

PREVENTIVE APPROACHES TO HEALTH RISKS FROM ENDOCRINE-DISRUPTING CHEMICALS BISPHENOL-A (BPA): LITERATURE REVIEW

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ARTICLE INFO

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Kata kunci:

Bisphenol-A
Pendekatan Preventif
Risiko Kesehatan
Senyawa Pengganggu
Endokrin

Keywords:

Bisphenol-A
Preventive Approach
Health Risk
Endocrine-Disrupting
Chemicals

Original submission:

June 4, 2025

Accepted:

June 20, 2025

Published:

September 20, 2025

ABSTRAK

Bisphenol-A (BPA) merupakan bahan kimia sintesis yang banyak digunakan secara luas dalam produksi plastik polikarbonat dan resin epoksi. BPA diklasifikasikan sebagai senyawa pengganggu endokrin (endocrine disrupting chemical/EDC) yang dapat menimbulkan berbagai dampak negatif terhadap kesehatan manusia. Studi biomonitoring di Amerika Serikat, Jerman, dan Kanada menunjukkan bahwa lebih dari 90% populasi memiliki kadar BPA yang terdeteksi dalam sampel urin. Hal tersebut menandakan adanya paparan yang meluas dan berkelanjutan di populasi umum. Lebih lanjut, temuan ini menegaskan pentingnya penerapan pendekatan preventif untuk meminimalkan risiko jangka panjang BPA terhadap kesehatan. Artikel ini bertujuan untuk meninjau literatur yang membahas berbagai strategi preventif dalam mengurangi risiko kesehatan akibat paparan BPA. Metode yang digunakan adalah tinjauan literatur dengan sumber referensi dari database Google Scholar, Scienedirect, dan PubMed dengan rentang publikasi tahun 2020–2025. Hasil studi menunjukkan bahwa pendekatan preventif dapat dilakukan melalui edukasi masyarakat, penguatan regulasi dan kebijakan, perubahan gaya hidup, serta penggunaan antioksidan. Kolaborasi lintas sektor dari peran individu, kebijakan publik yang kuat, edukasi berkelanjutan, serta pendekatan ilmiah yang terintegrasi diperlukan untuk menciptakan lingkungan hidup yang lebih aman dan sehat dari BPA.

ABSTRACT

Preventive Approaches to Health Risks from Endocrine-Disrupting Chemicals Bisphenol-A (BPA): A Literature Review. Bisphenol-A (BPA) is a synthetic chemical widely used in the production of polycarbonate plastics and epoxy resins. BPA is classified as an endocrine-disrupting chemical (EDC) that can cause various adverse effects on human health. Biomonitoring studies in the United States, Germany, and Canada have shown that over 90% of the population have detectable levels of BPA in urine samples. This indicates widespread and sustained exposure in the general population. Furthermore, these findings underscore the importance of implementing preventive measures to mitigate the long-term health risks associated with BPA exposure. This article aims to review the literature on various preventive strategies to reduce health risks associated with BPA exposure. The method employed is a literature review, drawing references from Google Scholar, ScienceDirect, and PubMed databases, encompassing publications from 2020 to 2025. The study results indicate that preventive measures can be implemented through public education, strengthening regulations and policies, promoting lifestyle changes, and utilizing antioxidants. Effective prevention requires cross-sectoral collaboration involving individual actions, strong public policies, continuous education, and an integrated scientific approach to create a safer and healthier environment free from BPA hazards.

INTRODUCTION

Plastic has become an inseparable part of human daily life. Its use is prevalent, encompassing various products such as food packaging, drinking bottles, and household items. Global plastic production currently exceeds 400 million tons per year, and without significant intervention, this number is expected to double by 2040¹. Behind the convenience and comfort that plastic offers, there lies a potential threat to human health due to the presence of harmful chemicals within it.

