfish (including marlin), southern bluefin tuna, barramundi, ling, orange roughy, rays and all species of shark, and Fish for which insufficient samples are available to analyze in accordance with clause 6	Mercury	Mean 1.0 mg/kg
China	Seafood	Methyl mercury	0.5 mg/kg
Taiwan	Seafood	Methyl mercury	0.5-2 ppm NOTE: MRL varies by seafood variety.
Europe	Fishery products and muscle meat of fish, except specific exclusions* * Exclusions	Mercury	0.5 mg/kg- 1.0 mg/kg

80 https://www.sgs.com/en/news/2014/02/methylmercury-in-food-risk-and-regulation

4.4.2 Indian regulations

Table 13: Indian regulations on Mercury

FOOD SAFETY AND STANDARDS (CONTAMINANTS, TOXINS AND RESIDUES) REGULATIONS of INDIA (FSSAI), 2011		
Metal contaminants	Article of food /drink	Parts per million (ppm) by weight
Mercury[81]	Fish	0.5
	Other foods	1.0
	Natural mineral water, expressed in mg/L	0.001
	Salt, food grade	0.1
	Non-predatory fish, crustaceans, cephalopods, molluscs	0.5
	Predatory Fish (Tuna, Marlin, Sword Fish, Elasmobranch)	1.0
Methyl Mercury (Calculated as the element)	All foods	0.25
Mercury (as Hg)[82]	Drinking water	0.001

81 https://www.fssai.gov.in/dam/jcr.../Compendium_Contaminants_Regulations.pdf
82 http://cgwb.gov.in/documents/wq-standards.pdf

05 Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls, commonly known as chlorobiphenyls or PCBs, are synthetic organic chemicals belonging to a broad family of chlorinated aromatic hydrocarbons. PCBs were first manufactured by Monsanto and were accepted as an important industrial breakthrough for various usages. Though PCBs are being produced in industrial processes, there is also PCB like substances released unintentionally in the environment during industrial activities. Later, it was found that PCBs are highly toxic and appropriate steps were taken to ban or reduce the use of PCBs to the extent possible.[83]

5.1 Uses

The PCBs have certain exceptional chemical properties like nonflammability, chemical stability, high boiling point, and electrical insulating properties, so PCBs were used widely in many industrial and commercial applications including:

- Electrical equipment,
- Heat transfer, and hydraulic equipment;
- As plasticizers in paints, plastics, and rubber products;
- In pigments, dyes, and carbonless copy paper and many other industrial applications.

5.2 Potential Health Impacts

- Skin rashes
- Itching and burning
- Eye irritation
- Skin and fingernail pigmentation changes
- Disturbances in liver function and the immune system
- Irritation of the respiratory tract
- Headaches, dizziness, depression, memory loss, nervousness, fatigue, and impotence
- Elevated risk of cardiovascular disease, hypertension, and diabetes
- Liver damage
- Reproductive and development effects
- Possibly cancer
- Pregnant women exposed to high levels ofPCBs in the workplace or from eating fish contaminated with PCBs had babies with lower birth weight, lessened motor skills, and weak immune systems.

83 http://toxicslink.org/?q=content/factsheet-43-polychlorinated-biphenyls-pcbs-persistent-organic-pollutant

5.3 Research Studies on PCBs

PCBs are lipophilic (having an affinity for fat), they preferentially separate from water and adsorb to sediment at the bottoms of lakes and rivers. Bottom feeders and other aquatic organisms then ingest and accumulate PCBs, resulting in bioconcentration upward in the food chain.[84] Globally researchers did various studies which have shown the presence of PCBs in seafood items such as fish. In their studies, they have observed many of the congeners of PCB in various food matrices.

5.3.1 International studies

Researchers in most of the studies collected and analyzed fish samples from different sources. There are many other resources available that have discussed PCBs in fish and the precaution to be taken while choosing fish for consumption.[85-86-87-88-89] Table 14 has summarized some of the studies on PCBs in fish samples.

Table 14: International studies on PCBs

Year	Authors	Institute	Title	Important Findings
2017	Weiwei Jin, Masae Otake, Akifumi Eguchi, Kenichi Sakurai, Hiroko Nakaoka, Masahiro Watanabe, Emiko Todaka & Chisato Mori.[90]	National Institute of Health Sciences, Setagaya-ku, Tokyo, Japan	Dietary Habits and Cooking Methods Could Reduce Avoidable Exposure to PCBs in Maternal and Cord Sera.	• Determined the polychlorinated biphenyl (PCB) congeners in 101 marine fish samples obtained from tsunami-stricken areas following the Great East Japan Earthquake in 2011. • In the congener analysis, tetra-, penta-, hexa-, and hepta-chlorinated PCB congeners dominated in all samples (comprising over 86% of the ∑PCB).
2016	John Oluoch-Otiego & Elijah Oyoo-Okoth & Kipkorir Koross Godfrey Kiptoo & Emily J. Chemoiwa & Charles C. Ngugi & Gelas Simiyu & Elijah S. Omutange & Veronica Ngure & Mary A. Opiyo[91]	Division of Environmental Health, School of Environmental Studies, University of Eldoret, P.O. Box 1125, Eldoret, Kenya	PCBs in fish and their cestode parasites in Lake Victoria.	• Levels of PCBs in Lake Victoria were found moderate to high and in some sites; it was comparable with ranges of the PCB values found in other places of the world. • Comparatively, fish endoparasites bioaccumulate higher levels of PCBs than their piscine hosts. For this, cestode parasites are potential biomonitors of the degree of accumulation of PCBs in the aquatic environment and show corresponding increase with levels of PCBs in sediments and fish.

84 http://extoxnet.orst.edu/faqs/foodcon/pcb.htm
85 http://water.ky.gov/Fact%20Sheets/PCBs%20in%20Fish.pdf
86 https://www.fda.gov/downloads/food/guidanceregulation/ucm252404.pdf
87 http://seafood.edf.org/pcbs-fish-and-shellfish
88 https://oehha.ca.gov/fish/pcbs-fish-caught-california
89 https://www.sunset.com/food-wine/flavors-of-the-west/mercury-pcbs-fish-seafood?uni=l&utm_expid=.-3k7FtolQUWNvI0nkXNCqw.1&utm_referrer=https%3A%2F%2Fwww.google.co.in%2F
90 Uekusa Y, Takatsuki S, Tsutsumi T, Akiyama H, Matsuda R, Teshima R, et al. (2017) Determination of polychlorinated biphenyls in marine fish obtained from tsunami-stricken areas of Japan. PLoS ONE 12(4): e0174961. https://doi.org/10.1371/journal.pone.0174961
91 John Oluoch-Otiego & Elijah Oyoo-Okoth & Kipkorir Koross Godfrey Kiptoo & Emily J. Chemoiwa & Charles C. Ngugi & Gelas Simiyu & Elijah S. Omutange & Veronica Ngure & Mary A. Opiyo (2016) PCBs in fish and their cestode parasites in Lake Victoria. Environ Monit Assess 188:483 DOI 10.1007/s10661-016-5483-0 Also available on:https://www.researchgate.net/profile/Elijah_Oyoo-Okoth/publication/305221645_PCBs_in_fish_and_their_cestode_parasites_in_Lake_Victoria/links/579bbdb708ae5d5e1e138265/PCBs-in-fish-and-their-cestode-parasites-in-Lake-Victoria.pdf

Year	Authors	Institute	Title	Important Findings
2010	Hardell S, Tilander H, Welfinger-Smith G, Burger J, Carpenter DO[92]	Faculty of Health Sciences, Linköping University, Linköping, Sweden	Levels of Polychlorinated Biphenyls (PCBs) and three Organochlorine Pesticides in Fish from the Aleutian Islands of Alaska.	• The highest median PCB level was found in rock sole (Lepidopsetta bilineata, 285 ppb, wet weight), while the lowest level was found in rock greenling (Hexagrammos lagocephalus, 104 ppb, wet weight). • Lipid adjusted PCB values were also calculated and significant interspecies differences were found. Again, rock sole had the highest level (68,536 ppb, lipid weight). • Concerning the PCB congener patterns, the more highly chlorinated congeners were most common as would be expected due to their greater persistence.

5.3.2 Indian studies

India has never manufactured PCBs but is widely used in electric transformer oil, which is one of the sources of PCB exposure to the environment.[93] There are several of research studies in India which have established the presence of PCBs in food items.

In India, human breast milk (Bhatinda and Ludhiana) were tested for PCB, in their analysis, they recorded higher mean concentration on PCBs at Bathinda as compared to Ludhiana. The authors observed that the levels of PCBs were higher in primiparas as compare to multiparas. In another study, environmental and biota samples were tested which includes fish and dust samples as well. Among the target compounds, PCBs were the highest in all the human milk samples. High levels of POPs in human milk and fish samples from municipal dumping sites in and around the major cities of India were reported previously by Someya et al., (2010).[94]The summary of the research findings of the studies are presented in Table 15.

Table 15: Indian studies on PCBs

Year	Authors	Institute	Title	Important Findings
2018	Bawa, J. S. Bedi, J. P. S. Gill, R. S. Aulakh, A. Kumar, Kamal Arora[95]	School of Public Health and Zoonoses, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India And Department of Pediatrics, Dayanand Medical College and Hospital, Ludhiana, India	Persistent Organic Pollutants Residues in Human Breast Milk from Bathinda and Ludhiana Districts of Punjab, India.	• Studied the polychlorinated biphenyls and two other POPs in human breast milk collected from Bathinda and Ludhiana of Punjab (India). • In their analysis, they have recorded higher mean concentration of PCBs at Bathinda as compared to Ludhiana, which was 33.7 ng/g lipid wt. at Bathinda and 24.2 ng/g lipid wt. at Ludhiana. The authors observed that, the levels of PCBs were higher in primiparas as compare to multiparas.

92 Hardell S, Tilander H, Welfinger-Smith G, Burger J, Carpenter DO (2010) Levels of Polychlorinated Biphenyls (PCBs) and Three Organochlorine Pesticides in Fish from the Aleutian Islands of Alaska. PLoS ONE 5(8): e12396. https://doi.org/10.1371/journal.pone.0012396

93 http://envfor.nic.in/sites/default/files/NIP_0.pdf

94 Masayuki Someya a, Masako Ohtake, Tatsuya Kunisue, Annamalai Subramanian, Shin Takahashi, Paromita Chakraborty, Ramesh Ramachandran, Shinsuke Tanabe. Persistent organic pollutants in breast milk of mothers residing around an opendumping site in Kolkata, India: Specific dioxin-like PCB levels and fish as a potential source. Environment International 36 (2010) 27–35

95 P. Bawa, J. S. Bedi, J. P. S. Gill, R. S. Aulakh, A. Kumar, Kamal Arora (2018) Persistent Organic Pollutants Residues in Human Breast Milk from Bathinda and Ludhiana Districts of Punjab, India. Archives of Environmental Contamination and Toxicology-https://link.springer.com/article/10.1007/s00244-018-0512-

Year	Authors	Institute	Title	Important Findings
2016	M. Noor Ahmed, Sukesh Narayan Sinha, Sudershan Rao Vemula, P. Sivaperumal, K. Vasudev, Shaik Ashu, Vishnu Vardhana Rao Mendu & V. Bhatnagar[96]	Food and Drug Toxicology Research Centre, National Institute of Nutrition, Hyderabad, India	Accumulation of polychlorinated biphenyls in fish and assessment of dietary exposure: a study in Hyderabad City, India	• Daily dietary intakes of PCBs at the 95th-percentile-measured concentrations were twice the values of the 50th-percentile-measured concentrations in all socio-economic groups. • The observed estimated daily intakes (EDIs) for all socio-economic sections (0.0087 µg/kg/ day) crossed the cancer benchmark concentration of 0.0003 µg/kg/day.
2012	Gnanasekaran Devanathan , Tomohiko Isobe, Annamalai Subramanian, Kwadwo Ansong Asante, Srinivasan Natarajan, Perumal Palaniappan, Shin Takahashi and Shinsuke Tanabe[97]	Center for Marine Environmental Studies (CMES), Ehime University, Bunkyo-cho 2-5, Matsuyama 790-8577, Japan Department of Plant Biology and Biotechnology, Guru Nanak College, Velachery Road, Chennai 600042, India	Contamination status of polychlorinated biphenyls and brominated flame retardants in environmental and biota samples from India.	• Studied the polychlorinated biphenyls and brominated flame retardants in environmental and biota samples from India. • In their study they collected human breast milk samples from Chennai, Bangalore, suburban Chidambaram, fishing village, and municipal dumping sites at Kolkata. • The fish and dust samples were also collected along with the milk samples • It was observed that, among the target compounds, PCBs were the highest in all the human milk samples (mean: 36 ng/g lipid wt.), followed by PBDEs (mean: 1.5 ng/g lipid wt.) and HBCDs (0.38 ng/g lipid wt.) from the general population of India. • Among the locations, human milk samples from the municipal dumping site in Kolkata had significantly ($p < 0.05$) higher concentrations of PCBs and PBDEs (mean: 1700 and 5.7 ng/g lipid wt., respectively) than the other locations in India (PCBs: 3.2 to 160 and PBDEs: 0.10 to 15 ng/g lipid wt., respectively) which clearly indicates the presence of prominent sources of these contaminants in a municipal dumping site. • The present levels of PCBs in human milk from mothers living near the dump-sites of India (1700 ng/g lipid wt.) were at the highest end of their reports.

96 Ahmed, M. N., Sinha, S. N., Vemula, S. R., Sivaperumal, P., Vasudev, K., Ashu, S., ... Bhatnagar, V. (2016). Accumulation of polychlorinated biphenyls in fish and assessment of dietary exposure: a study in Hyderabad City, India. Environmental Monitoring and Assessment, 188(2).

97 Gnanasekaran Devanathan, Tomohiko Isobe , Annamalai Subramanian , Kwadwo Ansong Asante , Srinivasan Natarajan, Perumal Palaniappan, Shin Takahashi and Shinsuke Tanabe (2012) Contamination status of polychlorinated biphenyls and brominated flame retardants in environmental and biota samples from India. Interdisciplinary studies on environmental chemistry—environmental pollution and ecotoxicology, pp. 269–277. Also Available on : https://www.terrapub.co.jp/onlineproceedings/ec/06/pdf/PR633.pdf

Year	Authors	Institute	Title	Important Findings
2010	Masayuki Someya a, Masako Ohtake, Tatsuya Kunisue, Annamalai Subramanian, Shin Takahashi, Paromita Chakraborty, Ramesh Ramachandran, Shinsuke Tanabe.[98]	Center for Marine Environmental Studies (CMES), Ehime University, Bunkyo-cho 2-5, Matsuyama 790-8577, Japan	Persistent organic pollutants in the breast milk of mothers residing around an open dumping site in Kolkata, India: Specific dioxin-like PCB levels and fish as apotential source.	• Dioxins and related compounds (DRCs) were detected in all the human breast milk samples analyzed, suggesting that residents of Kolkata are widely exposed to these contaminants

5.4 Regulations of PCBs in food

5.4.1 International regulations

The US-Environmental Protection Agency (EPA) restricted limits for drinking water to 0.0005 ppm as the maximum contaminant level. Whereas Food and Drugs Authority (FDA)mandates tolerances of 0.2-3.0 ppm PCBs for all foods, with a tolerance level in fish of 2 ppm. FDA also limits PCBs in paper food-packaging materials to 10 ppm. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) allow a daily PCB intake of 6 µg/kg per day.[99]

Table 16: Standards, regulations, and recommendations for PCBs

Agency[100]	Levels	Comment
EPA	0.0005 ppm	Enforceable MCL
FDA	0.2-3.0 ppm (all foods) 2.0 ppm (fish) 10 ppm (paper food-packaging materials)	Enforceable; Tolerance level
WHO, FAO	6.0 µg/kg per day	Allowable daily intake
MCL (maximum contaminant level): enforceable level for drinking water		

5.4.2 Indian regulations

As per the Stockholm Convention, the parties to it can no longer produce PCBs and are obliged to stop using this chemical. However, existing equipment that contains or is contaminated with PCBs may continue to be used until 2025 and to ensure that all PCB uses are ceased by 2025.[101]

The manufacture, import and export of PCBs and PCB containing equipment or trade of PCB contaminated equipment shall be regulated as per the provisions of the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008. The use of PCB in any form shall be completely prohibited by 31st December, 2025. Table 17 has presented the limit of PCBs in fish and fish products in India.

