Review

Chemical food contaminants: a growing concern for public health

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ABSTRACT

Significant health hazards are posed by the startling increase in chemical pollutants in food, threatening both public health and quality of life. Food contamination by chemicals is becoming a serious danger that needs to be addressed right away. As per the third Sustainable Development Goal of the United Nations, it is imperative to significantly decrease illnesses resulting from chemical exposure by 2030. In order to address chemical contamination, it is necessary to promote sustainable farming practices, tighten food safety legislation and comprehend the sources of contamination. Embracing international best practices is crucial to closing knowledge gaps and advancing development faster. In underdeveloped nations, embracing global experience and creative ideas can boost economic development, lower health risks and improve food safety. Global collaboration, information exchange and technical support can guarantee that everyone has access to wholesome food. Government, private sector, civil society and individuals must work together effectively to safeguard the food supply and advance a healthy future. This review seeks to analyze the types and origins of chemical contaminants found in food, extent of individual exposure and the subsequent health consequences, particularly within the Indian food system.

Keywords: Food; contaminants; public health; pollutants; hazards

INTRODUCTION

The threat of chemical contamination in food poses a significant and persistent risk to human health globally, with devastating consequences for individuals, communities and nations (Naidu et al 2021). In India, approximately 600 million people fell ill annually due to food contamination, resulting in 115,000 hospitalizations and 4,200 deaths (Anon 2017). Chemical contaminants in food can trigger a range of adverse health effects, from mild ailments to life-altering conditions such as birth defects, developmental disorders and cancer (Shittu et al 2023). The origins of these contaminants are diverse, encompassing environmental pollutants, food processing and storage practices, pesticide use, climate change and globalization. India's rapid industrialization and environmental pollution have exacerbated the issue, with inadequate agricultural practices, poor food handling and insufficient regulatory oversight contributing to widespread contamination (Agrawal et al 2010).

To combat this critical public health concern, a comprehensive and multifaceted approach is imperative. This requires integrating cutting-edge technologies, sustainable agricultural practices, stringent regulations, collaborative research, public awareness campaigns and education programmes. Effective prevention of chemical contaminants in food demands a proactive, holistic and science-driven strategy that

prioritizes food safety, sustainability and human well-being (Bachmann et al 2022). This review aims to examine the types and sources of chemical contaminants in food, individual exposure levels and resulting health impacts, with a focus on the Indian context. By understanding the scope of this issue, effective strategies to mitigate food contamination can be identified, sustainable practices can be promoted and safer and healthier food for the Indian population can be ensured.

Chemical contaminants present in food

The health of humans is significantly and persistently threatened by chemical pollutants found in food, which disproportionately harm disadvantaged groups, especially children (Adeola 2021). In addition to having developing immune systems, children eat more food relative to their body weight, which makes them more vulnerable to the negative effects of chemical pollutants (Mastorci et al 2021). Serious and protracted health concerns, such as cancer, developmental difficulties, neurological impairments and reproductive problems, can result from exposure to these dangerous compounds (Leoci and Ruberti 2021). Chemical pollutants can also have an additive and synergistic effect, which intensifies their negative impacts on human health (Aziz et al 2022). There are many different and extensive sources of chemical contamination in food, which can occur at different points in the food supply chain. Contaminants like fertilizers, herbicides and pesticides can find their way into the food chain during manufacturing (Mastorci et al 2021). Contamination can also result from storage and transportation circumstances, particularly in cases where hygienic standards are inadequate. Chemical pollutants have more potential to enter the food supply during food processing and preparation, whether through intentional addition to prolong shelf life or unintentional introduction as a result of poor hygiene procedures (Bachmann et al 2022). Moreover, raw foods including chicken, pork, fish and vegetables can introduce environmental diseases and naturally occurring toxins into the food chain.

Various risk points of food contaminants during production are given in Fig 1.

