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Review Article

Bisphenol A as a Reproductive Toxicant: An Interpretive Approach from Occupational Nursing

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ABSTRACT

Introduction: Bisphenol A (BPA) is a ubiquitous endocrine disruptor whose occupational exposure poses a risk to workers across multiple industrial sectors. The revision of Royal Decree (RD) 665/1997 through RD 612/2024 requires specific protection against reprotoxic agents; however, a gap remains between scientific evidence and health surveillance protocols within Occupational Nursing.
Aim: To analyse the scientific evidence regarding BPA as a reprotoxic disruptor from the perspective of Occupational Nursing, identifying implications for health surveillance and preventive education among exposed workers.
Method: A qualitative interpretative analysis was conducted following Braun and Clarke's six-step approach based on a systematic review retrieved from PubMed using the MeSH combination "Bisphenol A Compounds" AND "Endocrine Disruptors." Study quality was assessed according to PRISMA criteria.
Results: Five categories of effects were identified: alterations in female fertility, alterations in male fertility, effects on assisted reproduction, gestational and foetal effects, and other endocrine effects. From the analysis, four thematic categories emerged relevant to Occupational Nursing: reproductive health surveillance, protection during exposure, detection of endocrine disruption symptoms, and health education and prevention.
Conclusions: BPA represents a significant reprotoxic risk for workers. Occupational Nurses must ensure the early detection of endocrine disruption symptoms, provide comprehensive health education, and participate in risk assessment processes. This analysis reinforces the nursing role in occupational health, aligning practice with RD 612/2024 and current trends in reproductive protection at work.

Keywords: Bisphenol A Compounds; Fertility; Occupational Health; Occupational Health Nursing; Reproduction; Toxicity.

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Introduction

The production of Bisphenol A (BPA), a synthetic chemical compound first synthesised in 1890, has increased exponentially since the 1950s, becoming one of the most widely manufactured chemicals worldwide. Its production is estimated to reach 8.72 million tonnes by 2025, with projections of 11.98 million tonnes by 2030, representing an annual growth rate of 6.5% (1). Approximately 100 tonnes of BPA are released into the environment each year, making it a ubiquitous and virtually unavoidable substance for both humans and ecosystems (2).

Present in commonly used consumer products such as plastic bottles, dental sealants, and printing inks, BPA can leach or migrate from these products into food, beverages, and the environment, particularly when exposed to high temperatures, ultraviolet light, or mechanical degradation. This migration capacity accounts for the ubiquitous presence of BPA in human biological samples (blood, urine, saliva, breast milk, amniotic fluid), as documented in numerous biomonitoring studies across global populations (3).

In November 2006, the European Food Safety Authority (EFSA) published its first risk assessment of BPA, identifying its potential as an endocrine disruptor (4). Since then, European regulation has evolved: in 2011, its use was phased out from baby bottles and infant packaging; in 2018, it was banned from plastic bottles and infant feeding containers for children under 3 years of age; and in December 2024, the European Union prohibited its use in all food contact materials (5,6).

In the occupational context, BPA represents a significant exposure risk for workers across multiple industrial sectors. As a raw material, it is used in the manufacture of polycarbonates, epoxy resins, paints; and as an intermediate product, it participates in the synthesis of fungicides, antioxidants, dyes, phenolic resins, polyesters, and flame retardants. This ubiquitous presence poses a health risk to both the general population and, specifically, to occupationally exposed workers (7).

The most significant regulatory advancement for health protection has been the recent update to Royal Decree (RD) 665/1997. Through RD 612/2024, of 2 July, RD 665/1997 has been amended to explicitly incorporate the protection of workers against risks

associated with exposure to reprotoxic agents, i.e., substances that may adversely affect the sexual function and fertility of adults, as well as the development of their offspring (8).

BPA acts as an endocrine disruptor, a substance that interferes with the synthesis, transport, metabolism, or action of the body's natural hormones, thereby altering endocrine homeostasis through several interdependent mechanisms that are particularly hazardous during critical developmental periods (gestation, lactation, childhood, puberty), when tissues are more sensitive to hormonal signals. Additionally, BPA's effects follow a non-monotonic dose-response curve, whereby low concentrations sometimes produce more pronounced effects than intermediate ones, challenging the classical paradigm of "the dose makes the poison".