Table 17: Polychlorinated biphenyls (PCBs) in Fish and Fish Products

Name of the contaminants[102]	Article of food	Limit
Polychlorinated biphenyls (Sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180)	Inland and Migratory Fish	2.0 ppm
Polychlorinated biphenyls (Sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180)	Marine Fish, Crustaceans and molluscs	0.5 ppm

98 Masayuki Someya a, Masako Ohtake, Tatsuya Kunisue, Annamalai Subramanian, Shin Takahashi,Paromita Chakraborty, Ramesh Ramachandran, Shinsuke Tanabe. Persistent organic pollutants in breast milk of mothers residing around an open dumping site in Kolkata, India: Specific dioxin-like PCB levels and fish as apotential source. Environment International 36 (2010) 27–35

99 https://www.atsdr.cdc.gov/csem/csem.asp?csem=30&po=8

100 https://www.atsdr.cdc.gov/csem/csem.asp?csem=30&po=8

101 http://chm.pops.int/Implementation/IndustrialPOPs/PCBs/Overview/tabid/273/Default.aspx

102 fssai.gov.in/hi/dam/jcr:4cd60210.../Compendium_Contaminants_Regulations.pdf

06 Decabromodiphenyl Ether (Deca-BDE, DBDE or Deca)

Deca-bromodiphenyl ether (Deca-BDE) is used as an additive flame retardant in a variety of products, including thermoset resin plastics, textiles, adhesives sealants, coatings, and inks. Deca-BDE containing plastics are used in casings of computers and TVs, wires and cables, pipes and carpets. While Deca-BDE itself is not known to be highly toxic, it is capable of debrominating into other Polybrominated Diphenyl ether (PBDE) congeners such as penta-bromodiphenyl ether (penta-BDE) or octa-bromodiphenyl ether (octa-BDE) (Centers for Disease Control and Prevention [CDC], 2010, Environment Canada, 2010; Minnesota Pollution Control Agency [MPCA], 2008). Deca-bromodiphenyl ether (deca-BDE) belongs to a group of structurally related chemicals known as the Polybrominated diphenyl ethers (PBDEs).

The Stockholm Convention has listed Deca-BDE in Annex –A of the Stockholm Convention during COP–8 held in Geneva in May 2017 with specific exemptions for critical spare parts for the automotive and aerospace sector, polystyrene, and polyurethane foam for housing insulation. As per the agreed text of the Convention, Deca–BDE has been allowed to be used in automobiles until 2036.

6.1 Uses

- High impact polystyrene (HIPs) plastic
- Casing for television, computers, stereos mobile phones and other small electronics
- Various plastics: polycarbonates, polyester resins, polyamides, polyvinyl chloride, Polypropylenes, teraphthalates (PBT and PET),
- Rubber,
- Upholstery textiles (sofas, office chairs),
- Paints,
- Cables, lighting (panels, lamp, sockets)
- Smoke detecting switch boxes,
- Stadium seats.

6.2 Potential Health Impacts

- Neurological impact (symptoms such as a headache, rumbling in the stomach etc.)
- Long-term effects occur after exposure for a considerable period.
- Development of allergy (sensibilisation).
- The focus is on effects such as cancer, genotoxicity, reproductive effects (including particularly vulnerable groups such as pregnant women and children),
- Neurotoxicity, development of allergy, and other effects on the organs, e.g. injuries to the liver and kidneys.

6.3 Research Studies on Deca-bromodiphenyl Ether (Deca-BDE, DBDE or Deca)

Data on the levels of Deca-BDE in food are limited, but recent studies have shown low concentrations of Deca-BDE in a number of food groups, including meat, dairy products, fish, shellfish, eggs, and oils.

6.3.1 International Studies

Table 18: International studies on DecaBDE

Year	Authors	Institute	Title	Important Findings
2018	Boucher B.A., Ennis J.K., Tsirlina D., Harris S.A.[103]	Department of Nutritional Sciences, University of Toronto	A global database of polybrominated diphenyl ether flame retardant congeners in foods and supplements	• A global PBDE database was developed to improve diet and disease risk assessments • High levels of PBDE reported in fish oil supplements and poultry liver. • Dairy and plant groups had low PBDE concentrations.
2011	Trudel D., Tlustos C., Goetz N.V., Scheringer M. & Hungerbühler K.[104]		PBDE exposure from food in Ireland: optimising data exploitation in probabilistic exposure modelling	• The ingestion of salmon and lean fish was identified as the major source of exposure to PBDEs • Though concentration of PBDEs reported in dairy products are low but on a weight basis, contributes considerably (up to 25%) to total PBDE exposure.
2006.	Gomara B, Herrero L, Gonzalez MJ.[105]	Department of Instrumental Analysis and Environmental Chemistry, IQOG	Survey of polybrominated diphenyl ether levels in Spanish commercial foodstuffs.	• Data on the levels of deca-BDE in food are limited, but recent studies have shown low concentrations of deca-BDE in a number of food groups, including meat, dairy products, fish, shellfish, eggs and oils

103 Boucher B.A., Ennis J.K., Tsirlina D., Harris S.A. A global database of polybrominated diphenyl ether flame retardant congeners in foods and supplements. Journal of Food Composition and Analysis, 2018. 69: 171-188

104 Trudel D., Tlustos C., Goetz N.V., Scheringer M. & Hungerbühler K. PBDE exposure from food in Ireland: optimising data exploitation in probabilistic exposure modelling. Journal of Exposure Science & Environmental Epidemiology, 2011. 21: 565–575

105 Gomara B, Herrero L, Gonzalez MJ. 2006. Survey of polybrominated diphenyl ether levels in Spanish commercial foodstuffs. Environ Sci Technol 40:7541–7547

6.3.2 Indian studies

There is no available research study on the presence of Deca-BDE in food items in India.

6.4 Regulation on Deca-bromodiphenyl Ether (Deca-BDE, DBDE or Deca) in food:

6.4.1 International regulations

The decaBDE is a designated POPs in Stockholm Convention and efforts have made to phase out the chemical from the products to protect the environment and this effort will also prevent the chemical to enter in the food chain. State such as Maine, Maryland, Oregon, and Washington have also introduced legislation that bans the sale of certain products containing Deca-BDE (EPA 2009).

The US EPA in 2017 has calculated the following screening level in tap water.

Table 19: Level of Deca-BDE in water

Chemical	Tap Water µg/L
Deca-BDE	110

6.4.2 Indian regulation:

There is no regulation in India on Deca-BDE pertaining to food products. However, India as the party to the Stockholm Convention has accepted to phase it out from various products within the stipulated time period. In India, Deca-BDE is used for various products including automobiles and textile.

07 Pentabromodiphenyl Ether (Penta-BDE, PBDE or Penta)

Polybrominated biphenyl ethers (PBDEs) are a group of Brominated flame-retardant chemicals that are used in the manufacturing of several household consumer goods, including foam cushioning used in furniture and plastics as well as being used in televisions and computers. PBDEs are Brominated hydrocarbons in which 2-10 bromine atoms are attached to the molecular structure. PBDEs are used as flame retardants in a wide variety of products, including plastics, furniture, upholstery, electrical equipment, electronic devices, textiles, and other household products.[106_107]

In 2009, Penta- BDE was added as a POPs in Stockholm Convention and has been put in Annexure -A to eliminate the use of this chemical in various products.

7.1 Uses

- In products such as Polyurethane foams in mattresses, seat cushions,
- Other upholstered furniture and foam packing
- Carpet padding,
- Imitation wood,
- Sound insulation panels,
- Small electronics parts,
- Fabric coating,
- Epoxy resin,
- Conveyor belts.

7.2 Potential Health Impacts

Various toxicological research studies show that effect of Penta-BDE effects on

- Reproductivity
- Neurodevelopment
- Thyroid hormones in aquatic organisms and in mammals. The vulnerable groups are pregnant women, embryos and infants
- Potential human exposure pathways to PBDEs are through ingestion, inhalation or dermal contact.

106 ATSDR. 2015. "Draft Toxicological Profile for Polybrominated Diphenyl Ethers." Pdf available on www.atsdr.cdc.gov/toxprofiles/tp207.pdf

107 EPA. 2009. "Polybrominated Diphenyl Ethers (PBDEs) Action Plan Summary." www.epa.gov/ assessing-and-managing-chemicals-under-tsca/ polybrominated-diphenyl-ethers-pbdes-action-plan

7.3 Research Studies on Penta-bromodiphenyl Ether (Penta-BDE, PBDE or Penta)

There are very few research studies on the PBDE in foods.

7.3.1 International Research

Table 20: International studies on Penta-BDE

Year	Authors	Institute	Title	Important Findings
2010	Schecter.A, Haffner. D., Colacino. J., Patel. K., Päpke. O., Opel. Matthias, and Birnbaum. L.[108]	University of Texas, School of Public Health	Polybrominated Diphenyl Ethers (PBDEs) and Hexabromocyclodecane (HBCD) in Composite U.S. Food Samples	The most heavily PBDE contaminated food was butter with total concentration of 6,180 pg/g wet weight (ww). The next highest contaminated items were canned sardines and fresh salmon, with 1,487 and 925 pg/g ww, respectively
2009	Schecter. A., Shah. N., Colacino. J.A., Sawant. M., Brummitt. S.I., Harris. T. R., Lohmann. N., & Päpke. O.[109]	University of Texas, School of Public Health	Polybrominated diphenyl ether (PBDE) levels in fruit, vegetables, and food of vegetable origin purchased in the United States	PBDE levels were observed in food of animal origin in the US. Of the 14 food samples collected in Dallas, Texas, the total sum of five PBDE congeners were observed, Σ5 PBDE, ranged from 2.6 to 90 pg g−1 or parts per trillion (ppt) wet weight (ww). The highest PBDE level was observed in wheat bread (90 pg/g) and lowest in soy milk (2.6 pg/g)

7.3.2 Indian Studies

Table 21: Indian research on Penta-BDE

Year	Authors	Institute	Title	Important Findings
2009	Devanathan. G., Isobe.T., Subramanian.A.,Asante. K.A., Natarajan. S., Palaniappan. P., Takahashi. S., and Tanabe. S.,[110]	Center for Marine Environmental Studies (CMES), Ehime University, Japan	Contamination Status of Polychlorinated Biphenyls and Brominated Flame Retardants in Environmental and Biota Samples from India	The concentration by PBDEs (mean: 1.5 ng/g lipid wt.) in Human milk samples from the municipal dumping site in Kolkata had significantly ($p < 0.05$) higher concentrations of PCBs and PBDEs (mean: 1700 and 5.7 ng/g lipid wt., respectively) than the other locations in India.

108 Schecter.A, Haffner. D., Colacino. J., Patel. K., Päpke. O., Opel. Matthias., and Birnbaum. L.(2010) Polybrominated Diphenyl Ethers (PBDEs) and Hexabromocyclodecane (HBCD) in Composite U.S. Food Samples. *Environ Health Perspect. 2010 Mar; 118(3): 357–362*.Published online 2009 Oct 28. doi: 10.1289/ehp.0901345.

109 Schecter. A., Shah. N., Colacino. J.A., Sawant. M., Brummitt. S.I., Harris. T. R., Lohmann. N., & Päpke. O. (2009) Polybrominated diphenyl ether (PBDE) levels in fruit, vegetables, and food of vegetable origin purchased in the United States. Journal Toxicological & Environmental Chemistry Volume 91, 2009- Issue 4.

110 Devanathan. G., Isobe.T., Subramanian.A., Asante. K.A., Natarajan. S.,Palaniappan. P., Takahashi. S., and Tanabe. S., (2012) Contamination Status of Polychlorinated Biphenyls and Brominated Flame Retardants in Environmental and Biota Samples from India. Interdisciplinary Studies on Environmental Chemistry—Environmental Pollution and Ecotoxicology, pp. 269–277. Eds.,

Year	Authors	Institute	Title	Important Findings
2005	Kannan. K, Ramu K., Kajiwara. N., Sinha. R.K., Tanabe. S.[111]	Wadsworth Center, New York State Department of Health and Department of Environmental Health, USA.	Organochlorine pesticides, polychlorinated biphenyls, and polybrominated diphenyl ethers in Irrawaddy dolphins from India.	This study focused on concentration of PBDEs in the blubber of Irrawaddy dolphins at the concentration ranging from 0.98 to 18 ng/g lipid weight.

7.4 Regulation on Penta-bromodiphenyl Ether (Penta-BDE, PBDE or Penta) in food

7.4.1 International regulations

In 2007, the Food Standards Australia& New Zealand (FSANZ, 2007) carried out a study of PBDE-concentrations in foods in Australia and performed a dietary exposure assessment for different groups of the population. The mean dietary intake estimated for adults was 49 and 54 ng/kg bw per day (upper bound estimates), for males and females, respectively. The limited toxicity data suggest that for the more toxic [less Brominated] PBDE congeners [eg. BDE-47 and BDE-99] adverse effects would be unlikely to occur at doses of less than approximately 100 µg/kg bw per day. Following an independent review of the available toxicological data, FSANZ concurs with the conclusions of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). This threshold dose (100 µg/kg bw/day) proposed by JEFCA (FAO/WHO, 2006) has been used as the basis for determining the magnitude of the MOE for all PBDEs.

In 2007, the Swedish National Food Administration (NFA) conducted a risk assessment of persistent chlorinated and brominated environmental pollutants in food (NFA, 2007). The estimated mean dietary intake of PBDEs in Sweden was reported to be about 0.7 ng/kg bw/day.

Table 22: International regulations on PentaBDE

Food Items	Restricted Limit
Food (high lipid content >4% fat) Meat fat, vegetable oils, butter, cheese, milk, eggs, fish, marine mammals	50-70 pg/g
Solids Biosolids, dust, soil and sediments	100-200 pg/g[112]
Penta -BDE in Canadian Freshwater	7.6 – 74 ng/L

7.4.2 Indian regulation:

Regulations of Persistent Organic Pollutants Rules -2018 have prohibited the sale, manufacture and import and use of Penta –BDE in India from March -2019which is a significant step to restrict the burden of this chemical on food however as of now there is no regulation of this chemical in food.

111 Kannan K, Ramu K, Kajiwara N, Sinha RK, Tanabe S. Organochlorine pesticides, polychlorinated biphenyls, and polybrominated diphenyl ethers in Irrawaddy dolphins from India. Arch Environ Contam Toxicol. 2005 Oct;49(3):415-20. Epub 2005 Sep 15.

112 Draft USEPA Method published on 1614 August 2003.

08 Octa -bromodiphenyl Ether (Octa-BDE, OBDE, or Octa)

Octa-BDE is a designated commercial mixture containing polybrominated diphenyl ethers, typically consisting of Penta- to deca-bromo-diphenyl ether congeners with varying degrees of bromination. It is used as an additive flame retardant mainly in the plastics industry for polymers used for housing and office equipment. Octa-BDE was mainly used in thermoplastic resins, such as the hard-plastic components of televisions and computers, with the most prevalent use in acrylonitrile butadiene styrene (ABS) plastic.

