



# **Crude Oil–Derived Plastics and Maternal Health in Nigeria: Investigating Bisphenol A Exposure from Plastic-Packaged Foods Using Pregnant Rat Models**

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## **Abstract**

The extensive use of plastics derived from crude oil has led to increased consumption of plastic-packaged foods worldwide, including in Nigeria, raising concerns about the migration of chemical compounds such as bisphenol A (BPA). BPA is an endocrine-disrupting chemical capable of crossing the placental barrier, potentially affecting both maternal and fetal health. This review explores the production and applications of petrochemical plastics, mechanisms of BPA migration into food, and associated health risks, with particular focus on pregnancy outcomes. Plastics commonly used in Nigeria, including polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), and polyvinyl chloride (PVC), are analyzed for their suitability, additives, and potential to release BPA under various conditions. BPA's chemical characteristics and estrogen-like activity are examined, along with evidence from global studies linking prenatal exposure to adverse outcomes such as preterm birth, low birth weight, gestational diabetes, and disruptions in neurodevelopment. Research using rat models provides insights into the mechanisms of BPA-induced reproductive toxicity, including effects on implantation, placental development, and fetal growth. Despite extensive international data, information from Nigeria and Sub-Saharan Africa remains scarce,

with few studies assessing maternal BPA exposure or its impact on pregnancy outcomes. The review highlights the need for localized biomonitoring studies, longitudinal cohort research, and integration of animal and human data to better assess BPA-related reproductive risks and guide public health strategies in regions with high reliance on plastic-packaged foods.

**Keywords:** Crude Oil, Plastics, Maternal Health, Bisphenol A, Rat Models

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## Introduction

The global crisis of plastic pollution has emerged as a critical ecological and public health emergency, with far-reaching consequences for biodiversity and international economic stability (Geyer et al., 2017; Ugoy et al., 2025). The massive manufacturing and ubiquitous application of synthetic polymers most notably those derived from polyethylene have resulted in the massive build-up of non-biodegradable waste across land and sea (Chamas et al., 2020; Agu et al., 2023a).

A significant driver of this environmental burden is the reliance on single-use packaging, such as sachet water films and shopping bags, which are utilized briefly but endure in the biosphere for centuries. This phenomenon is particularly acute in emerging economies, where such materials remain the primary medium for essential water delivery and retail packaging (Stoler et al., 2015; Ekpunobi et al., 2025).

The longevity of traditional plastics in the environment is a direct result of their specialized molecular engineering, which is specifically designed to withstand biological and chemical breakdown (Andrady & Neal, 2009; Agu et al., 2023b). Polyethylene, for instance, resists natural degradation for hundreds of years, eventually breaking down into microplastics that contaminate global food webs and destabilize ecosystems (Chamas et al., 2020; Uwanta et al., 2023a).

Furthermore, the rapid expansion of petroleum-based plastic use in food packaging, fueled by urbanization and the demand for convenience, has raised urgent alarms regarding chemical leaching (Adeyi & Babalola, 2019; Tipale, Shukla, & Balaji, 2023). Specifically, the migration of

Bisphenol A (BPA), a potent endocrine disruptor into food and water poses a significant risk to maternal and fetal health, as it can penetrate the placental barrier (Hiyama et al., 2018; Laguerre et al., 2021).

This review examines the patterns of plastic utilization within Nigeria, the pathways of BPA exposure, the subsequent health implications, and the utilization of animal models to investigate the effects of these toxins on pregnancy outcomes in the Nigerian population.

## Crude Oil-Derived Plastics in Nigeria, Their Chemical Additives and Health Risks

Crude oil-derived plastics are synthetic polymers produced from petrochemical feed-stocks, which are hydrocarbon fractions obtained during crude oil refining. These feed-stocks are processed into monomers such as ethylene and propylene, which are polymerized to produce widely used plastics, including polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET) (Gerassimidou *et al.*, 2023; Tipale, Shukla, & Balaji, 2023). These plastics are extensively used in food packaging due to their durability, lightweight nature, and cost-effectiveness, while providing barriers against moisture, oxygen, and other environmental factors (Food Research International, 2025). However, chemical additives and residual monomers in these plastics can migrate into food, particularly under heat, acidic conditions, or prolonged storage, posing potential health risks to consumers (Gerassimidou *et al.*, 2023; MDPI Foods, 2023). In Nigeria, plastic packaging is ubiquitous in the food supply chain, including bottled water, sachets, canned foods, and fast-moving consumer goods, reflecting a heavy reliance on crude oil-derived polymers for food storage and distribution (Tipale *et al.*, 2023).