BPA exerts reproductive and developmental toxic effects in humans by modulating oxidative, hormonal, and genetic pathways in both sexes and during gestation. In women, it induces ovarian oxidative stress that damages follicles, reduces ovarian reserve (low antimüllerian hormone and antral follicle count), disrupts the oestrogen-FSH-LH balance and growth factors such as oestradiol, and is associated with endometriosis and polycystic ovary syndrome. In men, it inhibits testicular antioxidants, damages germinal RNA and sperm mitochondria, impairs sperm capacitation via proteoglycans and tyrosine phosphorylation, resulting in oligoasthenoteratospermia, sperm DNA fragmentation, hypoandrogenism (low testosterone due to Leydig cell dysfunction), and sexual dysfunctions such as reduced libido and altered ejaculation (9,10).

Prenatal exposure exacerbates these risks, as BPA crosses the placenta and accumulates in the foetus, interfering with sexual differentiation (hypospadias, cryptorchidism, testicular atrophy, and genital feminisation in males), neurodevelopment (dopaminergic, serotonergic, and cholinergic alterations leading to anxiety, depression, ADHD, and cognitive deficits due to reduced hippocampal dendritic density, among others), and foetal thyroid function (hypothyroxinaemia, low TSH, and altered receptors, inter alia)(9,10).

Although the RD emphasises the role of the occupational physician, Occupational Nursing plays a critical and insufficiently recognised role (11). Occupational nurses are responsible for collecting biological samples for biomonitoring, are often the first professional healthcare contact for workers and thus able to detect symptoms early,

intervene in health education and preventive measures, or record clinical-occupational histories including reproductive history, among other functions (12).

The current gap between scientific evidence on BPA reprotoxicity and its incorporation into occupational health surveillance protocols represents a significant opportunity for Occupational Nursing to make a meaningful contribution. An analysis of the evidence would enable the translation of scientific findings into concrete surveillance and prevention actions, identification of early indicators of reproductive impairment, development of specific nursing diagnoses and interventions for workers exposed to BPA, and strengthening of the professional role of Occupational Nursing as an essential discipline in occupational health. Accordingly, the following objectives were formulated.

General objective

To conduct an interpretative analysis of scientific findings on Bisphenol A (BPA) as a reprotoxic disruptor, reinterpreting the evidence from the specific perspective of Occupational Nursing in order to identify actions for health surveillance and preventive education applicable to exposed workers, within the context of the update to RD 665/1997

Specific objectives

To propose recommendations for minimising BPA exposure among workers of reproductive age and pregnant women, taking into account current legislation.

To contribute to strengthening the role of Occupational Nursing in the surveillance of workers exposed to reprotoxic agents, aligning with the provisions of the regulatory update and emerging trends in occupational health.

Methods

A secondary qualitative study was conducted with an interpretative analysis of the studies identified through a literature search in PubMed to address the research question in PICO format: How does BPA affect the reproductive health of workers?

A search was conducted on Bisphenol A and endocrine disruption using the MeSH term combination: ("Bisphenol A Compounds"[Mesh]) AND ("Endocrine Disruptors"[Mesh]).
Systematic reviews published in any language and without date restrictions were included. Documents that did not address the research question were excluded.
Study quality was assessed following the PRISMA statement.

The interpretative analysis was conducted according to Braun and Clarke's six-step process (13): familiarisation with the systematic review through repeated readings; generation of codes by labelling relevant excerpts on reproductive effects and occupational applicability; collation of codes into potential themes; review of theme coherence; definition of thematic categories; and narrative synthesis applied to the functions of Occupational Nursing.

Results

Seven reviews were identified, of which six were excluded. One focused exclusively on neurobehavioural aspects or ADHD in children, two did not address BPA as an endocrine disruptor, and three were reviews of assisted reproductive techniques without reference to BPA. The selected systematic review was: "Bisphenol A and human fertility: a systematic review".

This review demonstrated adequate methodological quality (search across three databases, 28 studies included following PRISMA protocol and risk-of-bias assessment), focused on the human reprotoxicity of BPA, and was recently published, covering literature searches up to September 2024. The review achieved 81% compliance with PRISMA standards and included experimental studies, observational studies, literature reviews, and meta-analyses on BPA and human fertility.

Twenty-two initial codes were generated on reproductive effects and occupational applicability, which were grouped into five potential themes and iteratively reviewed for internal coherence (conceptual homogeneity within each theme) and external differentiation (clear distinction between themes), resulting in four final thematic categories aligned with nursing functions. Thematic saturation was achieved, confirmed by the absence of new categories upon re-reading the data. The identified effects can be consulted in Table 1.

Table 1. Synthesis of BPA reproductive effects.