The estimated annual worldwide production of commercial Octa-BDE (cOcta-BDE) in 1994 was 6,000 tonnes. Globally 70% of c-Octa-BDE has been used in acrylonitrile butadiene styrene (ABS) (POPRC Draft report, 2008).

In 2009, the Octa- BDE was listed as POPs in Stockholm Convention and added to Annexure -A to eliminate the use of this chemical in various products.

8.1 Uses

- Acrylonitrile-butadiene-styrene (ABS) plastic:
- Casing for fax machines, computers, and other electronics
- Automobile trim, telephones handsets, kitchen appliance casing, small electronics parts, audio videos equipment, remote control products
- In United Kingdom the use of c-Octa-BDE as a flame retardant in polymer pellets and as a flame retardant in finished products (wearing apparel, textiles, rubber and plastic products and furniture) however, the production of Octa-BDE has been stopped since 1997 (POPRC, 2008).

8.2 Potential Health Impacts

- The available data on toxicity and ecotoxicity of Octa-BDE is seen on mammals and birds including slight fetotoxicity
- Increased liver weights, and
- Delayed skeletal ossification
- Other observed effects include immunotoxicity and neurotoxicity.

8.3 Research Studies on Octa-Bromodiphenyl Ether (Octa-BDE, OBDE, or Octa)

One of the research studies has tested breast milk samples of European women which found the presence of Octa-BDE. Similarly, the other study has also found and correlated the human exposure to Octa-BDE through food intake possibly from consumption of milk or seafood. These studies are summarized in Table 23.

8.3.1 International studies

Table 23: International studies on Octa-BDE

Year	Authors	Institute	Title	Important Findings
2006	Boyd. D. and Wallace S.[113]	University of British Columbia, Canada	Fireproof Whales and Contaminated Mother's Milk: The Inadequacy of Canada's Proposed PBDE Regulations	• In 2003, the European Union banned the use of certain PBDEs (penta-BDE and octa-BDE) over concerns about the health impacts of these chemicals and direct evidence of these chemicals accumulating in the breast milk of European women
2003	EU RAR[114]	Institute for Health and Consumer Protection European Chemicals Bureau	European Union, Risk Assessment Report. Diphenyl ether, octa-bromo derivative (octa-bromodiphenyl ether	• Some congeners of Octa-BDE have been found in the serum, adipose tissue and in breast milk of women.

8.3.2 Indian studies

There are no studies available on Octa-BDE in food products in the Indian context.

8.4 Regulation on Octa-Bromodiphenyl Ether (Octa-BDE, OBDE, or Octa) in foods

8.4.1 International Regulations

The European Union has carried out a comprehensive risk assessment under the Existing Substances Regulation 793/93/EEC.[115] As a consequence, the EU has banned the use of octaBDE since 2004.[116]

In the United States, as of 2005, "no new manufacture or import of" pentaBDE and octaBDE occurred. [117] As of mid-2007, a total of eleven states in the U.S. had banned octaBDE.[118]

In May 2009, commercial octaBDE was added to the Stockholm Convention as it meets the criteria for the so-called persistent organic pollutants of persistence, bioaccumulation and toxicity.[119]

8.4.2 Indian Regulations

There is no regulation in India on Penta- BDE pertaining to food products. However the Regulations of Persistent Organic Pollutants Rules -2018 has prohibited the sale, manufacture, import and use of Penta-BDE in India.

113 Boyd. D. R. and Wallace. S. S. (2006) ***Fireproof Whales and Contaminated Mother's Milk: The Inadequacy of Canada's Proposed PBDE Regulations.*** Report by David Suzuki Foundation.
114 EU RAR (2003). ***European Union, Risk Assessment Report. Diphenyl ether, octabromo derivative (octabromodiphenyl ether)***.CAS No. 32536-52-0, EINCES No. 251-087-9.
115 European Union risk assessment report. Diphenyl ether, octabromo derivative. Luxembourg: Office for Official Publications of the European Communities, 2003. Publication EUR 20403 EN.
116 Directive 2003/11/Ec of the European Parliament and of the Council of 6 February 2003 amending for the 24th time Council Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (pentabromodiphenyl ether, octabromodiphenyl ether). Official Journal of the European Union 15.2.2003.
117 U.S. Environmental Protection Agency. Polybrominated diphenylethers (PBDEs). "Last updated on Thursday, August 2nd, 2007." Accessed 2007-10-26.
118 Maine Joins Washington, Bans PBDEs. Archived 2007-08-02 at the Wayback Machine Washington, DC: National Caucus of Environmental Legislators, June 18, 2007
119 https://en.wikipedia.org/wiki/Octabromodiphenyl_ether

B. Organochlorine pesticides (OCPs)

Organochlorine pesticides were very commonly used across the globe and the impact of these pesticides on health and environment are well documented. Some of these organochlorine pesticides such as Lindane, Methoxychlor, Chlorpyrifos, DDT are well-known EDCs and can have an acute impact on the environment and human health. As these are pesticides used in agriculture, there is a high chance of contamination of the food chain from these pesticides. Though some of these are prohibited for agricultural use, since they are persistent in characteristics, there is the likelihood that these chemicals are present in the soil and continue to cross contaminate the food chain.

09 Lindane

Lindane is the gamma-isomer of benzene hexachloride, which is colorless or white synthetic, crystalline solid with a slight musty odor that emits toxic fumes of hydrochloric acid and other chlorinated compounds when heated to decomposition. The World Health Organization (WHO) classifies Lindane as "moderately hazardous", and its international trade is restricted and regulated under the Rotterdam Convention on Prior Informed Consent.[120]Lindane is a persistent organochlorine compound (list produced by Faraday in 1825) which is widely distributed in the environment. Long distance transport of lindane is evidenced by its presence in the Arctic, where it has never been used. Most of the lindane present in the environment is in water, although a significant amount is also found in the soil/sediment and some in the air. Lindane has also been shown to bioaccumulate in the fatty tissue of organisms.[121-122]

9.1 Uses

Lindane is used as an insecticide in fruit and vegetable crops as well as to treat lice and scabies.[123-124-125]Lindane has been used as a broad-spectrum insecticide for seed and soil treatment, foliar applications, tree and wood treatment and against ectoparasites in both veterinary and human applications.

9.2 Potential Health Impacts

Exposure to Lindane may occur from eating contaminated food or by breathing air contaminated during formulation or use. Lindane is quite toxic to humans.

- The acute (short-term) effect of Lindane through inhalation exposure in humans consists of irritation of the nose and throat and affects the blood.
- A chronic (long-term) exposure to Lindane by inhalation in humans has been associated with effects on the liver, blood, and nervous, cardiovascular, and immune systems.
- Animal studies indicate that Lindane causes reproductive effects, while developmental effects have not been noted.
- Oral animal studies have shown Lindane to be a liver carcinogen. EPA has classified Lindane as a Group B2/C, possible human carcinogen.126

120 World Health Organization, the WHO Recommended Classification of Pesticides by Hazard, 2005.
121 Persistent Organic Pollutant Review Committee (POPRC). Draft risk management evaluation for lindane. May, 2007. "Archived copy" *(PDF). Archived from* the original *(PDF) on 2007-09-27*. Retrieved 2007-09-05
122 http://www.icontrolpollution.com/articles/lindane--a-contaminant-of-global-concern-.php?aid=45606
123 https://www.epa.gov/sites/production/files/2016-09/documents/lindane.pdf
124 https://pubchem.ncbi.nlm.nih.gov/compound/lindane#section=Top
125 https://medlineplus.gov/druginfo/meds/a682651.html
126 https://pubchem.ncbi.nlm.nih.gov/compound/lindane#section=Top

9.3 Research Studies on Lindane

There are very few studies on Lindane in food, the available studies, have found the presence of Lindane residue in the tested samples.

9.3.1 International studies

Globally, research studies have been carried out on Lindane residue in unprocessed food as well as water, sediment and fish samples. The detailed results are described in Table 24.

Table 24: International studies on Lindane

Year	Authors	Institute	Title	Important Findings
2009-2013		The European Food Safety Authority (EFSA)[127]	NA	• Provided approximately 25000 monitoring results on Lindane residues in unprocessed food products reported by EU Member States, as well as Norway and Iceland for the products for which currently Codex has established Codex Maximum Residual limits CXLs. • The tested products were obtained from more than 60 different countries • Varied level of residual Lindane was observed in the analysis;
2010		The European Food Safety Authority (EFSA)	The 2010 European Union Report on Pesticide Residues in Food[128]	• Lindane was detected in swine meat
2008	Lawrence Ikechukwu Ezemonye, Thomas Ohwofasa Ikpesu, and Isioma Tongo[129]	Department of Animal and Environmental Biology (AEB), University of Benin, Benin City, Nigeria	Distribution of Lindane in water, sediment, and fish from the Warri river of the Niger delta, Nigeria.	• Attempted to quantify the levels and the distribution pattern of Lindane in the surface water, sediment and fish (*Chrysichthys furcatus* and *Tilapia zilli*) collected from three different stations (Ovwian, Ekakpamre, and Ovu) of the Warri River in the western Niger Delta of Nigeria in 2006 • A total of 96 samples (24 samples each for water, sediment, and fish) were analyzed • It was found to have the presence of Lindane residue at varied levels (below the detection limit (BDL) to 1.37µg/L in water, BDL to 12.66 µg/g dry weights (dw) in sediment, BDL to 16.67 µg/gdw in *Chrysichthys furcatus*, and BDL to 0.15 µg/gdw in *Tilapia zill.*) • The observed values were above the ecological benchmarks (0.01 µg/L) recommended by the Nigerian Environmental Protection Agency and the European Union. • Lindane levels were higher in C. furcatus than in sediment, which suggests possible bioaccumulation and poor elimination in the fish.

127 http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/JMPR/Evaluation2015/LINDANE__048_.pdf
128 https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2013.3130
129 Lawrence Ikechukwu Ezemonye, Thomas Ohwofasa Ikpesu, and Isioma Tongo (2008) Distribution of lindane in water, sediment, and fish from the Warri River of the niger delta, Nigeria. arh hig rada toksikol 2008;59:261-270. PDF available on :https://hrcak.srce.hr/file/46464

9.3.2 Indian studies

Indian researchers have tested various tissues of *Channa gachua* fishes, in which they have found bioaccumulation of Lindane. The details of their findings are represented in Table 25.

Table 25: Indian studies on Lindane

Year	Authors	Institute	Title	Important Findings
2009	S.M. Shingare, M.V. Gaikwad, T.S. Pathan, P.B. Thete and Y.K. Khillare[130]	Department of Zoology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra	Study on Bioaccumulation of Lindane in Various Tissues of *Channa gachua* from Aurangabad District (MS) India.	• Lindane was observed in varied levels in all the tissues, such as: between 0.1430 and 0.1435 µg/g in kidneys, 0.1410 and 0.1415 µg/g in livers and 0.359 and 0.365 µg/g in body muscles • The fishes collected from all the locations showed different values of bioaccumulation of Lindane in their body muscles, liver and kidney • The values were slightly constant in each type of tissues. The higher Lindane bioaccumulation in liver and kidneys as compared to body muscles can be correlated to the fact that, the Lindane being lipophilic in nature gets more accumulated in the high lipid-containing organs of the body.

9.4 Regulations of Lindane in food

9.4.1 International regulations

The guidelines on the Lindane are as follows[131]

- In Japan, all uses of HCH and Lindane were prohibited in 1971.
- The European Community legislation prohibits the placing on the market, and the use, of HCH containing less than 99% of the gamma-isomer.
- In several other countries, the use of Lindane has been more or less severely restricted, e.g., Argentina, Brazil, Czechoslovakia, and the USA.
- In the Federal Republic of Germany, Lindane should not be handled by adolescents or by pregnant or nursing women.
- The ecological benchmark recommended by the Nigerian Environmental Protection Agency and European Union is0.01 µg/L.
- As per the FAO/WHO Guideline of 1979, the Maximum Residue Limit (MRL) in 35 food commodities is from 0.05 to 3 mg/kg
- As per WHO Guidelines of 1983, the concentration of Lindane in drinking water is 3 µg/L
- As per the FAO/WHO Guideline of 1989, the Acceptable Daily Intake (ADI) from Plants per kg of body weight is 0 - 0.008 mg/kg[132]
- The ecological benchmark recommended by the Nigerian Environmental Protection Agency and European Union is 0.01 µg/L.[133]

130 S.M. Shingare, M.V. Gaikwad, T.S. Pathan, P.B. Thete and Y.K. Khillare (2009) Study on Bioaccumulation of Lindane in Various Tissues of Channa gachuafrom Aurangabad District (MS) India. World Journal of Zoology 4 (2): 148-152. PDF available on:http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.501.9232&rep=rep1&type=pdf

131 http://www.inchem.org/documents/hsg/hsg/hsg054.htm

132 http://apps.who.int/iris/bitstream/handle/10665/41418/9241510544eng.pdf?sequence=1&isAllowed=y

133 Ezemonye, Lawrence Ikechukwu et al. "Distribution of lindane in water, sediment, and fish from the warri river of the niger delta, Nigeria." *Arhiv za higijenu rada i toksikologiju* 59 4 (2008): 261-70 .

9.4.2 Indian regulations

As per the Food Safety and Standards of India (FSSAI) regulations, the tolerance limit in various food categories is presented in Table 26.

Table 26: Limit of Lindane in food as per FSSAI norms in India

Food	Tolerance limit mg/kg(ppm)[134]
Food grains except rice	0.10
Milled food grains Nil Rice grain Unpolished	0.10
Rice grain polished	0.05
Milk	0.01 (on whole basis)
Milk products	0.20
Milk products (having less than 2 per cent fat)	0.20 (on whole basis)
Fruits and vegetable	1.00
Fish	0.25
Eggs	0.10 (on shell free basis)
Meat and poultry	2.00 (on whole basis)
Carbonated Water	0.001

134 https://fssai.gov.in/upload/uploadfiles/files/Compendium_Contaminants_Regulations_20_05_2019.pdf

10 Methoxychlor

The pesticide Methoxychlor was first introduced in 1948 and by the year 1970, it was widely used. This industrially manufactured pesticide was regarded as a "safer alternative" to DDT[135]. Methoxychlor is also known as DMDT, Marlate® or Metox®[136]. The pesticide can dissolve in a liquid carrier, which means that it can be easily absorbed by the soil, and contaminate groundwater and possibly enter the food chain. Methoxychlor is known to impact waterways and is highly toxic to aquatic animals.[137] Most of it enters into the environment while it is applied in agricultural crops, forests, and farm animals. Methoxychlor released to the air gets settled on ground.[138]

10.1 Uses

Methoxychlor is used as an insecticide against flies, mosquitoes, cockroaches, chiggers, and a wide variety of other insects. It is used on agricultural crops and livestock, and in barns, grain storage bins, home garden, and pets.

10.2 Potential Health Impacts

Methoxychlor is known to primarily target reproductive health. This is also detrimental to the central nervous system and the digestive tract. The harmful pesticide may also negatively affect the kidneys, lungs, eyes, and the skin.

10.3 Research Studies on Methoxychlor

Globally the research studies of Methoxychlor and other pesticide residues focus on different samples such as citrus fruits while other studies have only analyzed the fish samples to determine the pesticide residue. The details are presented in Table 27.