Methyl mercury: a neurotoxic contaminant

Through the metabolic processes of algae and bacteria, mercury is converted into organic compounds, such as methyl mercury (MeHg), which then bioaccumulates up through trophic levels (Kolipinski et al 2020). Fish is a common food source of methyl mercury, which is known to be neurotoxic and detrimental to human development. All fish contain methyl mercury, a known neurotoxicant in sufficient dosage (Clarkson et al 2003). Despite its negative effects, dietary fish is a rich source of Omega-3 poly-unsaturated fatty acids (Zibaeenezhad et al 2017). However, consideration of fish species and portion size is crucial to minimize methyl mercury exposure.

Polychlorinated biphenyls: industrial pollutants

Polychlorinated biphenyls (PCBs) are industrial chemicals that persist in the environment and accumulate in animal tissues, including fish and meat. The main exposure route to PCBs for humans is the consumption of contaminated food, mainly fish, seafood and dairy products (Schecter et al 2010, Feinberg et al 2011). Both human and experimental animal studies of early-life exposures to PCBs have documented adverse neurodevelopmental outcomes across domains related to cognition (eg IQ, language, memory, learning), attention, behavioral regulation and executive function and social behavior, including traits related to attention deficit hyperactivity disorder and autism spectrum disorders (Carlson et al 2023). Although PCB levels have declined, children are still exposed to low levels. Recent studies have linked PCBs to various disease conditions, including endometriosis.

Polybrominated diphenyl ethers (PBDEs): endocrine disruptors

Several investigators have identified PBDEs in meat, fish and dairy products (Domingo 2004, Domingo et al 2006, Harrad et al 2004, Manchester-Neesvig et al 2001, Schecter et al 2006). Numerous studies have shown that exposure to PBDEs is associated with endocrine dysfunction, developmental neurotoxicity and reproductive disorders (Costa et al 2014, Gao et al 2016, Jiang et al 2018). Endocrine disruptors have effects on male and female reproduction, breast development and cancer, prostate cancer, neuroendocrinology, thyroid, metabolism and obesity and cardiovascular endocrinology.

Bisphenol A: a well-researched endocrine disruptor

Bisphenol A (BPA) interferes with normal hormone functioning, primarily through dietary exposure from food and drink containers. The National Toxicology Programme has reported negative effects on the brain, behaviour and prostate gland due to BPA exposure during fetal development, infancy and