Population	**Main effects**	**Mechanisms of action**
Women	Reduction in ovarian reserve	Oxidative stress
	Menstrual irregularities	Apoptosis
	Oestrogenic alterations and follicle-stimulating hormone	Local inflammation
	Polycystic ovary syndrome	
	Endometriosis	
Men	Oligoasthenoteratospermia	Oxidative stress
	Sperm DNA fragmentation	Inhibition of testicular antioxidants
	Decreased libido	Germinal RNA damage
	Ejaculatory alterations	Damage to gene expression
	Hypoandrogenism	
Assisted reproduction	Reduced ovarian response	Apoptosis
	Reduction in mature oocytes	
	Reduced fertilisation	
	Reduced implantation	
	Reduced embryo quality	
Gestation and foetal development	Miscarriages	Sexual differentiation alterations
	Preterm births	Neurodevelopment alterations
	Hypospadias	Thyroid function alterations
	Cryptorchidism	
	Testicular atrophy	
	Reduced hippocampal dendritic density	
	Hypothyroxinaemia	
	ADHD, anxiety, and depression in children	
Others	Metabolic alterations (insulin resistance, hyperglycaemia,	Oxidative stress

	dyslipidaemia, increased risk of type 2 diabetes)	
	Thyroid alterations (increased anti-thyroid antibodies, autoimmune thyroiditis)	
	Weight gain	
	Obesity	

Reinterpretation from the perspective of Occupational Nursing

Four thematic categories emerged from the interpretative analysis, linking the scientific findings with key functions of Occupational Nursing in the surveillance of workers exposed to BPA.

- *Category 1: Reproductive health surveillance in exposed workers.*

Purpose: To identify changes in sexual function, fertility, and reproductive parameters that may indicate impairment due to occupational BPA exposure.

Specific nursing interventions:

Conduct a detailed reproductive anamnesis during health examinations, including: menstrual cycle regularity (women), changes in cycles, history of infertility, spontaneous abortions, preterm births, history of neonatal anomalies; changes in libido and sexual function (both sexes), history of couple infertility.

Semiological assessment: changes in weight, menstrual irregularities, thyroid alterations, mild neurological symptoms (headaches, sleep disturbances, mood changes).

- *Category 2: Reproductive protection during occupational exposure.*

Purpose: To implement specific preventive measures for workers during critical periods of vulnerability (reproductive age, family planning, gestation, lactation).

Specific nursing interventions:

Preconceptional counselling: information on BPA risks to fertility and foetal development; recommendations for minimising exposure.

Recommendations for specific personal protective equipment (PPE): gloves, gowns, respiratory protection where indicated, personal hygiene before eating or drinking and after the work shift, etc.

Information on everyday BPA exposure (thermal receipt paper, reusable plastic bottles, plastic food containers, etc.).

Assessment of the possibility of job reassignment for pregnant women with documented BPA exposure.

- *Category 3: Detection of endocrine disruption symptoms.*

Purpose: Early identification of signs and symptoms of reproductive or endocrine impairment that can be detected by nursing staff during health surveillance.

Specific nursing interventions:

Semiological assessment: Menstrual changes (amenorrhoea, oligomenorrhoea, irregular cycles), changes in libido or sexual function, infertility or difficulty conceiving, thyroid alterations (suggestive symptoms), unexplained weight changes, mild neurological symptoms (headaches, sleep disturbances, mood changes), stress or anxiety, history of spontaneous abortions or preterm births, etc.

Biomonitoring where indicated.

- *Category 4: Health education and prevention.*

Purpose: To provide specific information and counselling for minimising BPA exposure in both occupational and everyday contexts.

Specific nursing interventions:

Educational content: Information on what BPA is, where it is found, exposure routes (inhalation, dermal, oral), specific risks of BPA to fertility in women and men, specific risks during gestation and lactation, preventive measures in occupational and daily settings.

Integrated interpretative synthesis

The interpretative analysis of the findings from Schmidt et al.'s systematic review, from the perspective of Occupational Nursing, identifies that BPA reprotoxicity constitutes a significant risk for workers across multiple industrial sectors, with specific implications for reproductive health surveillance, preventive education, and the development of nursing interventions.

The four emergent thematic categories link scientific evidence to specific Occupational Nursing functions, providing a structured framework for incorporating BPA reprotoxicity into health surveillance protocols, aligned with the provisions of the recent update to RD 665/1997.