135 https://www.medicaldaily.com/popular-pesticide-1970s-methoxychlor-found-have-lasting-effects-health-three-generations-294852
136 https://www.atsdr.cdc.gov/toxfaqs/tfacts47.pdf
137 http://www.pesticides.news/2017-11-11-methoxychlor-toxicity-side-effects-diseases-and-environmental-impacts.html
138 https://www.atsdr.cdc.gov/toxfaqs/tfacts47.pdf

10.3.1 International studies

Table 27: International studies on Methoxychlor

Year	Authors	Institute	Title	Important Findings
2017	Husejin Keran, Nihada Ahmetovic, Emir Imširović, Enida Karić, Mehmed Hero [139]	University of Tuzla, Faculty of Technology, Tuzla, Bosnia and Herzegovina	Dietary exposure residues of pesticides from citrus fruits and risk assessment.	• Studied the residue levels of Methoxychlor, Chlorpyrifos and six other pesticides in citrus fruits (Oranges-11 nos. and Grapes-12 nos.). • Out of 11 oranges samples, seven samples (63.6%) were found to have the presence of one or several pesticides in quantified concentrations. • Multiple residues were detected in one sample • In the analyzed samples the presence of residues of Methoxychlor, Chlorpyrifos and other three pesticides were found. Similarly from the 12 samples of grapefruit, six samples (50%) were not found to have any pesticide residues, while the other six samples (50%) contained one or several pesticides in quantified concentrations. Multiple residues were detected in three samples. In the analyzed samples, the presence of residues of Methoxychlor, Chlorpyrifos and other two types of pesticides were observed. • The actual results of the analysis are as follows: in two samples of orange, the level of Methoxychlor was 0.01 mg/kg. In two grapefruit samples, the level of Methoxychlor residue ranged from 0.01 to 0.02 mg/kg, where the established residue value of 0.02 mg/kg exceeded the MRL value (i.e. 0.01 mg/kg). In two orange samples, the level of residual Chlorpyrifos was 0.01 mg/kg. In five grapefruit samples, the level of residual Chlorpyrifos ranged from 0.01 to 0.61 mg/kg, while in one sample the level was 0.61 mg/kg, which exceeded the MRL value (i.e. 0.3 mg/kg).
2016	Al-Zahraa MD, Soumia MD, Fathy EE[140]	Department of Dairy Science, Faculty of Agriculture, Assiut University, Egypt	Analysis of Organochlorine and Organophosphorus Pesticide Residues in Dairy Products and Baby Foods from Egyptian Markets	• Tested Dairy Products and Baby foods from Egyptian Markets for the residual estimation of Organochlorine and Organophosphorus Pesticides. • Fruit yoghurt was the only food that had 9.158-9.467 µg/kg (Avg- 9.346 ± 0.095). Other food items were not found to contain residue of Methoxychlor. None of the food items contained residue of Chlorpyrifos.

139 Husejin Keran, Nihada Ahmetovic, Emir Imširović, Enida Karić, Mehmed Hero (2017) Dietary exposure residues of pesticides from citrus fruits and risk assessment. International Journal of Advances in Agricultural Science and Technology, Vol.4 Issue.11, November- 2017, pg. 34-39 ISSN: 2348-1358 Also available on: http://ijaast.com/publications/vol4issue11/V4I1104.pdf

140 Al-Zahraa MD, Soumia MD, Fathy EE (2016) Analysis of Organochlorine and Organophosphorus Pesticide Residues in Dairy Products and Baby Foods from Egyptian Markets. J Environ Anal Toxicol 6: 412. doi: 10.4172/2161-0525.1000412. Also available on: https://www.omicsonline.org/open-access/analysis-of-organochlorine-and-organophosphorus-pesticide-residues-indairy-products-and-baby-foods-from-egyptian-markets-2161-0525-1000412.php?aid=82529

Year	Authors	Institute	Title	Important Findings
2013	Akan JC, Mohammed Z, Jafiya L, Ogugbuaja VO[141]	Department of Chemistry, University of Maiduguri, Maiduguri, Borno State, Nigeria	Organochlorine Pesticide Residues in Fish Samples from Alau Dam, Borno State, North Eastern Nigeria	• Collected four fish samples and studied the levels of organochlorine (gamma-BHC, Alpha-BHC, Aldrin, o,p'-DDE, Endosulfan, Dieldrin, p,p'- DDT, Lindane, p,p'-DDD, o,p'-DDD and methoxychlor) pesticide residues in Alau Dam from Konduga Local Government, Borno State, Nigeria. • The recorded mean levels of Methoxychlor in different organs of each of the four fish species (Tilapia zill, Clarias gariepinus, Heterotis niloticus and Oreochromis niloticus)are as follows: • Liver- 0.65 ± 0.05 µg/g, 1.43a ± 0.05 µg/g, 0.35a ± 0.18 µg/g, 3.54a ± 0.27 µg/g; • Gill- 0.34 ± 0.01 µg/g, 1.21 ± 0.12 µg/g, 0.22 ± 0.01 µg/g, 2.66b ± 0.13 µg/g; • Stomach- 0.28 ± 0.02 µg/g, 0.76 ± 0.01 µg/g, 0.17 µg/g ± 0.02, 1.87 µg/g ± 0.44 µg/g; • Flesh- 0.23 ± 0.01 µg/g, 0.43 ± 0.24 µg/g, 0.12d ± 0.01 µg/g, 1.45 ± 0.11 µg/g.
2010		European Food Safety Authority	The 2010 European Union report on pesticide residues food[142]	• Chlorpyrifos was detected in milk, apple, lettuce, peaches, Tomatoes, oranges, rye, citrus, pears, peaches, peppers, barley and wheat in various concentration

10.3.2 Indian studies

There are no available research studies on Methoxychlor in India.

10.4 Regulations of Methoxychlor in food

10.4.1 International regulations

The use of Methoxychlor as a pesticide was banned in the United States in 2003[143] and in the European Union in 2002.[144] It is about to be banned under the Stockholm Convention.

10.4.2 Indian regulations

India does not have specific standards or regulation for Methoxychlor and the chemical has not been registered for pesticides used in India.

141 Akan JC, Mohammed Z, Jafiya L, Ogugbuaja VO (2013) Organochlorine Pesticide Residues in Fish Samples from Alau Dam, Borno State, North Eastern Nigeria. J Environ Anal Toxicol 3: 171. doi:10.4172/2161-0525.1000171. Also available on: https://www.omicsonline.org/organochlorine-pesticide-residues-in-fish-samples-from-alau-dam-borno-state-north-eastern-nigeria-2161-0525.1000171.pdf

142 https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2013.3130

143 U.S. Environmental Protection Agency (June 30, 2004). "Methoxychlor Reregistration Eligibility Decision (RED) EPA Publication No. EPA 738-R-04-010". Retrieved 2009-10-02.

144 European Union- DG SANCO. "EU Pesticides Database". Retrieved 2009-10-02.

11 Chlorpyrifos

It is one of the endocrine disrupting organophosphorus pesticides. They are also the most commonly used insecticides worldwide. It is acutely toxic to some species that are beneficial to agriculture, such as earthworms and honeybees.[145]Though Chlorpyrifos degrades rapidly in the environment, it can still be present in the environment. The regular use of Chlorpyrifos as a pesticide could cause its accumulation in soil, drinking water, air, milk, fruits, and vegetables.[146] There is some evidence that Chlorpyrifos can accumulate in the food chain in certain species, and it has been measured in fish in the Arctic as a result of global transport.[147-148-149-150] Residues are commonly found in vegetables, fruit, rice, and cereal products in many countries. It is also found in fish, dairy products, drinking water, and even soft drinks in some countries.

11.1 Uses

- Chlorpyrifos is used to control household pests (cockroaches, flies, termites, fire ants, mosquitoes, and lice),
- In agriculture to control the pests on various crops (cotton, grain, seed, nut, fruit, wine, and vegetable)
- It is also used in forestry, nurseries, food processing plants, on golf courses, and in water supplies to combat larvae, especially mosquitoes

11.2 Potential Health Impacts

- The studies observed the developmental neurotoxicity in human. Cholinergic symptoms, e.g. salivation, urination, defecation, gastrointestinal distress, and vomiting that are caused by nervous system damage.
- Even some studies showed that Chlorpyrifos was associated with Parkinson's disease.[151] It was also reported to cause memory problems, fatigue, and loss of muscle strength.
- There are many research studies focusing on the toxicity of the nervous system but some of the researchers reported its effects on the thyroid hormone system, which further associated with the hypothyroidism. Animal studies also showed the effect of Chlorpyrifos.

145 Andrea C. Gore, David Crews, Loretta L. Doan, Michele La Merrill, Heather Patisaul, and Ami Zota, Introduction to endocrine disrupting chemicals (EDCs) a guide for public interest organizations and policy-makers.December 2014, Endocrine Society
146 http://braindrain.dk/2013/08/indian-pesticides/
147 Racke KD. Environmental fate of chlorpyrifos. Rev Environ Contam Toxicol 1993; 131:1-150.
148 Hansen DJ, Goodman LR, Cripe GM, Macauley SF. Early life-stage toxicity test methods for gulf toadfish (Opsanus beta) and results using chlorpyrifos. Ecotoxicol Environ Saf 1986; 11:15-22
149 Hageman KJ, Simonish SL, Campbell DH, Wilson GR, Landers DH. Atmospheric deposition of current use and historic-use pesticides in snow in national parks in the western United States. Environ SciTechnol 2006; 0:3174-3180.
150 Landers DH, Simonish SL, Jaffe DA, Geiser LH, Campbell DH, Schwindt AR, Schreck CB, Kent 64 ML, Hafner WD, Taylor HE, Hageman KJ, Usenko S, Ackerman LK, Schrlau JE, Rose NL, Blett TF, Erway MM. 2008. The Fate, Transport, and Ecological Impacts of Airborne Contaminants in Western National Parks (US). Western Airborne Contaminants Assessment Project Final Report. Corvallis.
151 Gatto NM, Cockburn M, Bronstein J, Manthripragada AD, Ritz B. Well-water consumption and Parkinson's disease in rural California. Environmental Health Perspectives 2009; 117:1912-1918.

11.3 Research Studies on Chlorpyrifos

There are research studies on various samples to study the levels of Chlorpyrifos and other pesticide residues. These include citrus fruits, feed to duck and domestic food samples. The details of the studies are presented in Table 28.

11.3.1 International studies

Table 28: International studies on Chlorpyrifos

Year	Authors	Institute	Title	Important Findings
2017	Husejin Keran, Nihada Ahmetovic, Emir Imširović, Enida Karić, Mehmed Hero[152]	University of Tuzla, Faculty of Technology, Tuzla, Bosnia and Herzegovina	Dietary exposure residues of pesticides from citrus fruits and risk assessment.	As stated in Table 26, the researchers have studied the residue levels of Methoxychlor, Chlorpyrifos and six other pesticides in citrus fruits (Oranges-11 nos. and Grapes-12 nos.). • Out of 11 orange samples, seven samples (63.6%) were found to have the presence of one or several pesticides in quantified concentrations. • Multiple residues were detected in one sample • In the analyzed samples, the presence of residues of Methoxychlor, Chlorpyrifos and other three pesticides were found similarly from the 12 samples of grapefruit, six samples (50%) were not found to contain any pesticide residues, while other six samples (50%) contained one or several pesticides in quantified concentrations. • Multiple residues were detected in three samples. In the analyzed samples, the presence of residues of Methoxychlor, Chlorpyrifos and other two types of pesticides were observed. The actual results of the analysis are: • In two orange samples, the level of residual Chlorpyrifos was 0.01 mg/kg. In five grapefruit samples, the level of residual Chlorpyrifos ranged from 0.01 to 0.61 mg/kg, while in one sample, the level was 0.61 mg/kg which exceeded the MRL value (i.e. 0.3 mg/kg).
2015	Rui Li, Xiaofeng Ji, Liang He, Zhiqiang Liu, Wei Wei, Mingrong Qiang, Qiang Wang, and Yuwei Yuan [153]	State Key Laboratory Breeding Base for Zhejiang Sustainable Plant Pest Control, Agricultural Ministry Key Laboratory for Pesticide Residue Detection, Zhejiang Province Key Laboratory for Food Safety, and Institute of Quality and Standard for Agro-products, Zhejiang Academy of Agricultural Sciences, Hangzhou 310021, People's Republic of China	Evaluation of Chlorpyrifos Transferred from Contaminated Feed to Duck Commodities and Dietary Risks to Chinese Consumers	• This study describes Chlorpyrifos residues in duck commodities through the duck food chain, transfer factors, and dietary risks to Chinese consumers • Chlorpyrifos residues found in all the samples collected from the ducks on maximum estimated dose group (3.20 mg/kg level) were from <0.0005 to 0.019 mg/kg • The residue levels of the fat, intestine, and tongue were obviously higher than those of the meat and other edible tissue • The transfer factors of all duck commodities were from 0.0001 to 0.0049 among different contamination levels, which indicated that Chlorpyrifos had a low persistence in duck meat and metabolism organs • The chronic exposure assessment revealed that only 0.034–0.150% of the acceptable daily intake (ADI; 0–0.01 mg/kg/bw/day) of Chlorpyrifos was consumed via the duck commodities for different age and gender groups in China • The acute exposure assessments of different age and gender groups were only 0.019–0.082% of the acute reference dose (ARfD; 0–0.1 mg/kg/bw) • The results show that the single dietary exposure risk of Chlorpyrifos raised by the intake of duck commodities was quite low in China.

152 Husejin Keran, Nihada Ahmetovic, Emir Imširović, Enida Karić, Mehmed Hero (2017) Dietary exposure residues of pesticides from citrus fruits and risk assessment. International Journal of Advances in Agricultural Science and Technology, Vol.4 Issue.11, November- 2017, pg. 34-39 ISSN: 2348-1358 Also available on: http://ijaast.com/publications/vol4issue11/V4I1104.pdf

153 Rui Li, Xiaofeng Ji, Liang He, Zhiqiang Liu, Wei Wei, Mingrong Qiang, Qiang Wang, and Yuwei Yuan (2015) Evaluation of Chlorpyrifos Transferred from Contaminated Feed to Duck Commodities and Dietary Risks to Chinese Consumers. J. Agric. Food Chem., 2015, 63 (21), pp 5296–5304 DOI: 10.1021/acs.jafc.5b01839

11.3.2 Indian studies

Indian researches also analyzed various milk and freshwater fish sample to find out the Chlorpyrifos pesticide residue in them. The detailed findings are presented in Table 29.

Table 29: Indian studies on Chlorpyrifos

Year	Authors	Institute	Title	Important Findings
2018	Jasbir S Bedi, JPS Gill, P. Kaur and R.S. Aulakh[154]	Guru Angad Dev Veterinary and Animal Sciences University	Pesticide residues in milk and their relationship with pesticide contamination of feedstuffs supplied to dairy cattle in Punjab (India).	• Collected the samples of animal concentrate feed, fodder, water, and milk from 55 different dairy farms in Punjab (India) • The study showed that Chlorpyrifos pesticide was the main contaminant detected at mean level of 6.01, 4.05 and 2.58 ng/g in the concentrate feed, fodder, and milk samples, respectively • Chlorpyrifos was the only pesticide detected in one water sample.
2016	Bhatnagar. A., Yadav. S. A, and Cheema. N.,[155]	Department of Zoology, Kurukshetra University, Haryana, India	Genotoxic Effects of Chlorpyrifos in Freshwater Fish *Cirrhinus mrigala*using Micronucleus Assay	• In general, significant effects for both concentration and duration of exposure were observed in treated fish. It was found that Micronucleus (MN) induction was the highest on day 14 at 0.08 mg/L concentration of Chlorpyrifos. • It was concluded that Chlorpyrifos is genotoxic pesticide causing nuclear anomalies in *Cirrhinus mrigala*.
2011	Aarti Goyal[156]	Department of Zoology College of Basic Sciences and Humanities © Punjab Agricultural University Ludhiana	Effect of Processing on Pesticide Residues in Some Edible Fresh Water Fishes (Ph.D. Thesis)	• In this study *Catla catla* and *Cirrhinus mrigala* fishes tested for the presence of Chlorpyrifos and other pesticides and the author also studied the effect of different processing on pesticide levels • The level of Chlorpyrifos were 0.58 (SD 0.0030) mg/kg and 0.14 (SD 0.023) mg/kg in *Catla catla* and *Cirrhinus mrigala* respectively • In frying process it was observed a loss of 44.8 % and 42.8% of Chlorpyrifos in *Catla catla* and *Cirrhinus mrigala* respectively • In steaming by pressure cooker it was observed a loss of 15.5% and 14.3% of Chlorpyrifos in *Catla catla* and *Cirrhinus mrigala* respectively • In Microwave oven it was observed a loss of 20.6 % and 21.4% of Chlorpyrifos in *Catla catla* and *Cirrhinus mrigala* respectively and • It was observed that baking in as oven led to a loss of 18.9% and 21.4% of Chlorpyrifos in *Catla catla* and *Cirrhinus mrigala* respectively.