Some toxic compounds found in plastics include phthalates, polyvinyl chloride (PVC), styrene, and Bisphenol-A (BPA). BPA is one of the main chemicals used in the production of polycarbonate plastics and epoxy resins². Manufacturers widely use these compounds because they enhance the strength, clarity, and heat resistance of plastic products. Researchers classify BPA as an endocrine-disrupting chemical (EDC) that interferes with the hormonal systems of both humans and animals³. Various studies have linked BPA exposure to a range of health issues, particularly in the reproductive system. BPA exposure can lead to decreased sperm quality, developmental disorders in fetuses, and even infertility⁴. Additionally, BPA is also known to play a role in early puberty, hormone-dependent tumours such as breast and prostate cancer, and metabolic disorders like polycystic ovary syndrome (PCOS)⁵.

BPA exposure in humans is currently widespread. Biomonitoring studies in the United States, Germany, and Canada support this, showing that over 90% of the population has detectable levels of BPA in their urine samples⁶. In Indonesia, researchers have detected BPA migration in six regions: Medan, Bandung, Manado, Jakarta, Banda Aceh, and North Aceh, with the highest levels reaching 0.09 ppm per litre during the period 2021- 2022⁷. These regions show BPA migration that exceeds the safe threshold as regulated by the Food and Drug Administration (BPOM) Regulation Number 20 of 2019, which is 0.06 ppm⁸. This data indicates that a majority of individuals have been exposed to BPA in their daily lives, often without realizing it, particularly in certain areas.

Various experimental and epidemiological studies have demonstrated that BPA has significant potential as an endocrine-disrupting compound, negatively impacting human health through complex biological mechanisms. However, most research has focused more on the toxicological aspects and biological effects of BPA. Studies on preventive strategies to reduce BPA exposure, whether through education, exposure reduction policies, or changes in community behaviour, are still very limited. However, preventive approaches are crucial to minimize the long-term health risks associated with BPA. Therefore, researchers need to address the existing gap by analyzing effective prevention strategies to mitigate health risks associated with BPA exposure. This article addresses the research gap by providing a comprehensive understanding of BPA's impact as an endocrine disruptor and examining preventive approaches to reduce related health risks. The primary focus of this article is on prevention strategies through education, behavioral interventions, and policies to reduce BPA exposure in daily life.

METHOD

The method used in this study is a literature review and the basis of data retrieval is obtained from secondary data obtained from previous research. The reference collection is conducted through online databases, including Google Scholar, ScienceDirect, and PubMed. Searches were performed using a combination of keywords such as "Bisphenol-A", "Endocrine Disruptors", "Health

Risk", "Preventive Approach", "BPA Exposure", and "Public Health Prevention". Boolean operators, such as AND and OR are used to expand and narrow search results. The inclusion criteria for this study include scientific articles published within the last 5 years (2020-2025) that are written in English or Indonesian, available in full-text format, open access, and discuss the relationship between BPA and health risks, as well as preventive approaches to BPA exposure. Meanwhile, the excluded articles include those published before 2020, articles in foreign languages other than English or Indonesian, articles with private access, and those without full text.

RESULT

Table 1. Research Findings on Preventive Approaches to Health Risks from the Endocrine-Disrupting Chemical Bisphenol-A