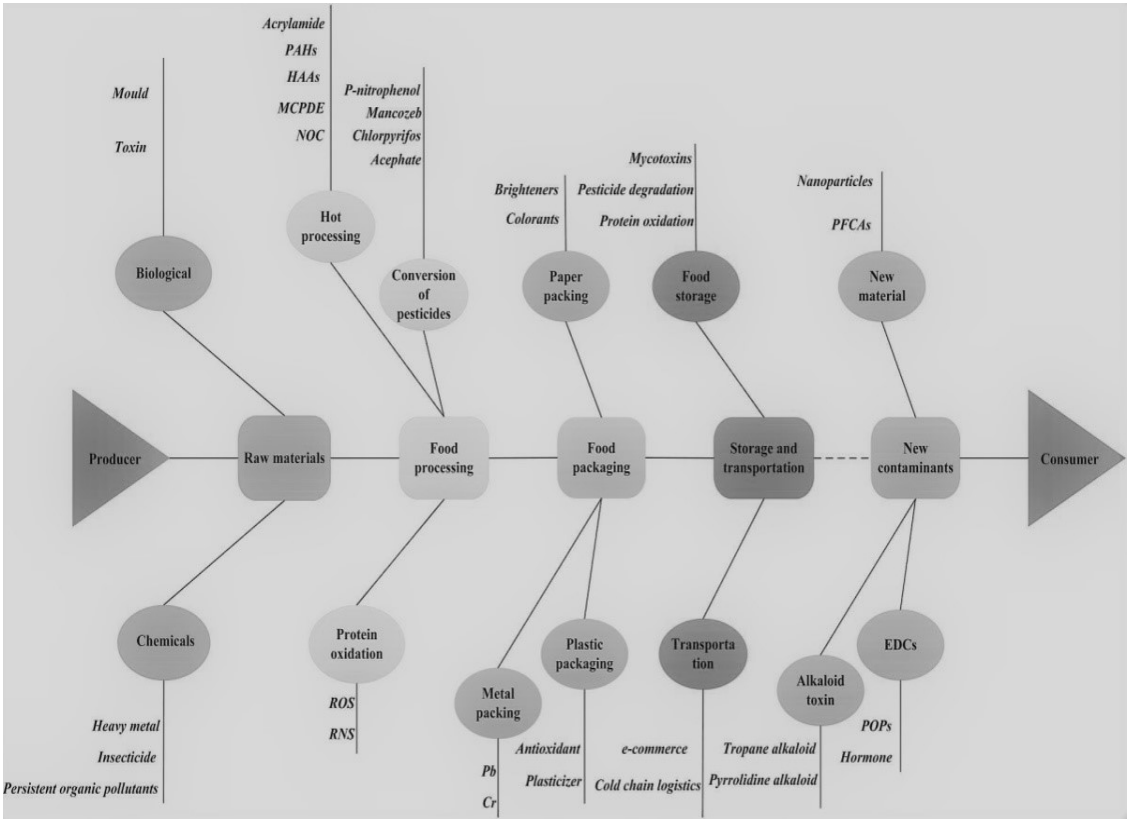

Fig 1. Various risk points of food contaminants during production

Source: Li et al (2021)

childhood. Regulatory measures have been taken to restrict BPA use in food containers and consumer products. There are some concerns associated with BPA exposure that have led developed countries to take practical measures to minimize exposure of the public to BPA through diet. The use of BPA in developed countries has been reduced due to a combination of consumer pressure and government regulations (Baluka and Rumbeiha 2016).

Phthalates: toxic chemicals in food

Phthalates are a group of toxic chemicals that are commonly found in a variety of fatty foods, including dairy products, fish, seafood, and oils. Additionally, exposure to these chemicals in infants occurs through the consumption of breast milk and infant formula, which can be contaminated with phthalates (Onyeaka et al 2024). Phthalates cause hormonal imbalance by interacting with nuclear receptors, hormonal receptors, signaling pathways and modulate gene expression linked with reproduction, thereby, disrupting the HPG axis that affects fertility (Hlisníková et al 2020, Li et al 2020). The European Food Safety Authority (EFSA) has established tolerable daily intake levels for low molecular weight phthalates.

Perchlorate: a thyroid disruptor

There are many exposure sources such as drinking water, foodstuffs and indoor dust, among which foodstuffs make the predominant contribution to human intake of perchlorate (Huber et al 2011, Zhang et al 2015a, 2015b).

Perchlorate competitively inhibits the uptake of iodide into the thyroid gland, where iodine is essential for the synthesis of thyroid hormones triiodothyronine (T3) and thyroxine (T4). In fetuses and infants, thyroid hormones are critical for normal growth and development of the central nervous system. Pregnant women and their fetuses and newborns have the greatest potential for risk of adverse health effects following exposure to perchlorate (Trumbo 2010). Monitoring and controlling perchlorate presence in the food supply is crucial to protect public health.

Prevention and control

Ensuring the safety and quality of food requires a comprehensive and multifaceted approach to prevent and control chemical food contaminants (Bachmann et al 2022). This begins with implementing good agricultural practices (GAPs) that minimize chemical

residues, such as restricting fertilizer and pesticide use, ensuring safe irrigation water and controlling harvesting conditions (Naidu et al 2021). Effective food processing methods, including cleaning, peeling and stewing, can reduce contaminant levels. Optimizing heating conditions and pH levels prevents harmful substance formation and microbial growth. Temperature is the most important environmental factor to delay microbial spoilage, as it directly affects the duration of lag phase and the growth rate (Jay et al 2005, Adams and Moss 2008). Where environmental pH deviates from optimal pH levels, microbial growth rates decrease (Rosso et al 1995).