154 Jasbir S Bedi, JPS Gill, P. Kaur and R.S. Aulakh, 2018, Pesticide residues in milk and their relationship with pesticide contamination of feedstuffs supplied to dairy cattle in Punjab (India). Journal of Animal and Feed Sciences 27(1). Also available on https://www.researchgate.net/publication/322663595_Pesticide_residues_in_milk_and_their_relationship_with_pesticide_contamination_of_feedstuffs_supplied_to_dairy_cattle_in_Punjab_India

155 http://dx.doi.org/10.1155/2016/9276963

156 http://krishikosh.egranth.ac.in/bitstream/1/5810000826/1/whole%20thesis.pdf

11.4 Regulations of Chlorpyrifos in food

11.4.1 International regulations

Many countries have either banned or restricted the use of Chlorpyrifos. In Europe, it was used to control insect infestations in residential and commercial buildings until it's banned from sale in 2008.[157] Chlorpyrifos was restricted from termite control in Singapore as of 2009.[158] It was banned from residential use in South Africa as of 2010.[159] Chlorpyrifos has not been permitted for agricultural use in Sweden at all.[160]China prohibited its uses in 2016.[161]In 2016, the U.K. decided to ban all uses of Chlorpyrifos, except for use on Brassica seedlings using a specific method.[162]

11.4.2 Indian regulations

In India, the use of Chlorpyrifos in food is regulated through food safety and standards (contaminants, toxins, and residues) regulations, 2011[163]

Table 30: Limit of Chlorpyrifos in food in India

Food	Tolerance limit mg/kg(ppm)
Food grains	0. 05
Milled food grains	0.01
Fruits	0.5
Potatoes and Onions	0.01
Cauli Flower and Cabbage	0.01
Other vegetables	0.2
Meat, and Poultry	0.1 (carcass fat)
Milk and Milk Products	0.01(fat basis)
Cottonseed	0.05
Cottonseed oil (crude)	0.025
Carbonated Water	0.001

157 Directive 98/8/EC of the European parliament and of the council of 16 February 1998, concerning the placing of biocidal products on the market. Published in the Official Journal of the European Communities, April 24th 1998

158 *Yong, Koh Chin (2009-01-01). "Prohibition on the use of chlorpyrifos in Singapore" (PDF). National Environment Agency*. Retrieved 2014-08-14.

159 "Harmful pesticide banned in SA- South Africa". IOL News. Retrieved 2014-08-08.

160 https://en.wikipedia.org/wiki/Chlorpyrifos

161 http://www.cirs-reach.com/news-and-articles/List-of-Banned-and-Restricted-Pesticide-Products-in-China.html

162 https://www.factcheck.org/2017/04/the-facts-on-chlorpyrifos/

163 https://www.fssai.gov.in/dam/jcr.../Compendium_Contaminants_Regulations.pdf

12 Dichlorodipheny ltrichloroethane (DDT)

DDT was largely meant for vector control. It was also widely used for agriculture until its ban globally. DDT is accepted as POPs in the Stockholm Convention and several countries have taken measures to phase out DDT even from the vector control. India is the only country globally to produce DDT for vector control and some African countries are still importing DDT from India for this purpose. Though DDT has been phased out, it is still found in the ecosystem as well as in the food crops and fishes. **DDT is also a well-known endocrine disruptor.**[164-165]

12.1 Uses

It is used for vector control

12.2 Potential Health Impacts

- Carcinogenic to human
- DDT is an estrogen mimic
- Breast cancer and other types of cancer
- Male infertility
- Miscarriages and low birth-weight
- Delay in development
- Nervous system damage
- Liver damage

12.3 Research Studies on DDT

There are recent studies where DDT has been found in various food crops as well as in the fishes.

12.3.1 International studies

Fish samples were studied to see the levels of organochlorine. The details of these research studies are presented in Table 31.

164 "Endocrine (Hormone) Disruptors". United States Fish and Wildlife Service. Retrieved 8 April 2015.
165 "Endocrine Disruptors" *(PDF).* National Institute of Environmental Health Sciences. 2007.

Table 31: International studies on DDT

Year	Authors	Institute	Title	Important Findings
2015	Zoltán Juvancz, Edina Garai, Loránt Szabó, Rita BodaKendrovics, Gabriella Köteles-Suszter[166]	Department of Environmental Engineering, Óbuda University, Doberdó, Italy	Determination of Recent Concentration of DDT and its Metabolites in Breast Milk in the Teaching of Behaviors of Persistence Organic Compounds	• The results demonstrate the presence of DDE traces in the breast milk of majority of the Hungarian mothers, even after the agricultural use of DDT was banned in 1968. No fresh DDT pollution was recognized in the tested samples. Correlations were established among the DDE contents of the breast milk samples and the ages and weights of the tested mothers. The measurements also show the persistency and bio-magnification feature of DDT.
2013	Akan JC, Mohammed Z, Jafiya L, Ogugbuaja VO[167]	Department of Chemistry, University of Maiduguri, Maiduguri, Borno State, Nigeria	Organochlorine Pesticide Residues in Fish Samples from Alau Dam, Borno State, North Eastern Nigeria	• Collected four fish samples and studied the levels of organochlorine (Gamma-BHC, Alpha-BHC, Aldrin, o,p'-DDE, Endosulfan, Dieldrin, p,p'- DDT, Lindane, p,p'-DDD, o,p'-DDD and Methoxychlor) pesticide residues in Alau Dam from Konduga Local Government, Borno State, Nigeria. • The recorded mean levels of the pesticide in each of the four fish species (Tilapia zill, Clarias gariepinus, Heterotis niloticus and Oreochromis niloticus) different organ are as follows: – Liver- 0.65 ± 0.05 µg/g, 1.43a ± 0.05 µg/g, 0.35a ± 0.18 µg/g, 3.54a ± 0.27 µg/g; – Gill- 0.34 ± 0.01 µg/g, 1.21 ± 0.12 µg/g, 0.22 ± 0.01 µg/g, 2.66b ± 0.13 µg/g; – Stomach- 0.28 ± 0.02 µg/g, 0.76 ± 0.01 µg/g, 0.17 µg/g ± 0.02, 1.87 µg/g ± 0.44 µg/g; – Flesh- 0.23 ± 0.01 µg/g, 0.43 ± 0.24 µg/g, 0.12d ± 0.01 µg/g, 1.45 ± 0.11 µg/g.

12.3.2 Indian studies

Indian scientists have studied the fishes, goat blood, buffalo milk and vegetables and found the residue of DDT. The detailed findings are represented in Table 32.

Table 32: Indian studies on DDT

Year	Authors	Institute	Title	Important Findings
2017	B.N. Paul, P.Singh, S. Nag, R.N. Mandal, and P.P. Chakrabarti[168]	Regional Research Centre, ICAR-Central Institute of Freshwater Aquaculture, Rahara, Kolkata-700118, India.	Pesticide residues in INDIAN major carps reared in wastewater	Analyzed Indian major carps (IMC), viz., Rohu (Labeo rohita), Catla (Catla catla) and Mrigal (Cirrhinus mrigala), (n=6, for each species) for the presence of pesticide residue, the samples were collected from farms of West Bengal. In their experiment, DDT was observed in the muscle of all fishes which were ranging from 0.224 ±0.07 0.44 ±0.05 0.16 ±0.03 mg/kg respectively.

166 Zoltán Juvancz, Edina Garai, Loránt Szabó Rita Boda, Kendrovics, Gabriella Köteles-Suszter,Determination of Recent Concentration of DDT and its Metabolites in Breast Milk in the Teaching of Behaviors of Persistence Organic Compounds. Acta Polytechnica Hungarica Vol. 12, No. 8, 2015

167 Akan JC, Mohammed Z, Jafiya L, Ogugbuaja VO (2013) Organochlorine Pesticide Residues in Fish Samples from Alau Dam, Borno State, North Eastern Nigeria. J Environ Anal Toxicol 3: 171. doi:10.4172/2161-0525.1000171. Also available on : https://www.omicsonline.org/organochlorine-pesticide-residues-in-fish-samples-from-alau-dam-borno-state-north-eastern-nigeria-2161-0525.1000171.pdf

168 B.N. Paul, P.Singh, S. Nag, R.N. Mandal, and P.P. Chakrabarti (2017) Pesticide residues in INDIAN major carps reared in wastewater. Explor Anim Med Res,Vol.7, Issue- 2, 2017, p. 190-193

Year	Authors	Institute	Title	Important Findings
2015	Arpana Singh, Subir Kumar Nag & Sultan Singh[169]	PAR Division, Indian Grassland and Fodder Research Institute, Jhansi, India	Persistent organochlorine pesticide residue in tissues and blood of goat	The pesticide residues (DDT and Endosulfan isomers and metabolites) were also observed in 32% of analysed blood samples of goat which were collected from the dairy farm of Indian Grassland and Fodder Research Institute, Jhansi, India
2013	Mohd Aslam, Sumbul Rais, Masood Alam[170]	Department of Applied Sciences and Humanities, Faculty of Engineering and Technology, Jamia Millia Islamia, New Delhi, India.	Quantification of Organochlorine Pesticide Residues in the Buffalo Milk Samples of Delhi City, India	Collected twenty fresh samples of buffalo milk and tested for pesticide residue, most of the samples observed the presence of organochlorine pesticide residue and in most cases, the values of detected OCPs exceeded the tolerance levels of FAO/WHO.[171]
2012	Rashi Bankar, Ashwini Kumar Ray, Ajai Kumar, Kuruba Adeppa, Sadhana Puri[172]	Dayanad Girls Postgraduate Degree College, Kanpur, Uttar Pradesh , India	Organochlorine pesticide residues in vegetables of three major markets in Uttar Pradesh, India	Analyzed 120 vegetable samples (collected from three major markets in Uttar Pradesh India) for the 14 organochlorine pesticide residues including DDT. Out of the 120 samples analyzed, 50 samples had presence of pesticide residue with varied concentration. DDT was observed in 11 samples which ranged between 5.45-8.34 mg/kg.
2010	NA	Indian Council of Medical Research[173]	-	2205 samples of dairy milk were collected from rural and urban areas of 12 states representing different geographical regions of India. These samples were analyzed for residues of DDT and different isomers of HCH by gas-liquid chromatography. The residues of DDT and HCH were detected in more than 80% of samples analyzed. Concentrations of DDT residues exceeded their maximum residue limits prescribed by the Ministry of Health and Family Welfare of the Indian Government in 37 Median values of DDT found in dairy milk in India, which was more than the corresponding values reported from most other countries. The results showed significant variations in the incidence as well as the level of these contaminants in dairy milk from different regions of the country.

169 Arpana Singh, Subir Kumar Nag & Sultan Singh (2015) Persistent organochlorine pesticide residue in tissues and blood of goat, Journal of Applied Animal Research, 43:3, 366-371, DOI: 10.1080/09712119.2014.978776 also available on https://www.tandfonline.com/doi/full/10.1080/09712119.2014.978776

170 Mohd Aslam1, Sumbul Rais, Masood Alam (2013) Quantification of Organochlorine Pesticide Residues in the Buffalo Milk Samples of Delhi City, India. Journal of Environmental Protection, 2013, 4, 964-974. Also available on :https://pdfs.semanticscholar.org/bce9/1e2ef2c22908ea8bb243d86ee1a92f45c2d0.pdf

171 https://pdfs.semanticscholar.org/bce9/1e2ef2c22908ea8bb243d86ee1a92f45c2d0.pdf

172 Rashi Bankar, Ashwini Kumar Ray, Ajai Kumar, Kuruba Adeppa, Sadhana Puri (2012) Organochlorine pesticide residues in vegetables of three major markets in Uttar Pradesh, India. Research Article, Acta Biologica Indica 2012, 1(1):77-80. Also available on : https://www.researchgate.net/publication/322049472_Organochlorine_pesticide_residues_in_vegetables_of_three_major_markets_in_Uttar_Pradesh_India

173 R. L. Kalra, H. Kaur, S. Sharma, S. K. Kapoor, R. B. Kshirasagar, R. C. Vaidya, R. B. Sagade, S. B. Shirolkar, T. S. S. Dikshith, R. B. Raizada, M. K. ivastava Sr, K. M. Appaiah, M. A. inivasa Sr, M. Usha Rani, S. N. Rama Rao, G. S. Toteja, J. Dasgupta & P. K. Ghosh (1999) DDT and HCH residues in dairy milk samples collected from different geographical regions of India: a multicentre study, Food Additives & Contaminants, 16:10, 411-417, DOI: 10.1080/026520399283803

12.4 Regulations of DDT in food

12.4. International regulations

In the Stockholm Convention list, DDT is currently listed in Annex B with its production and/or use restricted for disease vector control purposes following related World Health Organization (WHO) recommendations and guidelines. Countries that are party to the Convention can produce and/or use DDT for disease vector control when locally safe, effective, and affordable alternatives are not available. Parties are required to notify the Secretariat of such production or use or the intention to use DDT. Following are some regulations and Guidelines Applicable to DDT/DDE/DDD[174]

Agency	Description	Information
EPA - Water	Designated as a hazardous substance in accordance with Section 311(b)(2)(A) of the Clean Water Act—DDT and DDD	
	Effluent guidelines and standards; designated as a toxic pollutant pursuant to Section 307(a)(1) of the Clean Water Act—DDT and metabolites	
	Reportable quantities for hazardous substances designated pursuant to Section 311 of the Clean Water Act—DDT and DDE	1 pound
FDA - Food	Action levels (ppm)— DDT/DDE/DDD Fat of meat (cattle, goats, hogs, horses, sheep), fish	• 5
	Carrot	• 3
	Manufactured dairy products	• 1.25
	Beans (cocoa, whole raw), peppermint oil, potatoes, soya bean oil (crude), spearment oil, sweet potatoes	• 1.0
	Artichokes, asparagus, barley grain (food, feed), broccoli, Brussels' sprouts, cabbage, cauliflower, celery, collards, eggs, endives (escarole), hay, kale, kohlrabi, lettuce, maize grain (food, feed)	• 0.5
	Milo sorghum grain (food, feed), mushrooms, mustard greens, oat grain (food, feed), peppermint hay, rice grain (food, feed), rye grain (food, feed), spearmint hay, spinach, Swiss chard, tomato pomace (dried, for use in dog and cat food), wheat grain (food, feed)	• 0.5
	Apricots, avocadoes, beans, beans (dried), beets (roots, tops), cherries, guavas, mangoes, nectarines, okra, onions (dry bulb), papayas, parsnips (roots, tops), peaches, peanuts, peas, pineapples, plums (fresh prunes), radishes (roots, tops), rutabagas (roots, tops), soya beans (dry), turnips (roots, tops)	• 0.2
	Apples, blackberries, blueberries (huckleberries), boysenberries, citrus fruit, maize (fresh sweet plus cob with husk removed), cottonseed, cranberries,	• 0.1
	cucumbers, currants, dewberries, eggplant, gooseberries, hops (fresh), loganberries, melons, pears, peppers, pumpkins, quinces, raspberries, squash, squash (summer), strawberries, youngberries Grapes, hops (dried), tomatoes, lettuces	• 0.05

174 https://www.atsdr.cdc.gov/toxprofiles/tp35-c8.pdf

12.4.2 Indian regulations

DDT is covered under the Insecticides Act, 1968 and 1971 of the Ministry of Agriculture, Government of India. As per vide order No. S.O 378(E) dated 26th May 1989. Government of India has withdrawn the use of DDT in agriculture. But the use of DDT is restricted for Disease Vector Control purpose only.