Author	Article Title	Method	Result
Dewi Kurniawati, Maulana Andinata Dalimunthe, Syukur Kholil, Aulia Rahma Ritonga, and Teguh Agum Pratama	Reduction of microplastics through waste management: Evaluation of water quality and health risks in the communication policy of the ministry of environment and forestry ⁹	Qualitative Research with a Phenomenological Approach	Existing regulations need to be updated in light of the development of Science and technology and constantly strengthened, tightened, and made more specific. Collaboration among governments, communities, and businesses in the initiation of technology is also necessary to support preventive measures aimed at reducing microplastic waste.
Muhammad Faisal Manzoor, Tayyaba Tariq, Birjees Fatima, Amna Sahar, Farwa Tariq, Seemal Munir, Sipper Khan, Muhammad Modassar Ali Nawaz Ranjha, Aysha Sameen, Xin-An Zeng, and Salam A. Ibrahim	An insight into bisphenol-A, food exposure and its adverse effects on health: A review ¹⁰	Quantitative research and qualitative analysis (mixed-method)	The reproductive systems of both sexes can be affected by exposure to BPA. BPA can cause infertility in women by mimicking estrogen. BPA slows testicular growth, decreases sperm motility, decreases sperm quality and count, and can cause infertility in men.
Rosaria Meli, Anna Monnolo, Chiara Annunziata, Claudio Pirozzi, and Maria Carmela Ferrante	Oxidative Stress and BPA Toxicity: An Antioxidant Approach for Male and Female Reproductive Dysfunction ¹¹	Literature Review	Several antioxidants, including melatonin, vitamin C, vitamin E, N-acetylcysteine, lipoic acid, ginger extract, and gallic acid, can help mitigate the toxic effects of BPA on male reproductive health.
Joana Santiago, Joana V. Silva, Manuel A. S. Santos, and Margarida Fardilha	Fighting Bisphenol-A Induced Male Infertility: The Power of Antioxidants ¹²	Literature Review	Eruca sativa water extract containing natural antioxidants, such as polyphenols (gallic acid) and flavonoids (quercetin, kaempferol, cirsilineol, and acacetin) has been shown to effectively

			protect against BPA toxicity in the reproductive systems of men and women.
Wanda Maczka, Małgorzata Grabarczyk, and Katarzyna Wińska	Can Antioxidants Reduce the Toxicity of Bisphenol? ¹³	Literature Review	Some antioxidants, such as genistein, lycopene, curcumin, luteolin, naringin, quercetin, and taurine, found in vegetables, fruits, and herbal medicines are known to reduce the negative impact of BPA on cancer risk.
I Nyoman Gede Suyasa, I Wayan Jana, and Desak Gde Diah Dharma Santhi	Faktor-Faktor yang Berhubungan dengan Keberadaan Bahan Berbahaya Bisphenol-A (BPA) yang Terkandung dalam Kontainer Plastik Makanan dan Minuman ¹⁴	Cross-Sectional Observational Study	Education is crucial in preventing exposure to BPA. A significant correlation was found between homemakers' knowledge of the presence of BPA-containing plastic containers and their subsequent actions regarding them.
Leah Martin, Yu Zhang, Olivia First, Vicente Mustieles, Robin Dodson, Gabriela Rosa, Ayanna Coburn-Sanderson, Charleen D. Adams, and Carmen Messerlia	Lifestyle interventions to reduce endocrine-disrupting phthalate and phenol exposures among reproductive age men and women: A review and future steps ¹⁵	Experimental Study	The use of personal care products and the consumption of packaged foods can contribute significantly to EDC exposure.
Leila Christina Pedroso de Paula and Creatio Alves	Food packaging and endocrine disruptors ¹⁶	Literature Review	Consumer lifestyle and behavior, such as the consumption of ultra-processed foods, the use of plastic containers to heat food, choosing fresh food, avoiding the use of plastic containers when heating food, and opting for BPA-free packaging, are recommended to reduce health risks.

DISCUSSION

Health Risks of BPA Exposure

Research in humans has shown a positive association between urinary BPA levels and an increased risk of heart disease, liver dysfunction, and diabetes¹⁷. Over the past decade, various studies, including in vitro research and epidemiological studies conducted in Asia, Europe, and America, have shown that BPA acts as a hormone-disrupting chemical, classified as an Endocrine-Disrupting Chemical (EDC). These studies have demonstrated that exposure to EDCs during adolescence may lead to a reduction in both the quantity and quality of sperm during puberty. Researchers also suspect that EDCs contribute to the proliferation of cancer cells, including those found in breast cancer. Specifically, researchers have shown that BPA plays a role in the pathogenesis of several endocrine disorders, including infertility in both men and women, early

onset of puberty, hormone-dependent tumors such as breast and prostate cancer, and metabolic disorders like polycystic ovary syndrome (PCOS)¹⁸.