Rigorous monitoring of raw material quality, coupled with regular testing and inspection, ensures compliance with food safety standards. Enforcement of stringent regulations and standards by regulatory agencies is critical. Promoting consumer awareness and education empowers individuals to make informed choices. Responsible food manufacturing and packaging practices, such as using non-toxic materials and minimizing waste, also play a vital role.

Investing in research and development in food safety technology enables the identification of innovative solutions (McCarthy et al 2018). Collaboration between governments, industries and stakeholders facilitates knowledge sharing and best practices adoption. Regular training and capacity-building programmes for food handlers and producers enhance their understanding of food safety protocols (Insfran-Rivarola et al 2020). By adopting this comprehensive strategy, the risk of chemical food contamination can be significantly minimized, ensuring safer and healthier food for consumers, protecting public health and preventing economic losses. Effective prevention and control measures safeguard the well-being of communities worldwide.

CONCLUSION

Due to the possible harm that chemical pollutants may do to human health, there has been an increase in concern over the years regarding their presence in food. Along the food supply chain, chemical pollutants are introduced that, if taken with food, could be harmful to consumers. The majority of food contamination is caused by naturally occurring poisons, environmental contaminants or food that has been processed, packaged, prepared, stored or transported.

Such pollutants are becoming easier to identify as technology develops. Research is still being done in this area; however, there are still a number of pollutants that are unknown. There are still efforts that need to be made to lower the health risks and diseases associated with chemical food contamination, even though the government has taken sufficient action to minimize individual exposure to food pollutants.

REFERENCES

Adams MR and Moss MO 2008. The microbiology of food preservation. In: Food microbiology, 3rd Edn (MR Adams and MO Moss, Eds), RSC Publishing, Cambridge, pp 92-97.

Adeola FO 2021. Global impact of chemicals and toxic substances on human health and the environment. In: Handbook of global health (I Kickbusch, D Ganten, D and M Moeti, Eds), Cham, Springer, pp 2227-2256.

Agrawal A, Pandey RS and Sharma B 2010. Water pollution with special reference to pesticide contamination in India. Journal of Water Resource and Protection **2(5):** 432-448.

Anonymous 2017. Food-borne diseases and food safety in India. CD Alert, Monthly Newsletter of the National Centre for Disease Control, Directorate General of Health Services, Government of India, March 2017.

Aziz FFA, Jalil AA, Hassan NS, Fauzi AA, Azami MS, Jusoh NWC and Jusoh R 2022. A review on synergistic coexisting pollutants for efficient photocatalytic reaction in wastewater remediation. Environmental Research **209:** 112748; doi: 10.1016/j.envres.2022.112748.

Bachmann N, Tripathi S, Brunner M and Jodlbauer H 2022. The contribution of data-driven technologies in achieving the sustainable development goals. Sustainability **14(5):** 2497; doi: 10.3390/SU14052497.

Baluka SA and Rumbeiha WK 2016. Bisphenol A and food safety: lessons from developed to developing countries. Food and Chemical Toxicology **92:** 58-63.

Carlson LM, Christensen K, Sagiv SK, Rajan P, Klocke CR, Lein PJ, Coffman E, Shaffer RM, Yost EE, Arzuaga X, Factor-Litvak P, Sergeev A, Toborek M, Bloom MS, Trgovcich J, Jusko TA, Robertson L, Meeker JD, Keating AF, Blain R, Silva RA, Snow S, Lin C, Shipkowski K, Ingle B and Lehmann GM 2023. A systematic evidence map for the evaluation of noncancer health effects and exposures to polychlorinated biphenyl mixtures. Environmental Research **220:** 115148; doi: 10.1016/j.envres.2022.115148.