The limit of D.D.T. (The limits apply to D.D.T., D.D.D., and D.D.E. singly or in any combination)[175] in various food categories is presented in Table 33.

Table 33: Limit of DDT in the food in India

Food	Tolerance limit mg/kg(ppm)
Milk and milk products	1.25 (on a fat basis)
Fruits and vegetables including potato	3.5
Meat, poultry, and fish	7.0 (on a whole product basis)
Eggs	0.5 (on a shell free basis)
Carbonated Water (D.D.T. (single))	0.001
Carbonated Water (D.D.D. (single))	0.001
Carbonated Water (D.D.E. (single)s)	0.001

175 https://www.fssai.gov.in/dam/jcr.../Compendium_Contaminants_Regulations.pdf

13 Endosulfan

Endosulfan is a chlorinated insecticide widely used in a variety of food and non-food crops. It is also known as Thiodan and in its commercial form, Endosulfan is composed of two stereoisomer's, α and β Endosulfan which is a combination of a 70:30 ratio. The Conference of the Parties, at the fifth meeting held in Geneva, Switzerland, from 25th to 29th April 2011, added technical Endosulfan and its related isomers to the list of POPs in the Stockholm Convention.

Endosulfan first entered the market in the mid-1950s. Since then it has been widely used in many countries under the trade name Thiodan as an insecticide. Due to human and environmental hazards related to its use, including bioaccumulation, Endosulfan has now been banned in at least 70 countries.[176] In India, it is registered as Insecticides / Pesticides under Section 9(3) of the Insecticides Act, 1968. Endosulfan acts as a contact poison for a wide variety of insects and mites. It is also used as a wood preservative. The commercial name of the product includes Thiodan, Endocide, Beosit, Cyclodan, Malix, Thimul and Thifor.

13.1 Uses

It is an insecticide that is applied extensively to cotton, oilseeds, potatoes, tea, coffee, cacao, soybean, tobacco, tomatoes, eggplant, sweet potato, broccoli, pears, pumpkins, corn, cereals, cashewnut and other vegetables.

13.2 Potential Health Impacts

- Endosulfan's predominant toxicological effect is over stimulation of the central nervous system,
- Endosulfan poisoning can cause convulsions,
- Psychiatric disturbances,
- Epilepsy, paralysis, brain edema, impaired memory, and death.[177]
- Endosulfan may affect the blood, resulting in irritability, convulsions and renal failure.
- High-level exposure will result in death.
- Ingestion of Endosulfan can cause nausea, vomiting, and diarrhea. Dizziness, agitation, nervousness, tremor, in coordination, and convulsions may also occur.
- Central nervous system depression will terminate in respiratory failure.
- Contact with Endosulfan will irritate or burn the skin, eyes, and mucous membranes

176 Fernando E.Vega, FranciscoInfante, Andrew J.Johnson. Chapter 11- The Genus Hypothenemus, with Emphasis on H. hampei, the Coffee Berry Borer Biology and Ecology of Native and Invasive Species. 2015, Pages 427-494

177 Information for the consideration of Endosulfan, Provision of information to the Stockholm Convention Secretariat for use by the POPs Review Committee (POPRC), Pesticide Action Network (PAN) International, 30 June 2008'.

13.3 Research Studies on Endosulfan

The research studies have observed Endosulfan in marine biota for different geographical regions of the Arctic, with higher bioaccumulation factors.

13.3.1 International studies

Table 34: International studies on Endosulfan

Year	Authors	Institute	Title	Important Findings
2009	Weber. J., Halsall. C. J., Muir. D., Teixeira. C., Small. J., SolomonC. K., Hermanson. M., Hung. H., Bidleman. T., [178]	Lancaster University, UK.	Endosulfan, a global pesticide: A review of its fate in the environment and occurrence in the Arctic	Residues of Endosulfan have been detected in marine biota for different geographical regions of the Arctic, with higher bioaccumulation factors (N103 –107) for zooplankton and various species of fish, compared to studies in warmer/temperate systems.

This compound is especially toxic for aquatic organisms (Broomhall, 2002; Capkin et al., 2006). In mammals, it can induce reproductive toxicity (Saiyed et al., 2003; Bharath et al., 2011). Endosulfan is not as persistent as the other OCs because it metabolises at a much faster rate to water-soluble metabolites and has a lower partition coefficient. It has even been reported that Endosulfan does not pass into the milk of cattle when ingested in feed for a prolonged period of time (Li et al., 1970; Surendra Nath et al., 2000).

13.3.2 Indian studies

Table 35: Indian studies on Endosulfan

Year	Authors	Institute	Title	Important Findings
2020	Gill et al[179]	School of Public Health and Zoonoses, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana	Pesticide Residues in Peri-Urban Bovine Milk from India and Risk Assessment: A Multicenter Study	Results reflected the presence of endosulfan residues in some of the bovine milk samples even after the bans or restrictions on their usage.
2012	Singh. L. Choudhary S. K , Singh P. K[180]	Galgotias College of Engineering and Technology, Greater Noida, U.P., India	Pesticide concentration in water and sediment of River Ganga at selected sites in middle Ganga plain	• High concentration of Endosulfan and other two pesticides were observed both in water and sediment samples of the river. • Endosulfan ranged from BDL to 739 ng/L in river sediments. α-Endosulfan was higher in water, the concentration varying from BDL to 739 ng/l in river water and from 35.5 to 50.47 ng/g in river sediment, whereas β Endosulfan was in the range of ND to 157.30 ng/l in river water and 34.40 to 303.09 ng/g in river sediment. The high concentration of α Endosulfan in water and β Endosulfan in river sediment might be explained as α and β Endosulfan are conformational isomers and can be interconnected without breaking bonds. • Endosulfan is highly toxic for aquatic organisms and has bioaccumulation effect especially in fish.

178 Weber. J., Halsall. C. J., Muir. D., Teixeira. C., Small. J., Solomon c. K., Hermanson. M., Hung. H., Bidleman. T., (2009) Endosulfan, a global pesticide: A review of its fate in the environment and occurrence in the Arctic. Science of the Total Environment 408 (2010) 2966–2984.

179 https://www.nature.com/articles/s41598-020-65030-z

180 Singh. L. Choudhary S. K , Singh P. Pesticide concentration in water and sediment of River Ganga at selected sites in middle Ganga plain. INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCES Volume 3, No 1, 2012 pdf available on http://ipublishing.co.in/ijesarticles/twelve/articles/volthree/EIJES31026.pdf

Year	Authors	Institute	Title	Important Findings
2011	Consumer Voice[181]	Delhi	Slow Poisoning by slack standards	• MRL of Endosulfan in cherry was found to be 5762.92ppb • Indian maximum limit allowed by the Food Safety and Standard Regulation is 2000 ppb,
2010	Pragya Pandey, R.B. Raizada and L.P. Srivastava[182]	Pesticide Toxicology Laboratory, Indian Institute of Toxicology Research, Post Box-80, M.G. Marg, Lucknow - 226 001, India	Level of organochlorine pesticide residues in dry fruit nuts	• This study conducted in India has indicated the presence of Endosulfan from ND-0.091 mg/kg in Cashew nuts and that it is not found in Makhana. • There are no MRL values established for nuts in the country

13.4 Regulation on Endosulfan in food

13. 4.1 International Standards:

(Exposure limit values)

Table 36: International Program on Chemical Safety (IPCS) Health and Safety (Endosulfan HEALTH and Safety Guide)[183]

Medium	Specification	Country/Organization	Exposure Limit description	Value	Effective Date
Food	Intake from	FAO/WHO	Acceptable Daily Intake (ADI)	0.008 mg/kg body weight	NA
		USSR	Acceptable Daily Intake (ADI)	0.002 mg/kg body weight	1983
	Plants	Argentina	Maximum limit	0.5-2 mg/kg	1969
		Brazil	Acceptable limits	0.01-2 mg/kg	
		FAO/WHO	Maximum residue limit	0.02-30 mg/kg	1987
		Germany,	Maximum residue limit	0.2 - 30.0 mg/kg	1984
		The Federal Republic of Finland	Maximum residue limit	0.5-1.0 mg/kg	1987
		Netherlands	Maximum residue limit	0.05-30 mg/kg	1987
		EEC	Maximum residue limit (Root vegetables)	1 mg/kg 0.2 mg/kg	1984 1976
		India	Maximum tolerable concentration	0.2-2.0 mg/kg	NA
		Kenya	Maximum limit	0.1-30.0 mg/kg	NA
		Sweden	Maximum tolerable concentration	0.2-0.5 mg/kg	1985[184]
		USA	Acceptable residue limit (in dried tea) Acceptable residue limit	24 mg/kg 0.1-2 mg/kg	
		USSR	Maximum residue limit for food products exported and imported by CMEA countries	0.1-1.0 mg/kg	1984
		USSR	The pesticide is prohibited in some food products	NA	1983

181 http://indiaforsafefood.in/wp-content/uploads/PDF/slow%20poisoning-consumer%20voice-2010.pdf
182 Pandey P, Raizada RB, Srivastava LP. Level of organochlorine pesticide residues in dry fruit nuts.J Environ Biol. 2010 Sep;31(5): 705-7.
183 http://www.inchem.org/documents/hsg/hsg/hsg017.htm
184 World Health Organization Report 1988 http://www.inchem.org/documents/hsg/hsg/hsg017.html.

Medium	Specification	Country/Organization	Exposure Limit description	Value	Effective Date
Water	Ambient	Mexico	Maximum permissible concentration (coastal) (estuarine)	0.0002 mg/L 0.002 mg/L	1973 1973[185]

13.4.2 Indian regulation

As per the Writ petition (civil) no. 213 of 2011 filed by the Democratic Youth Federation of India (DYFI) in the Supreme Court of India, Endosulfan poses a serious health hazard and the Honorable Court has the obligation to protect human life, which is guaranteed under Article 21 of the Constitution of India. Further, it was pointed out that its ill-effects have been clearly felt in the State of Kerala and its use has been completely banned. Considering the harmful health impacts of the chemical, the Supreme Court of India put an interim order to ban the manufacture, sale, use, and export of Endosulfan throughout the country from 13th May 2011. However, the Supreme Court later allowed export of the chemical produced before the ban was in place. Though Endosulfan as per the interim order in 2011 has been banned from production, export, and import, the import and export data of the Government of India depicts that there has been the export of Endosulfan in the last few years which raises eyebrows over the implementation of the Supreme Court order. Hence there is an urgent need for further investigation of this matter as it violates the order of the Hon'ble Supreme Court.

The tolerance limit of Endosulfan in food and water are presented in Tables 37 and 38 respectively.[186]

Table 37: Food Safety and Standards (Contaminants, Toxins, and Residues) for Endosulfan and its Isomers, 2011:

Sl. No.	Name of insecticides	Food	Tolerance limit mg/kg (ppm)
1.	Endosulfan (residues are measured and reported as the total of Endosulfan A and B and Endosulfan-Sulphate)	Fruits and Vegetables	2.0
		Cottonseed	0.5
		Cottonseed oil (crude)	0.2
		Bengal gram	0.20
		Pigeon Pea	0.10
		Fish	0.20
		Chilies	1.0
		Cardamom	1.0

Table 38: Tolerance limit of Endosulfan in water

Sl. No.	Name of insecticides	Food	Tolerance limit mg/kg (ppm)
1.	Endosulfan A	Carbonated Water	0.001
2.	Endosulfan B	Carbonated Water	0.001
3.	Endosulfan-Sulphate	Carbonated Water	0.001

185 World Health Organization Report 1988 http://www.inchem.org/documents/hsg/hsg/hsg017.html.
186 https://fssai.gov.in/hi/dam/jcr...5b17.../Compendium_Contaminants_Regulations.pdf

C. Environmental bi-products

In this section, two important environmental bi-products: Dioxins and Furans are addressed. Both of these chemicals are unintentionally produced during the production of the intentional product and they have no use in any kind of products. These are very harmful in nature and studies have found its presence in food items such as dairy products. It possesses serious health risk hence it is important to regulate.

14 Dioxins

Dioxins and related compounds are Halogenated Aromatic chemicals with similar chemical and physical properties and structures commonly known as polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs). Around 419 types of dioxins have been identified of which approximately 30 are considered to have significantly high toxicity. Out of these 2,3,7,8-tetrachlorodibenzo-paradioxin (TCDD) is the most toxic. Dioxins are released unintentionally in various industrial processes such as waste incineration, ferrous and nonferrous metal production, heat and power generation, production of mineral products, transportation etc. Uncontrolled combustion such as forest fire/open burning of waste / accidental fire etc. contributes to the release of dioxins. Dioxins are trans-boundary in nature and can travel a long distance from the source of emission and bioaccumulates in the food chain. Through the food chain, they enter the human body and deposit in the fatty tissues for a long period and causes serious health hazard (Fig 4). Dioxins are designated as POPs in the Stockholm Convention and have been included in Annexure- C (Unintentional Release) of the Convention.

14.1 Uses

It is unintentionally released and has no use as such.

14.2 Potential Health Impacts

The Dioxins are generally associated with various health ailments including skin lesions, reproductive disorders, endocrine disruptors, and cancer.

- Short-term exposure causes: Skin lesions, such as chloracne and patchy darkening of the skin, and altered liver, thymus and spleen function.
- Long-term exposure causes impairment of the immune system, the developing nervous system, the endocrine system and reproductive functions.[187-188]
- Chronic exposure (in animals) causes several types of cancer, chromosome break.
- Pregnant women, newborn and developing fetus are sensitive to dioxins exposure.
- Other effects in humans may include:
  - Developmental abnormalities in the enamel of children's teeth
  - Thyroid disorders[189]
  - Endometriosis[190]
  - Diabetes[191]

187 Baccarelli A, Mocarelli P, Patterson DG, et al. 2002. "Immunologic effects of dioxin: new results from Seveso and comparison with other studies". Environ. Health Perspect. 110 (12): 1169–73.