BPA Migration Mechanism

According to Urbelliz and Copper¹⁹, four main mechanisms explain how endocrine-disrupting compounds such as BPA can migrate from packaging into food. First, migration through direct contact is the most common form, occurring when the packaging is in physical contact with the food. Second, diffusion mechanisms occur when chemical compounds from the packaging migrate into the food due to concentration differences, a process influenced by the chemical properties of the substance, environmental temperature, and the duration of contact. Third, leaching occurs when chemical compounds in the plastic are not firmly bound to the polymer structure, allowing these substances to be released and contaminate the food. The risk of leaching increases significantly when food is heated in a microwave or is in prolonged contact with the packaging. Fourth, heating itself serves as a critical triggering factor, as elevated temperatures can accelerate the migration process by altering the chemical structure of the compounds within the packaging, thereby facilitating their entry into the food.

Preventive Approaches to BPA Exposure Risk

1. Community Education-based Prevention

One of the most effective ways to prevent exposure to Bisphenol-A (BPA) from plastic materials used in food and beverage packaging is through public education about the dangers of BPA and the safe use of plastics. Several research studies and community service programs in Indonesia have demonstrated that education can significantly enhance public knowledge and influence behaviour regarding plastic usage. A study conducted by Suyasa, Jana, and Santhi¹⁴ found a strong correlation between behavioural patterns and knowledge levels regarding the presence of BPA-containing plastic containers in households. One of the key contributing factors was behavior, which played an important role. These findings suggest that education can help reduce the use of unsafe plastic products in daily life.

Supporting these findings, Diningsih and Rangkuti²⁰ implemented an outreach program in Labuhan Rasoki Village, focusing on homemakers as the primary users and managers of plastic materials at home. The program emphasized the importance of recognizing "food-grade" labels on plastic, choosing safe types of plastic, and avoiding the use of plastic containers for hot food. The results showed that increased knowledge was significantly associated with behavioral changes in selecting and using safer plastic containers. Marliza, Eltrikanawati, and Arini²¹ reported similar findings in their educational outreach project in Batam. Their program increased public knowledge about plastic categorization from 20% to 90% and awareness of the health risks associated with plastic from 10% to 80%. These changes further support the evidence that community-based education is effective in reducing BPA exposure by translating knowledge into practical action.

At the global level, Pedroso de Paula and Alves¹⁶ emphasized the importance of involving healthcare professionals in raising public awareness about the dangers of BPA and its alternatives. The recommended educational strategies include avoiding the heating of food in plastic containers, promoting the use of alternative materials such as glass or stainless steel, and highlighting the importance of reading food safety labels. This demonstrates how education

can be effective on a community scale and can also be integrated into healthcare systems as part of preventive health promotion.

In conclusion, evidence from various sources suggests that community-based educational approaches are a viable and effective method for reducing health risks associated with BPA exposure. Increased knowledge, along with positive changes in attitudes and behaviors regarding the selection and use of safe plastic containers, can significantly minimize exposure to toxic chemicals, especially BPA. Therefore, educators and health professionals should tailor their efforts to meet community needs in order to reduce exposure to BPA effectively.

2. Strengthening and Updating Regulations

In the context of hazardous chemicals such as Bisphenol-A (BPA), regulatory approaches serve as one of the primary preventive strategies for protecting public health. Policymakers consider regulatory implementation to be more impactful than recommendation-based approaches, which rely solely on individual behavior and consumption changes²². The presence of BPA in various consumer products remains a significant concern due to regulatory loopholes and weak enforcement, which can pose serious risks to public health. This situation highlights the need for existing regulations to be continuously strengthened and updated—not only in terms of technical control of hazardous substances but also in the supervision of production, distribution, and public education to prevent BPA exposure comprehensively. Regulations should not merely exist as formalities but must carry absolute and enforceable authority.