Discussion

This interpretative analysis of Schmidt et al.'s systematic review identifies Bisphenol A as a reprotoxic agent with significant occupational relevance for workers across multiple industrial sectors. The evidence synthesised in the systematic review consistently documents that BPA exposure is associated with alterations in fertility parameters in both women and men, adverse effects on gestation and foetal development, and neuroendocrinological disruptions. Reinterpreting these findings from the perspective of Occupational Nursing enables the identification of concrete implications for occupational health surveillance among workers of reproductive age.

The emergent thematic categories link scientific evidence to specific functions within the nursing discipline. This represents a contribution to strengthening the role of Occupational Nursing in the surveillance of workers exposed to reprotoxic agents, as required by the recent update to RD 665/1997 through RD 612/2024, although it should be noted that the analysed study had methodological limitations, such as formal bias assessment, heterogeneity of study designs and populations, and the non-occupational origin of the studies.

The scarcity of specific occupational health surveillance protocols for workers exposed to BPA (7), as well as the lack of knowledge in this regard (14), contrasts with the robust scientific evidence on its reprotoxicity (10,15). The analysis conducted provides a structured framework that enables Occupational Nursing professionals to identify particularly vulnerable workers by systematically collecting reproductive history information during health examinations, detect early symptoms of reproductive or endocrine impairment, provide comprehensive health education on minimising exposure, and biologically monitor such exposure (16).

BPA reprotoxicity represents an emerging challenge in occupational health that requires an integrated response from multidisciplinary teams. Occupational Nursing, as a specialty dedicated to the protection, promotion, and maintenance of workers' health, bears responsibility and leadership capacity in the health surveillance of workers exposed to BPA and other reprotoxic agents. The update to RD 665/1997 provides a regulatory framework that facilitates this leadership (8,11).

This interpretative analysis contributes to documenting the specific role of Occupational Nursing by providing concrete, evidence-based proposals for incorporating reprotoxicity surveillance into occupational health protocols, aligning with emerging trends in the comprehensive protection of workers' reproductive health (17).

Conclusions

BPA exposure is associated with significant alterations in female and male fertility, adverse gestational effects, foetal developmental impairments, and neuroendocrinological disruptions. This reprotoxicity constitutes an important occupational risk for workers in sectors such as polycarbonate, epoxy resin, paint, and thermal paper manufacturing, among others; with specific implications for workers of reproductive age, pregnant women, and those in the lactation period.
The analysis identifies four thematic categories that provide a conceptual basis for developing specific occupational health surveillance protocols for workers exposed to BPA.

This analysis documents that Occupational Nursing can and must identify workers particularly vulnerable to BPA exposure, systematically collect information on their reproductive history during health surveillance, detect early symptoms of reproductive or endocrine impairment, provide comprehensive health education for minimising exposure, and participate in risk assessment and the proposal of preventive measures.

Strengths and limitations

The present interpretative analysis has methodological limitations that must be considered. It is based exclusively on a single systematic review, so its robustness depends on the methodological quality of the index study. Furthermore, the proposed nursing interventions and surveillance measures for exposed workers derive from a theoretical reinterpretation from the perspective of Occupational Nursing rather than empirical evidence obtained from real occupational populations, requiring validation through specific studies, particularly in workplace settings.

Conversely, this analysis is grounded in a comprehensive and transparent systematic review, featuring searches across multiple databases, explicit inclusion criteria, and involvement of several reviewers. The proposal aligns with the recent regulatory update (RD 612/2024), conferring relevance by addressing new requirements for protection against reprotoxic agents.

The disciplinary approach from Occupational Nursing offers applicable and structured proposals that facilitate integration into surveillance and prevention programmes.

Finally, the explicit identification of vulnerable occupational groups, such as women of reproductive age or pregnant workers, enhances its practical utility for guiding targeted interventions and strengthening health surveillance in the workplace.

Implications for practice

In light of the evidence on BPA reprotoxicity and the existing regulatory gap, the following are recommended: (1) implementation of specific reproductive health surveillance protocols in

occupational health services; (2) training Occupational Nurses in the detection of endocrine disruption signs and symptoms; (3) development of preconceptional educational interventions for exposed workers; (4) biomonitoring of workers in high-risk sectors (polycarbonates, epoxy resins, thermal paper). Future research should empirically validate these proposals in real workplace settings.

Notes

Artificial intelligence tools (Perplexity, OpenEvidence, and NotebookLM) were used as support in the drafting, methodological structuring, critical review, and infographic development phases. All generated content was carefully adapted and reviewed by the authors.

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