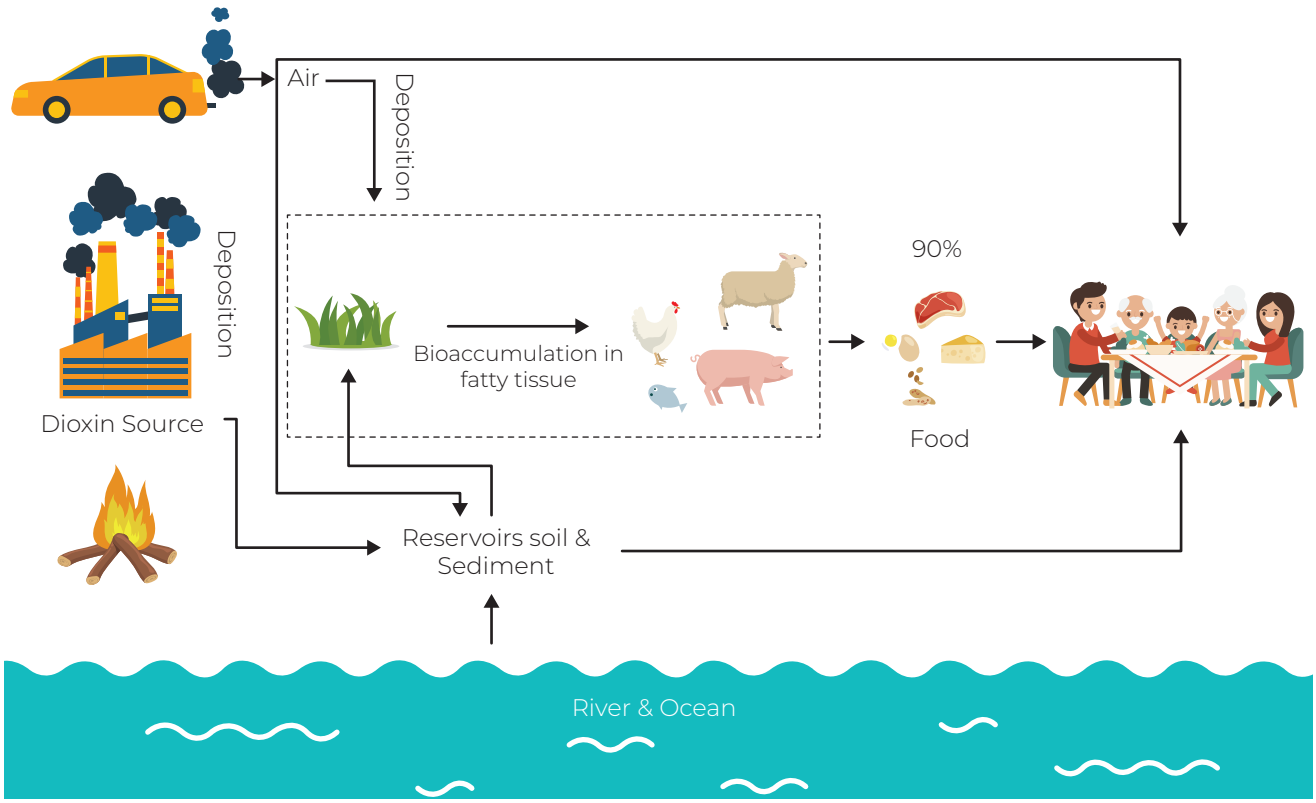
188 Pelclová D, Urban P, Preiss J, et al. 2006. "Adverse health effects in humans exposed to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)". Reviews on environmental health 21 (2): 119–38. PMID 16898675.

189 Pavuk M, Schecter AJ, Akhtar FZ, Michalek JE. 2003. "Serum 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) levels and thyroid function in Air Force veterans of the Vietnam War". Annals of epidemiology 13 (5): 335–43.

190 Eskenazi B, Mocarelli P, Warner M, et al. 2002. "Serum dioxin concentrations and endometriosis: a cohort study in Seveso, Italy". Environ. Health Perspect. 110 (7): 629–34.

191 Arisawa K, Takeda H, Mikasa H. 2005. "Background exposure to PCDDs/PCDFs/PCBs and its potential health effects: a review of epidemiologic studies". J. Med. Invest. 52 (1–2): 10–21.

Figure 4: **Sources of dioxin in food**



14.3 Research studies on dioxin

Dioxins dissolve in fat and are not easily broken down. They tend to accumulate in fatty tissues and are passed up the food chain from plants to animals to humans. The level of dioxins in food is expressed as toxic equivalent TEQ (unit is picogram (pg) per gram or parts per trillion (ppt).There are research studies on the presence of dioxin in food and feed, milk, gaur gram, eggs, pork meat, etc. which showed the presence of Dioxins.

14.3.1 International studies

Table 39: **International studies on Dioxin**

Year	Authors (s)	Institute	Title	Important Findings
2017	Rainer Malisch[192]	European Union Reference Laboratory (EU-RL) for Dioxins and PCBs in Feed and Food, Chemisches und Veterinäruntersuchungsamt Freiburg (CVUA; State Institute for Chemical and Veterinary Analysis of Food), Freiburg, Germany	Incidents with Dioxins and PCBs in Food and Feed-Investigative Work, Risk Management and Economic Consequences	• The key to trace the source was the detection of a high level of 7.86 pg ITEQ/g lipid in milk from a road tanker which had collected milk from 70 farms for transportation to the dairy. An immediate investigation of the 12 biggest farms led to a farm which had 4.83 pg I-TEQ/g lipid—this was about fivefold higher than in previous years.

192 Malisch, R. (2017) Incidents with Dioxins and PCBs in Food and Feed-Investigative Work, Risk Management and Economic Consequences. Journal of Environmental Protection, 8, 744- 785. PDF available on http://file.scirp.org/pdf/JEP_2017062815443094.pdf

Year	Authors (s)	Institute	Title	Important Findings
2008	Wahl, Kerstin, Kotz, Alexander, Haedrich, Johannes, Malisch, Rainer, Anastassiades, Michelangelo & Sigalova, I[193]	Community Reference Laboratory (CRL) for Dioxins and PCBs in Feed and Food, State Laboratory for Chemical and Veterinary Analysis (Chemisches und Veterinäruntersuchungsamt, CVUA), Bissierstr. 5, D-79114 Freiburg, Germany	The Guar Gum Case: Contamination with PCP and Dioxins and Analytical Problems	• The contamination levels of dioxins and pentachlorophenol found in certain batches of guar gum were very high. The initially found levels of up to 480 pg WHO-PCDD/F-TEQ/g product and 4 mg PCP/kg gave cause for serious concern.

14.3.2 Indian studies

As such there are no available studies in India on Dioxins content in food. However, Toxics Link had conducted a study of dioxins in eggs in 2005 and found high content of Dioxins.

Table 40: Indian studies on Dioxin

Year	Authors	Institute	Title	Important Findings
2005	Joseph DiGangi and Jindrich Petrlik[194]	International POPs Elimination Network (IPEN)	The egg report	• Collected and tested the egg samples for dioxin, it was observed that the levels of dioxin were 5.5 times higher than the European Union safe dioxin limit for eggs.

14.4 Regulations on Dioxin in food

14.4.1 International regulations

In many countries, dioxin content in foods is well regulated. There are prescribed limits for the dioxin content in food items that would have an impact on human health. Dioxins are usually measured as Toxicity Equivalent Quantities (TEQs) or parts per trillion (ppt) of toxicity equivalents. Toxic Equivalents (TEQs) report the toxicity-weighted masses of mixtures of PCDDs, and PCDFs. Many countries have put a maximum permissible limit (TEQ) for dioxin content in various food items to check contamination as presented in Table 41.

Table 41: Permissible "TEQ" Limit of Dioxins in Foods

Standards in TEQ or ppt	Fish & shellfish	Milk& milk products	Pork	Egg	Beef
US EPA	5	-	-	1	-
EU	4	3	1	3	3
Australia	-	3	1	5	6

In November 2001 Council (Brussels) adopted a regulation setting legally binding limits on the presence of dioxin in food (IP/02/1698), the details are presented in Table 42.

193 Malisch, R. (2017) Incidents with Dioxins and PCBs in Food and Feed-Investigative Work, Risk Management and Economic Consequences. Journal of Environmental Protection, 8, 744- 785. PDF available on http://file.scirp.org/pdf/JEP_2017062815443094.pdf

194 Joseph DiGangi and Jindrich Petrlik, 2005, The egg report-Contamination of chicken eggs from 17 countries by dioxins, PCBs and hexachlorobenzene

Table 42: Maximum limits for Dioxin in food[195]

Products	Maximum levels for dioxins (PCDD + PCDF)[a] (pg WHO-PCDD/F-TEQ/g fat or products)
1. Meat and meat products[d] originating from	
– Ruminants (bovine animals, sheep)	3 pg WHO-PCDD/F-TEQ/g fat[b,c]
– Poultry and framed game	2 pg WHO-PCDD/F-TEQ/g fat[b,c]
– Pigs	1pg WHO-PCDD/F-TEQ/g fat[b,c]
2. Liver and derived products	6 pg WHO-PCDD/F-TEQ/g fat[b,c]
3. Muscle meat of fish and fishery products[e] and product thereof	4 pg WHO-PCDD/F-TEQ/g fresh weight[b]
4. Milk[f] and milk products, including butter fat	3 pg WHO-PCDD/F-TEQ/g fat[b,c]
5. Hen eggs and egg products[g,h]	3 pg WHO-PCDD/F-TEQ/g fat[b,c]
6. Oils and facts	
– Animal fat	
– from ruminants	3pg WHO-PCDD/F-TEQ/g fat[b]
– from poultry and framed game	2pg WHO-PCDD/F-TEQ/g fat[b]
– from pigs	1pg WHO-PCDD/F-TEQ/g fat[b]
– mixed animal fat	2 pg WHO-PCDD/F-TEQ/g fat[b]
– Vegetable oil	0.75 pg WHO-PCDD/F-TEQ/g fat[b]
– Fish oil intended for human consumption	2 pg WHO-PCDD/F-TEQ/g fat[b]

[a]Upperbound concentrations; upperbound concentrations are calculated assuming that all values of the different congeners less than the limit of determination are equal to the limit of determination
[b]These maximum levels shall be reviewed for the first time by 31 December 2004 at the latest in the light of new data on the presence of dioxins and dioxin-like PCBs, in particular with a view to the inclusion of dioxin-like PCBs in the levels to be set and will be further reviewed by 31 December 2006 at the latest with the aim of significantly reducing the maximum levels.
[c]The maximum levels are not applicable for food products containing < 1% fat.
[d]Meat of bovine animals, sheep, pig, poultry and farmed game as defined in Article 2 (a) of Council Directive 64/433/EEC (OJ 121 29.7.1964, p. 2012), as last amended by directive 95/23/EC (OJ L 243, 11.10.1995, p.7) and Article 2(1) of Council Directive 71/118/EEC (OJ L55, 8.3.1971, p. 23), as last amended by Directive 97/79/EC (OJ L24, 30.1.1998, p.31) and Article 2(2) of Council Directive 91/495/EC (OJ 268, 24.09.1991, p.41) as last amended by Directive 94/65/EC (OJ L 368, 31.12.1994, p.10), excluding edible offal as defined in Article 2(e) of Directive 64/433/EEC and Article 2(5) of Directive 71/118/EEC.
[e]Muscle meat of fish and fishery products as defined in categories (a), (b), (c), (e) and (f) of the list in Article 1 of Council Regulation (EC) No 104/2000 (OJ L 17, 21.1.2000, p.22). The maximum level applies to crustaceans excluding the brown meat of crab and to cephalopods without viscera.
[f](30) Milk (raw milk, milk for the manufacture of milk-based products and heat treated milk as defined in Council Directive 92/46/EEC (OJ L 268, 14.9.1992, p.1) as last amended by Council Directive 94/71/EC (OJ L368, 31.12.1994, p.33).
[g](31) Hen eggs and egg products as defined in Article 2 of Council Directive 89/437/EEC (OJ L 212, 22.07.1989, p.87).
[h](32) Free-range or semi-intensive eggs as defined in Article 18 of Commission Regulation (EEC) No 1274/91 (OJ L121, 16.5.1991, p.1) must comply with the maximum level laid down as from 1 January 2004.

In July 2002, limits were set by the European Commission (EC) for dioxins in foods that contribute significantly to the total dietary intake of these chemicals in WHO-TEQ/kg fat basis in nanograms, such as, Meat-1 to 3; Liver-6; Fish-4; Eggs-3; Milk and milk products-3; Fats and oils depending on type 0, 75 to 3.[196]. The Tolerable Daily Intake (TDI) of Dioxins by various international regulatory bodies is stated in Table 43.

Table 43: Tolerable daily intake (TDI) of dioxins

Regulatory Body	TDI (pg/kg of body weight/ day)
WHO	14-4
FDA EPA	0.7
European Union	1-4
Japan	4
Canada	2.3
Australia	2.3
Joint FAO/WHO Expert Committee on Food Additives	2.3

14.4.2 Indian regulations

In India, there are standards for various industries and incinerators on release of dioxins into the environment. However, there are no such regulation on dioxins standards in food.[197-198-199]

195 europa.eu/rapid/press-release_IP-02-959_en.pdf
196 https://foodfacts.org.za/dioxins/
197 www.ipen.org/sites/default/files/documents/Toxics%20Link%20Dioxins%20and%20Furans%20booklet.pdf
198 toxicslink.org/docs/DIOXIN-Factsheet44.pdf
199 https://ipen.org/sites/default/files/documents/Toxics%20Link%20Dioxins%20and%20Furans%20booklet.pdf

15 Furans

Furan (C_4H_4O) is a colorless, heterocyclic compound with high volatility, consisting of a five-membered aromatic ring with four carbon atoms and one oxygen atom. It has been reported that thermal processing is the main cause of furan formation. Thermal processing such as cooking, roasting, baking, pasteurization, and sterilization[200-201] is involved in many food preparing processes, from the home kitchen to industrial food processing facilities, and it ensures the microbiological safety of the food for preservation and maintains particular sensory features.[202] One of the known reactions during thermal processing is the Maillard reaction. This is a non-enzymatic browning reaction, which involves the reaction of amino acids, peptides, and proteins with reducing sugars and vitamin C[203]. Some studies have reported that the formation of Furans occurs to a large extent during the Maillard reaction. This review presents the current status of commercial food monitoring databases and possible methods applied by various agencies for reducing Furan formation in food.[204]

15.1 Uses

It is unintentionally released through the same process and sources as in the case of Dioxins

15.2 Potential Health Impacts

The health impact of Furans is more or less similar to Dioxins which include

- Short-term exposure causes Skin lesions, such as chloracne and patchy darkening of the skin, and altered liver, thymus & spleen function.
- Long-term exposure cause Impairment of the immune system, the developing nervous system, the endocrine system and reproductive functions.[205-206]
- Chronic exposure (in animals) causes several types of cancer, chromosomal rupture.
- Pregnant women, new born and developing fetus are sensitive to exposure of Furans.
- Other effects in human may include:
  - Developmental abnormalities in the enamel of children's teeth
  - Thyroid disorders[207]
  - Endometriosis[208]
  - Diabetes[209]

200 Becalski A., Seaman S. Furan precursor in food: a model study and development of a simple headspace method for determination of determination furan. *J. AOAC Int.* (2005);88:102–106. [PubMed]
201 Crews C., Castle L. A review of the occurrence, formation and analysis of furan in heat-processed foods. *Trends Food Sci. Technol.* (2007);18:365–372. doi: 10.1016/j.tifs.2007.03.006. [Cross Ref]
202 Hasnip S., Crews C., Castle L. Some factors affecting the formation of furan in heated foods. *Food Addit. Contam.* (2006);23:219–227. doi: 10.1080/02652030500539766. [PubMed] [Cross Ref]
203 Perez Locas C., Yaylayan V.A. Origin and mechanistic pathways of formation of the parent furan--a food toxicant. *J. Agric. Food Chem.* (2004);52:6830–6836. doi: 10.1021/jf0490403. [PubMed] [Cross Ref]
204 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4609971/
205 Baccarelli A, Mocarelli P, Patterson DG, et al. 2002. "Immunologic effects of dioxin: new results from Seveso and comparison with other studies". Environ. Health Perspect. 110 (12): 1169–73.
206 Pelclová D, Urban P, Preiss J, et al. 2006. "Adverse health effects in humans exposed to 2,3,7,8-tetrachlorodibenzo- p-dioxin (TCDD)". Reviews on environmental health 21 (2): 119–38. PMID 16898675.
207 Pavuk M, Schecter AJ, Akhtar FZ, Michalek JE. 2003. "Serum 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) levels and thyroid function in Air Force veterans of the Vietnam War". Annals of epidemiology 13 (5): 335–43.
208 Eskenazi B, Mocarelli P, Warner M, et al. 2002. "Serum dioxin concentrations and endometriosis: a cohort study in Seveso, Italy". Environ. Health Perspect. 110 (7): 629–34.
209 Arisawa K, Takeda H, Mikasa H. 2005. "Background exposure to PCDDs/PCDFs/PCBs and its potential health effects: a review of epidemiologic studies". J. Med. Invest. 52 (1–2): 10–21.

