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Study of Routes of Exposure to Bisphenol A in Mammals

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ABSTRACT

Bisphenol A (BPA) is one of the most relevant environmental toxins worldwide. BPA is primarily utilized in the manufacture of epoxy resins and polycarbonate plastics. Mammals, as well as aquatic and wildlife animals, are highly vulnerable to BPA exposure due to the widespread use of plastic products. Mammals are exposed to BPA mainly through ingestion, inhalation, and skin contact. The most significant exposure route is oral, as BPA can leach into food and drinks from polycarbonate containers and epoxy-lined cans. Dermal exposure can happen through contact with products like thermal paper receipts that contain BPA. The way BPA enters the body and its potential health effects vary by exposure route, with ingestion typically leading to higher systemic levels. Understanding these exposure pathways is essential for evaluating BPA's health impact and creating effective exposure reduction strategies.

KEYWORDS: *Bisphenol A, BPA, Mammal, Health, Toxin, Polycarbonate, Oral exposure, Inhalation, Dermal absorption.*

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INTRODUCTION

Bisphenol A (BPA) is a synthetic organic compound globally recognized as a major environmental toxicant. Chemically, it is formulated as 4,4'-dihydroxy-2,2-diphenyl propane (CAS No. 80–05–7). BPA was first synthesized in the year 1891 by the Russian chemist Aleksandr Dianin, and its synthesis was later formalized in 1905 by the German scientist Theodor Zincke. The compound is produced through a condensation reaction between phenol and acetone, and water is produced as a by-product (Kumari and Thakur, 2026; Cull and Winn, 2025).

BPA is widely used in the production of polycarbonate plastics, epoxy resins, and various other polymeric products. It is also commonly employed in the manufacturing of food and beverage containers, water bottles, thermal paper, dental sealants, electronic devices, water pipes, and as a protective coating inside metal cans to avoid rusting and contamination (Kumari et al., 2026).

According to the EFSA (2023), BPA exposure from food is probably harmful at current levels across all age groups and represents a public health concern, particularly because of immune-related effects. Stricter regulatory control is necessary to protect public health.

BPA can be discharged into the environment at different stages, including its production, usage, or degradation, either directly or indirectly. It presents significant risks to human health and the environment because of its toxic nature and ease of penetration into the body (Charkiewicz et al., 2024). BPA can enter the body through multiple routes such as ingestion, inhalation, and dermal absorption, leading to its widespread bioavailability. Continuous exposure, even at low concentrations, has been associated with endocrine disruption and potential long-term physiological disorders including neurotoxicity, impaired immune response, respiratory damage, hepatotoxicity, genotoxicity, and reproductive toxicity (Ma et al., 2019; Rochester, 2013).

Environmental Occurrence of BPA:

BPA is pervasive in the environment and can enter waterbodies as a result of improper disposal of household and industrial wastewater, ineffective removal at wastewater treatment plants (WWTPs), and the gradual deterioration of plastic materials. As a

result, BPA has been found in surface waters in a number of European, American, Asian, and African nations (Santos et al., 2024).

Industrial processes, degradation of plastic waste, and leaching from consumer goods all release BPA into the environment. Surface water, soil, air, and food items are among the environmental matrices in which it has been found. Chronic exposure in mammals is a result of environmental persistence and its extensive distribution. Because of the dust and materials that contain BPA, indoor environments in particular serve as important reservoirs (Vandenberg et al., 2007).

BPA and other phenolic compounds have been found in multiple environmental matrices at levels of up to 3900 μg kg^{-1} in indoor dust, up to 9730 μg kg^{-1} in dust, up to 39,000 μg kg−1 in thermal receipts, up to 898.7 ng L^{-1} in drinking water, up to 46.31 μg kg^{-1} in sediment sample, up to 81.39 μg kg^{-1} in sediment organic matter, and up to 2.79 μg L^{-1} in human urine (Akcetin et al., 2025).

Different Routes of Exposure in Mammals:
BPA may enter into the body through oral route, respiratory route, or transdermal absorption.

Oral Route:
oral exposure of BPA is one of the most common routes. Polycarbonate plastics and epoxy resin linings can release BPA into food and drink, particularly when exposed to heat, acidity, or frequent use (Lee et al., 2025). After being orally consumed, BPA enter into the body through the mesenteric blood vessels, then it is quickly absorbed by the digestive system and first-pass metabolized in the liver to produce BPA-glucuronide (Thayer et al., 2015; Tominaga et al., 2006). Continuous dietary exposure causes detectable BPA levels in biological fluids despite metabolic detoxification, suggesting ongoing systemic exposure (Zimmers et al., 2014; Cao et al., 2012).

Respiratory Route:
BPA is inhaled through airborne dust particles and aerosols found in industrial and indoor settings.

After being inhaled, BPA can enter the systemic circulation and absorbed through the pulmonary epithelium. It contributes to chronic low-dose exposure. Respiratory exposure is comparatively less significant than ingestion or oral exposure (Guignard et al., 2016; Geens et al., 2012).

BPA exposure exhibit strong toxic effects on healthy respiratory cells, especially lung and tracheal fibroblasts. It can damage healthy cells even without any pre-existing disorders, highlighting that long-term or high-level exposure may lead to severe respiratory damages and potentially cancer by disrupting the cell cycle and promoting cell death (Aysin et al., 2024).

Dermal Absorption:
Direct contact with BPA-containing materials, such as plastic products, cosmetics, and photoactive dies present in thermal paper receipts, can result in dermal absorption (Bernier and Vandenberg, 2017).

BPA absorbed through the skin avoids hepatic first-pass metabolism, in contrast to oral exposure, which may result in increased bioactive concentrations in the systemic circulation. Occupational exposure is a major concern, especially for industrial workers and cashiers handling thermal receipts (Sasso et al., 2020; Ndaw et al., 2016).

Measures to Limit BPA Exposure:
The following measures can be adopted to reduce BPA exposure:

1. Using BPA-free substitutes.
2. Food items should not be heated in plastic containers.
3. Minimizing the intake of canned food products.
4. Reducing the contact with thermal paper receipts such as ATM receipts, grocery bills, train or flight tickets etc.
5. Improving waste management and recycling procedures.

Conclusion:
BPA is a ubiquitous environmental pollutant that can be ingested, inhaled, or absorbed through the skin by mammals. Although oral exposure is still the most common route, inhalation and dermal routes also play a major role in total exposure. Understanding exposure pathways is crucial for efficient risk assessment and mitigation because BPA disrupts hormones and is linked to a number of health issues. To lower the health risks associated with BPA, further research and more stringent regulations are required.

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