Clarkson TW, Magos L and Myers GJ 2003. The toxicology of mercury – current exposures and clinical manifestations. New England Journal of Medicine **349(18):** 1731-1737.

Costa LG, de Laat R, Sara Tagliaferri S and Pellacani C 2014. A mechanistic view of polybrominated diphenyl ether (PBDE) developmental neurotoxicity. Toxicology Letters **230(2):** 282-294.

Domingo JL 2004. Human exposure to polybrominated diphenyl ethers through the diet. Journal of Chromatography A **1054(1–2):** 321-326.

Domingo JL, Bocio A, Falcó G and Llobett JM 2006. Exposure to PBDEs and PCDEs associated with the consumption of edible marine species. Environmental Science and Technology **40(14**): 4394-4399.

Feinberg M, Soler L, Contenot S and Verger P 2011. Assessment of seasonality in exposure to dioxins, furans and dioxin-like PCBs by using long-term food-consumption data. Food additives and contaminants, Part A: Chemistry, Analysis, Control, Exposure and Risk Assessment **28(4):** 502-512.

Gao Y, Chen L, Wang C, Zhou Y, Wang Y, Zhang Y, Hu Y, Ji L, Shi R, Cui C, Ding G, Jin J and Tian Y 2016. Exposure to polybrominated diphenyl ethers and female reproductive function: a study in the production area of Shandong, China. Science of the Total Environment 572: 9-15.

Harrad S, Wijesekera R, Hunter S, Halliwell C and Baker R 2004. Preliminary assessment of UK human dietary and inhalation exposure to polybrominated diphenyl ethers. Environmental Science and Technology **38(8):** 2345-2350.

Hlisníková H, Petrovièová I, Kolena B, Šidlovská M and Sirotkin A 2020. Effects and mechanisms of phthalates' action on reproductive processes and reproductive health: a literature review. International Journal of Environmental Research and Public Health **17(18):** 6811; doi: 10.3390/ijerph17186811.

Huber DR, Blount BC, Mage DT, Letkiewicz FJ, Kumar A and Allen RH 2011. Estimating perchlorate exposure from food and tap water based on US biomonitoring and occurrence data. Journal of Exposure Science and Environmental Epidemiology **21(4):** 395-407.

Insfran-Rivarola A, Tlapa D, Limon-Romero J, Baez-Lopez Y, Miranda-Ackerman M, Arredondo-Soto K and Ontiveros S 2020. A systematic review and meta-analysis of the effects of food safety and hygiene training on food handlers. Foods **9(9):** 1169; doi: 10.3390/foods9091169.

Jay JM, Loessner MJ and Golden DA 2005. Low-temperature food preservation and characteristics of psychrotrophic microorganisms. In: Modern food microbiology, 7th Edn (JM Jay, MJ Loessner and DA Golden, Eds), Aspen Publishers Inc, Springer, New York, pp 395-413.

Jiang J, Zhao H, Sun S, Wang Y, Liu S, Xie Q and Li X 2018. Occurrence and profiles of halogenated phenols, polybrominated diphenyl ethers and hydroxylated polybrominated diphenyl ethers in the effluents of waste water treatment plants around Huang-Bo sea, north China. Science of the Total Environment **622-623:** 1-7.

Kolipinski M, Subramanian M, Kristen K, Borish S and Ditta S 2020. Sources and toxicity of mercury in the San Francisco bay area, spanning California and beyond. Journal of Environmental and Public Health **2020:** 8184614; doi: 10.1155/2020/8184614.

Leoci R and Ruberti M 2021. Pesticides: an overview of the current health problems of their use. Journal of Geoscience and Environment Protection **9(8):** 1-20.