15.3 Research studies on Furans

There are research studies on the presence of Furans in food and food products. In China, a team of researchers tested Chinese food and found furan in all analyzed food samples. Similarly, another team of researchers tested coffee samples, roasted coffee beans, infant formula meat products, soap, soy sauce vegetable and vegetable juice and found the presence of Furans. The detailed findings are presented in Table 44.

15.3.1 International studies

Table 44: International studies on Furans

Year	Authors	Institute	Title	Important Findings
2015	Seok. YJ., Her. JY., Kim. Y.G., Kim. M.Y., et. al.,	Department of Food Science and Biotechnology, Dongguk University, Nutrition Policy & Promotion Team, Korea Health Industry Development Institute,	Furan in Thermally Processed Foods - A Review[210]	In this study, Furan was detected in all food samples, and ranged from 0.77 ng/g to 193.95 ng/g, with red ginseng drinks containing the lowest levels and Korean seasoned beef containing the highest levels of furan. Food samples that are cooked with soy sauce, including canned sesame leaf and Korean seasoned beef, showed higher levels of furan than did other food samples.
2014	Sijia W., Enting W., Yuan Y. [211]	College of Quartermaster Technology, Jilin University, Changchun 130062, China	Detection of furan levels in select Chinese foods by solid phase micro-extraction Gas Chromatography/ Mass Spectrometry method and dietary exposure estimation of Furan in the Chinese population.	• Furan was detected in all analyzed food samples at levels ranging between not detectable in infant formula and 210.7 ng/g in soy sauce • In coffee, Furan was present at high levels, ranging between 13.5 and 150.7 ng/g, with an average of 60.6 ng/g. • These high levels were in agreement with previous studies • However, the detected levels of Furan in soy sauce were slightly higher than those reported in previous studies, with levels in China ranging from 59.5 to 210.7 ng/g, with an average of 128.8 ng/g (28). • This study suggests that soybean is one of the raw materials that more easily forms Furan during thermal processing, as soybean includes high levels of fat and proteins.

210 https://www.researchgate.net/publication/283634171

211 Sijia W., Enting W., Yuan Y. Detection of furan levels in select Chinese foods by solid phase microextractiongas chromatography/mass spectrometry method and dietary exposure estimation of furan in the Chinese population. *Food Chem. Toxicol.* (2014);64:34–40. doi: 10.1016/j.fct.2013.11.012. [PubMed][Cross Ref]

Year	Authors	Institute	Title	Important Findings
2013	Mariotti M.S., Toledo C., Hevia K., Gomez J.P., Fromberg A., Granby K., Rosowski J., Castillo O.,Pedreschi F. [212,213]	Department of Chemical Engineering and Biprocess, Pontificia Universidada Catolicad De, ChileSantiago	Are Chileans exposed to dietary furan?	• Furan was present in most of the samples analyzed • Furan levels varied considerably, depending on the food samples, and ranged from not-detectable in fried meat to high levels in crisps (259 ng/g) and coffee (936 ng/g). In the case of wheat crackers, Chilean products had a darker color than those from European countries. • This color difference would explain the higher levels of Furan in the Chilean product. • A darker color implies that the food was exposed to thermal processing for a long time; therefore, more Furan would be formed.
2010	Kim T.K., KimS., Lee K.G.[214]	Department of Food Science and Technology, Dongguk University-Seoul, 26, 3-Ga, Pil-dong, Chung-gu, Seoul 100-715, Republic of Korea	Analysis of Furan in heat-processed foods consumed in Korea using solid phase micro-extraction-Gas Chromatography/ Mass Spectrometry (SPME-GC/MS).	• In this study, Furan was detected in all food samples, and ranged from 0.77 ng/g to 193.95 ng/g, with red ginseng drinks containing the lowest levels and Korean seasoned beef containing the highest levels of Furan. Food samples that are cooked with soy sauce, including canned sesame leaf and Korean seasoned beef, showed higher levels of Furan than did other food samples.
2010	Liu Y.T., Tsai S.W.[215]	Institute of Environmental Health, College of Public Health, National Taiwan University, No. 17, Xuzhou Road, Taipei 100, Taiwan	Assessment of dietary Furan exposures from heat processed foods in Taiwan.	• The groups of food products containing high levels of Furan included baby foods, coffees, sauces, and soups. • The levels ranged between 0.4 ng/g (in beverages) and 150 ng/g(in coffee) (26). For baby foods, the detected furan levels ranged from 4.25 ng/gto 124.24 ng/g, depending on the composition of the baby foods. • Furan was also detected in infant formulas, with levels ranging from 2.4 ng/g to 28.7 ng/g. The detected Furan levels were higher in fruit-based food samples than in milk-based foods. • Among the food groups, coffee contained the highest Furan levels • It was assumed that excessively high temperature during roasting may be the major reason for the high levels of Furan in coffee • A group of miscellaneous foods, including sauces, broths, and soups, was also analyzed in this study • The Furan concentrations detected in these food commodities ranged from 1.5 ng/gto 123.0 ng/g • The highest level of Furan in this group was detected in barbecue sauce. The major component of barbecue sauce is soy sauce, which contains a relatively high level of Furan.

212 Mariotti M.S., Toledo C., Hevia K., Gomez J.P., Fromberg A., Granby K., Rosowski J., Castillo O., Pedreschi F. Are Chileans exposed to dietary furan? ***Food Addit. Contam. Part A***. (2013);30:1715–1721. doi: 10.1080/19440049.2013.815807. [PubMed] [Cross Ref]

213 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4609971/#B005

214 Kim T.K., Kim S., Lee K.G. Analysis of furan in heat-processed foods consumed in Korea using solid phase microextraction-gas chromatography/mass spectrometry (SPME-GC/MS). ***Food Chem.***(2010);123:1328–1333. doi: 10.1016/j.foodchem.2010.06.015. [Cross Ref]

215 Liu Y.T., Tsai S.W. Assessment of dietary furan exposures from heat processed foods in Taiwan. ***Chemosphere***. (2010);79:54–59. doi: 10.1016/j.chemosphere.2010.01.014. [PubMed] [Cross Ref]

15.3.2 Indian studies

Table 45: Indian study of Furans

Year	Authors	Institute	Title	Important Findings
2005	Toxics Link[216]	Toxics Link, New Delhi, India	Dioxins and Furans in egg samples	Collected and tested the egg samples for dioxin, it was observed that the levels of dioxin were 5.5 times higher than the European Union safe dioxin limit for eggs.

15.4 Regulations on Furans in food

15.4.1 International regulations

The Furans have similar properties like Dioxins and are toxics in nature . Therfore the EU and US have their progrmas to monior these chemicals in food. However unlike Dioxins, there is no such specific standard for Furnans in food. WHO has given guidelines for the maximum limit for furans in few food stuffs as mentioned in table 42.

15.4.2 Indian regulations

In India, Dioxins are well regulated in waste rules and efforts are going on to regulate it in food as well, however, on Furans there are no standards available.[217]

216 https://www.consumer-voice.org/food/egg-story/
217 https://ipen.org/sites/default/files/documents/Toxics%20Link%20Dioxins%20and%20Furans%20booklet.pdf

Discussions and Policy Recommendation

The research studies have confirmed that there are certain chemicals which interfere with the endocrine systems and can cause serious impairments to human as well as animals. These are collectively termed as Endocrine Disrupting Chemicals (EDCS). Globally, there are several studies being conducted by the various institutions and have determined the possible impact of EDCs on human health. This kind of research studies is few in India. Though there are many possible sources of exposure of EDCs, many of these studies have identified food as one of the important sources of exposure.

To restrict the impact of EDCs on the environment, global initiatives have been mooted to restrict their use in various products. Some of the major global regulations such as the Stockholm Convention on POPs, Rotterdam Conventions and Strategic Approach to International Chemical Management (SAICM) have made efforts on the various aspects of EDCs and to minimize the impact of chemicals on the environment and human health.

India is a party to many of these chemical conventions and SAICM has been looking forward to manage such chemicals to minimize the adverse impact on human health and the environment. There have been efforts made to phase out BPA from baby feeding bottles and other children's products. Some of the pesticides such as Endosulfan have been phased out for use in agriculture. Stringent standards have been placed for Dioxins content from various wastes. Regulations are in place to restrict some of the EDCs in food and agricultural products. However, in India there are multiple challenges in implementation of these regulations. Additionally, there is a lack of standards for many of the EDCs in foods. In this context, few recommendations have been drawn out, which could restrict EDCs in food in India, in order to minimize the adverse impact on human health and the environment.

1 Recognizing EDCs as a threat

The WHO report on the "**State of Endocrine Disrupting Chemicals**" released in 2012 has categorically stated that EDCs are a global threat and needs to be resolved. It has also proposed a set of recommendations include Strengthening knowledge of EDCs, improved testing for EDCs, reducing exposures and thereby vulnerability to disease and creating enabling environments for scientific advances, innovation and disease prevention. Hence, considering global developments focused on EDCs, the Government of India needs to recognize the emerging problems associated with EDCs and create a specific policy framework to manage these chemicals considering the larger public health consideration.

2 Preventive measures

There are multiple sources of EDCs that cause contamination of the food chain and the environment. Thus, it is paramount to address these contaminants with suitable preventive measures. In India, efforts have been to regulate many EDCs including the BPA, Endosulfan, DDT, Mercury and Triclosan etc. However, there are instances when these regulations are not being implemented and these chemicals are contaminating the food chain. Furthermore, chemicals such as BPA and Mercury have been dealt in an isolated manner in India and many of the products still contain these chemicals, which need to be addressed urgently. For example, Mercury containing lamps are not being managed appropriately and BPA is being used in thermal paper in a large scale. Concerted efforts are required for suitable preventive measures to address the issue of EDCs in India.

3 Setting the research agenda

Toxics link has done a review of research studies on EDCs in India titled: "Endocrine Disruptor: Review of Indian Research[218]". This has identified a number of studies that have been carried out globally as well as in India on the various aspects of EDCs. However, considering the scale of researches being undertaken in other countries including China on these chemicals, the numbers of studies in India are very scanty. Further, there are very few studies available on the presence and linkages of EDCs in food in comparison to global studies. Therefore, Indian research institutions need to carry out more research studies on EDCs and create more data that will help in developing and strengthening the policy framework and regulatory mechanism in the country. The government also needs to encourage more accredited laboratories to detect the presence of the chemicals in food.

4 Labelling to reduce exposure of EDCs in foods

EDCs as a category include the wide range of chemicals and there is a growing use of many of these chemicals in day-to-day life. Especially in a country like India due to lack of adequate understanding and awareness on the impact of many of these chemicals as well poor management system in place, there is every possibility that these chemicals are contaminating the environment as well as the food chain. Hence proper labeling of these chemicals in day-to-day use will help the regulators, manufacturers, and consumers to take appropriate measures in preventing contamination in food.

5 Updating the food regulations

India has adopted a stringent Food Safety Standards Act 2006 to promote food safety considering the larger public health. In the FSSA Act, the food safety and standards (contaminant, toxins, and residue) regulations 2011 have prescribed limits to various chemicals in food. However, with the newer research studies on emerging EDCs, the regulations need to be updated by incorporating these evidences. As an example, many of the countries including developed and developing countries have set standards for Dioxins in food. Ironically despite of Indian studies having found the presence of Dioxins and Furans in foods, the regulations have not prescribed standard for Dioxins and Furans. Therefore, there is a need for updating of Food Safety and Standards (contaminants, toxins and residue) Regulations 2011 based on the science and global benchmark.

6 Enhance Institutional capacity

In India the States have an important role to play in implementing food safety regulations. Hence, it is paramount to invest in setting up facilities including the laborites in States to detect the emerging chemicals including EDCs in food. Further enhancement of capacity and knowledge of the concerned agencies on these emerging issues are critical in preventing EDCs contamination in the food chain. Hence, it is paramount to invest in setting up facilities including the laboratories in States to detect the emerging chemicals including EDCs in food".

218 Endocrine Disruptor: Review of Indian research"

Conclusion

India has established a unique position in the world for its food diversity. However, with the economic liberalization and the changing lifestyles in India, there is an increase in demand for frozen and ready-to-eat food and packaged food is earning popularity among the upwardly mobile urban middle class. There are also instances of high chemical pesticides used in agriculture, coupled with cross contamination, adulteration, use of food additives and preservatives. These are coming to light and raises suspicion on the safety of the food we are eating. Further, unscrupulous management of the waste in India has enhanced the possibility of contamination of food with toxins.

Research studies have established the fact that many of the chemicals including pesticides, preservatives are EDCs and contaminating the food chains. There are also EDCs sourced from consumer products and ending up in the food chain. Indian Government has taken initiatives to phase out BPA from the baby feeding bottles, lead from paints and so on. Furthermore, India is a party to various chemical conventions including Rotterdam, Stockholm, and Minamata Conventions and also a signatory to SAICM that reflects its commitment towards better management of chemicals. However, many of these chemicals are ubiquitous and their use needs to be either managed or to be phased out in an environmentally sound manner, to prevent contamination of food.

Finally, the Indian food and grocery market is the world's sixth largest, with retail contributing 70 percent of the sales. The Indian food processing industry accounts for 32 percent of the country's total food market, one of the largest industries in India and is ranked fifth in terms of production, consumption, export and expected growth. The Government of India has a plan to boost the growth of the food processing sector by leveraging reforms such as 100 percent Foreign Direct Investment (FDI) in marketing of food products. At the same time, the country is also witnessing high growth in exports of food items. Thus, considering the various aspects of food contamination due to inadequate attention to EDCs in India, the government must act to ensure that the food we eat as well as export is safe for consumption.

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201. Endocrine Disruptor: Review of Indian research"

Annexure-I

Table 46: Food chain contamination due to EDCs

Categories	EDCs Examples	Possible Food/Environmental Exposure	Human Exposure to EDCs
Industrial application and consumer products	Bisphenol A	Leaching of chemicals to the food and beverages at certain conditions	Oral consumption
	Triclosan	Environmental exposure through consumer products	Oral consumption and through contaminated water or food chain
	Phthalates	Leaching of chemicals to the food and beverages at certain conditions	Oral consumption
	Poly Chlorinated Biphenyls	Contamination of soil ground water after the end of life of the product containing PCBs (ex. Transformers) which may take up by vegetable/ plants	Contaminated water or food chain
	Deca BDE	Contamination of soil ground water after the end of life of the product containing BFRs (ex. Electronic and electrical equipments, etc.) which may take up by vegetable/plants	Contaminated water or food chain
	Penta BDE		
	Octa BDE		
Organochlorine pesticides	Lindane	Contamination of water and soil, which may take up by vegetable/ plants	Contact with skin or inhalation
	Methoxychlor		
	Chlorpyrifos		
	DDT		
	Endosulfan		
Environmental bi products	Dioxins	Contaminated air to its deposition on vegetables and fodder, cattle grazing and contamination of milk	Contact with skin or inhalations well as through contaminated food chain
	Furans		

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