The most commonly used plastics for food packaging in Nigeria include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), and polyvinyl chloride (PVC), each selected based on durability, cost, and suitability for specific food products (Adeyi & Babalola, 2019; Omoyajowo *et al.*, 2024). Polyethylene (PE), particularly low-density (LDPE) and high-density (HDPE), is widely used for sachets, flexible wraps, and storage bags due to its flexibility, moisture barrier properties, and affordability (Omoyajowo *et al.*, 2024). Polypropylene (PP) is preferred for heat-resistant containers, takeaway boxes, and microwavable food packaging, as it can withstand higher temperatures without deformation (Adeyi & Babalola, 2019). Polyethylene terephthalate (PET) is extensively used for bottled beverages, soft drinks, and water sachets because of its clarity, lightweight nature, and excellent gas barrier properties (Eze *et al.*, 2023). Other plastics, such as polystyrene (PS), are used for disposable cups, trays, and food containers, while polyvinyl chloride (PVC) is sometimes used for cling wraps and packaging films (Adebayo & Akinyemi, 2022).

All the forms of plastics used in Nigeria are often enhanced with chemical additives like plasticizers, stabilizers, and colorants, which may migrate into foods under certain conditions, especially when exposed to heat or fatty foods (Adeyi & Babalola, 2019). The extensive use of these plastics in Nigeria reflects both the economic importance of plastic packaging in the food industry and the potential risk of human exposure to chemical migrants such as Bisphenol A (BPA) and phthalates (Omoyajowo *et al.*, 2024).

### **Bisphenol A (BPA) and Health**

Bisphenol A (BPA) can migrate from plastic food packaging into food through multiple mechanisms, primarily driven by diffusion and polymer degradation. Diffusion-controlled migration moves BPA from higher concentrations within the polymer to the food interface and is accelerated by heat, prolonged storage, and

repeated use of containers (Cao *et al.*, 2020; Geens *et al.*, 2012; Liu *et al.*, 2021). Hydrolytic degradation of polycarbonate plastics under heat, moisture, or acidic conditions releases free BPA monomers, while its lipophilic nature promotes accumulation in fat-rich foods, increasing dietary exposure (Huang *et al.*, 2018; Gallo *et al.*, 2023). Additional pathways, such as penetration migration and set-off from inks or coatings, further contribute to BPA leaching (Muncke *et al.*, 2020). These processes highlight that both packaging properties and food-contact conditions influence BPA release, raising concerns about chronic exposure through plastic-packaged foods.

### **Chemical Properties of Bisphenol A (BPA) and Endocrine-Disrupting Potential ‘**

Bisphenol A (BPA) is a synthetic organic compound classified as a diphenylmethane derivative (2,2-bis(4-hydroxyphenyl) propane) whose molecular structure—comprising two phenolic rings linked by a carbon bridge, confers lipophilicity and weak estrogenic activity (Vandenberg *et al.*, 2012). These properties underpin its extensive use in polycarbonate plastics and epoxy resins and facilitate its migration into foods and biological systems, particularly following oral exposure (Geens *et al.*, 2012; Rochester, 2013). BPA is widely recognized as an endocrine-disrupting chemical due to its ability to mimic endogenous estrogens and interact with estrogen (ER $\alpha$  and ER $\beta$ ), androgen, and thyroid hormone receptors, thereby disrupting hormonal signaling, synthesis, and metabolism even at low exposure levels (Rochester & Bolden, 2015; Vandenberg *et al.*, 2012). Notably, BPA exhibits non-monotonic dose-response relationships, where low-dose exposures may elicit significant biological effects not predicted by traditional toxicological models (Rubin, 2011). BPA can also cross biological barriers, including the placenta, resulting in direct fetal exposure during pregnancy, a critical hormonally sensitive period (Zhang *et al.*, 2017). Consequently, prenatal BPA exposure has been associated with alterations in reproductive development, metabolic regulation, immune function, and neurodevelopment in both

experimental models and human studies, raising significant concerns for maternal and offspring health (Braun, 2017; Rochester, 2013).

### **Prenatal BPA Exposure and Maternal-Fetal Health**

Global studies have consistently shown that prenatal exposure to bisphenol A (BPA) is associated with adverse maternal and fetal health outcomes. Elevated maternal BPA levels have been linked to disrupted glucose metabolism, increased risk of gestational diabetes, systemic inflammation, and pregnancy complications such as preeclampsia (Philippat *et al.*, 2023; Zhang *et al.*, 2021). For the fetus, BPA exposure has been associated with reduced birth weight, preterm delivery, impaired placental function, and altered neurodevelopment and metabolic programming (Ejaredar *et al.*, 2017; Zhou *et al.*, 2022). These findings highlight BPA's potential to interfere with critical endocrine and developmental processes during pregnancy, raising concerns about long-term health consequences for both mother and offspring (Rochester and Bolden, 2015).