Li C, Li C, Yu H, Cheng Y, Xie Y, Yao W, Guo Y and Qian H 2021. Chemical food contaminants during food processing: sources and control. Critical Reviews in Food Science and Nutrition **61(9):** 1545-1555.

Li X-N, Li H-X, Yang T-N, Li X-W, Huang Y-Q, Zhu S-Y and Li JL 2020. Di-(2-ethylhexyl) phthalate induced developmental abnormalities of the ovary in quail (*Coturnix japonica*) via disruption of the hypothalamic-pituitary-ovarian axis. Science of the Total Environment **741:** 140293; doi: 10.1016/j.scitotenv.2020.140293.

Manchester-Neesvig JB, Valters K and Sonzogni WC 2001. Comparison of polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) in Lake Michigan salmonids. Environmental Science and Technology **35(6):** 1072-1077.

Mastorci F, Linzalone N, Ait-Ali L and Pingitore A 2021. Environment in children's health: a new challenge for risk assessment. International Journal of Environmental Research and Public Health **18(19):** 10445; doi: 10.3390/ijerph181910445.

McCarthy U, Uysal I, Badia-Melis R, Mercier S, O'Donnell C and Ktenioudaki A 2018. Global food security – issues, challenges and technological solutions. Trends in Food Science and Technology **77:** 11-20.

Naidu R, Biswas B, Willett IR, Cribb J, Singh BK, Nathanail CP, Coulon F, Semple KT, Jones KC, Barclay A and Aitken RJ 2021. Chemical pollution: a growing peril and potential catastrophic risk to humanity. Environment International **156:** 106616; doi: 10.1016/j.envint.2021.106616.

Onyeaka H, Ghosh S, Obileke K, Miri T, Odeyemi OA, Nwaiwu O and Tamasiga P 2024. Preventing chemical contaminants in food: challenges and prospects for safe

and sustainable food production. Food Control **155:** 110040; doi: 10.1016/j.foodcont.2023.110040.

Rosso L, Lobry JR, Bajard S and Flandrois JP 1995. Convenient model to describe the combined effects of temperature and pH on microbial growth. Applied and Environmental and Microbiology **61(2):** 610-616.

Schecter A, Colacino J, Haffner D, Patel K, Opel M, Päpke O and Birnbaum L 2010. Perfluorinated compounds, polychlorinated biphenyls and organochlorine pesticide contamination in composite food samples from Dallas, Texas, USA. Environmental Health Perspectives **118(6):** 796-802.

Schecter A, Päpke O, Harris TR, Tung KC, Musumba A, Olson J and Birnbaum L 2006. Polybrominated diphenyl ether (PBDE) levels in an expanded market basket survey of US food and estimated PBDE dietary intake by age and sex. Environmental Health Perspectives **114(10):** 1515-1520.

Shittu E, Lakhanpaul M, Vigurs C, Sarkar K, Koch M, Parikh P and Campos LC 2023. A rapid systematic scoping review of research on the impacts of water contaminated by chemicals on very young children. Science of the Total Environment **891:** 164604; doi: 10.1016/j.scitotenv.2023.164604.

Trumbo PR 2010. Perchlorate consumption, iodine status, and thyroid function. Nutrition Reviews **68(1):** 62-66.

Zhang T, Chen X, Wang D, Li R, Ma Y, Mo W, Sun H and Kannan K 2015a. Perchlorate in indoor dust and human urine in China: contribution of indoor dust to total daily intake. Environmental Science and Technology **49(4):** 2443-2450.

Zhang T, Cooper S and Brockdorff N 2015b. The interplay of histone modifications - writers that read. EMBO Reports **16(11):** 1467-1481.

Zibaeenezhad MJ, Ghavipisheh M, Attar A and Aslani A 2017. Comparison of the effect of omega-3 supplements and fresh fish on lipid profile: a randomized, open-labeled trial. Nutrition and Diabetes **7:** 1; doi: 10.1038/s41387-017-0007-8.