### **Evidence From Animal Models on BPA-Induced Reproductive Toxicity**

Experimental evidence from animal models indicates that prenatal exposure to bisphenol A (BPA) disrupts endocrine signaling and adversely affects pregnancy and fetal development. BPA, a well-recognized endocrine-disrupting chemical, interferes with hormone receptors essential for implantation, placental development, and fetal growth (Rosenfeld, 2020; Peretz *et al.*, 2023). Studies in rodents and other mammalian models have linked gestational BPA exposure to implantation failure, placental dysfunction, oxidative stress, and fetal growth restriction through estrogen-like activity and altered placental gene expression involved in nutrient transport and metabolism (Mustieles & Fernández, 2022; Tait *et al.*, 2015). Recent mechanistic reviews continue to support the biological plausibility of BPA-induced

reproductive and developmental toxicity across experimental models (Gore *et al.*, 2023).

### **Human Epidemiological Evidence on BPA**

Human epidemiological studies similarly suggest associations between prenatal BPA exposure and adverse pregnancy and neonatal outcomes, although findings vary by population and exposure assessment methods. A recent systematic review reported that prenatal BPA exposure is generally associated with reduced birth weight, increased risk of preterm birth, and other unfavorable neonatal indicators, despite low to very low certainty of evidence (Ejaredar *et al.*, 2023). Beyond birth outcomes, emerging evidence indicates that maternal BPA exposure may affect early childhood neurodevelopment, with associations reported for altered emotional regulation and cognitive performance in children aged 2–5 years (Mustieles *et al.*, 2025). Collectively, evidence from animal experiments and human epidemiological studies underscores concerns that BPA exposure during pregnancy may negatively influence pregnancy outcomes and early child development.

### **Research Gaps on BPA Exposure in Nigeria and Sub-Saharan Africa**

Despite growing global concerns about BPA, research on its effects during pregnancy remains limited in Nigeria and Sub-Saharan Africa. Most studies have measured BPA in foods or general populations, but few have assessed maternal exposure or linked it to outcomes such as preterm birth or low birth weight (Akinwande *et al.*, 2019; Olujimi *et al.*, 2015). Biomonitoring data are scarce, with only isolated studies in South Africa showing maternal-fetal correlations, while similar data are largely absent in Nigeria (Mkwetshana *et al.*, 2022). Environmental assessments indicate BPA contamination in water sources, but potential pregnancy risks remain poorly characterized, and public awareness of BPA hazards is low (Adeyi & Babalola, 2019). These gaps highlight the need for longitudinal pregnancy cohorts, repeated biomonitoring, and region-specific exposure studies to better understand BPA's impact and

inform public health interventions (Omoyajowo *et al.*, 2024).

## Animal Models in Toxicology

### Use of Rats in Reproductive and Developmental Toxicology

Rats are among the most widely used animal models in reproductive and developmental toxicology because they offer practical advantages such as short gestation periods, well-characterized reproductive physiology, ease of handling, and the ability to control exposure conditions rigorously (Boster Bio, 2024). In reproductive toxicity research, rats are routinely exposed to chemicals, including endocrine disruptors like bisphenol A (BPA), throughout gestation to assess effects on maternal health, embryo–fetal development, and early postnatal outcomes. For example, studies administering BPA to pregnant Sprague-Dawley rats have identified adverse outcomes such as reduced maternal body weight gain and increased pregnancy failures at high doses, and changes in blood pressure and metabolic parameters in dams exposed during pregnancy, demonstrating how prenatal exposures can alter physiological processes in both mothers and offspring (Evaluation of developmental toxicity in rats exposed to BPA, 2024; Impact of intrauterine BPA exposure, 2020). These and similar rat studies enable detailed examination of endpoints, such as implantation success, fetal growth parameters, and placental function, that are central to understanding reproductive hazards and are difficult or unethical to study directly in humans.

### Relevance and Limitations of Rat Models in Reproductive Toxicology

The use of rats in toxicological studies contributes valuable mechanistic data that help infer potential human reproductive risks.

Regulatory guidelines for reproductive and developmental toxicity testing, such as those used in pharmaceutical safety assessment, often include rat models as a standard species because they can reveal hazards, dose-response relationships, and windows of susceptibility relevant to humans ((International Council for Harmonization [ICH], 2020; Kougias, 2025). However, the translational value of rat data requires careful interpretation because species differences in physiology, metabolism, and placental structure can influence how findings translate to human pregnancy outcomes (Habert *et al.*, 2013; Roos *et al.*, 2024). While rat models frequently identify potential hazards and inform risk assessments for chemicals with endocrine-disrupting properties, evidence suggests that not all effects observed in rodents predict human outcomes reliably, and results should be integrated with human epidemiological data wherever possible to strengthen relevance for human health risk assessment (Habert *et al.*, 2013; Kougias, 2025).

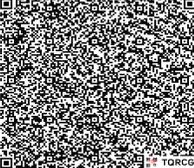
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