In line with this issue, research by Kurniawati et al.⁹, emphasizes that strengthening regulations is a crucial step in preventing the migration of BPA into the human body. One of the efforts highlighted is the need to revise waste management policies to specifically regulate hazardous chemicals, such as BPA, as existing legislation, including Law No. 18 of 2008, does not explicitly address this issue. Additionally, the Regulation of the Minister of Environment and Forestry (Permen LHK) No. P.94/MENLHK/SETJEN/KUM.1/12/2016, which initially focused on invasive species, could be adapted to address microplastics as invasive pollutants in aquatic ecosystems.

Through such regulations, strategies, including risk analysis of hazardous chemicals, control of the production and distribution of BPA-based products, and regular monitoring of environmental contamination in aquatic systems, can be implemented systematically. Regulations must also be supported by public education and effective communication strategies so that the public understands the dangers of BPA and participates in reducing the use of single-use plastics. By applying a comprehensive and evidence-based approach, policymakers aim to strengthen regulations to minimize BPA exposure and better protect both human health and the environment.

3. Lifestyle Changes

Health experts have identified lifestyle changes as a practical, non-regulatory approach to preventing Bisphenol-A (BPA) exposure. Daily lifestyles, including food consumption patterns, packaging choices, and food processing habits, directly contribute to an individual's level of exposure to BPA. Numerous studies have demonstrated that lifestyle-based interventions, including increased consumption of fresh foods and reduced use of certain plastic or metal packaging, have the potential to lower the risk of elevated BPA levels in the body.

Martin et al.¹⁵ found that individuals with a highly nutritious diet exhibited lower levels of BPA in their urine compared to those with a less healthy diet. Thus, highly nutritious foods, such as fresh fruits and vegetables, tend to have much lower BPA levels than processed foods. Therefore, the study concluded that dietary interventions focusing on reducing the consumption of packaged foods (e.g., canned foods) and increasing the intake of fresh foods can effectively reduce BPA exposure.

Based on an analysis of previous studies, Pedroso de Paula and Alves¹⁶ recommend several strategies to mitigate the risk of exposure to harmful chemicals, such as BPA. These measures include adopting a balanced diet, choosing fresh or minimally processed foods, and reducing the intake of canned products. Additionally, experts advise consumers to limit their consumption of food and beverages stored in plastic packaging—particularly those labeled with recycling codes 3 (phthalates), 6 (styrene), and 7 (bisphenols). Experts also recommend cooking at home more frequently and encouraging children to learn how to cook and manage fresh ingredients from an early age. Certain practices should be avoided to ensure safety and health. For instance, avoid heating food in plastic containers in the microwave, washing plastic containers in the dishwasher, or drinking water from PET bottles that have been exposed to high temperatures, such as those left in cars under direct sunlight. The choice of packaging also needs to be considered, with a preference for safer materials such as glass bottles, porcelain, stainless steel, or recyclable paper or cardboard packaging. Avoid serving hot milk in plastic bottles and storing food or drinks in plastic containers in the freezer. Additionally, opt for plastic products labeled 'BPA-Free.' To reduce the risk of exposure to BPA, it is best to avoid consuming hot beverages, such as tea and coffee, from plastic containers.

Thus, daily lifestyle plays a vital role in determining the level of BPA exposure in individuals. The analyzed studies show that BPA exposure prevention strategies depend not only on external regulations but also on individual decisions and daily life habits. These findings confirm that consumers' awareness of their food choices and how they manage them directly affects their level of exposure to harmful chemicals. Thus, lifestyle-based approaches are not only preventive but also empower individuals to actively safeguard their health and the environment sustainably.

4. The Role of Antioxidants

The mechanism of antioxidants in preventing the toxic effects of Bisphenol-A (BPA) is related to its ability to overcome oxidative stress induced by BPA compounds. BPA is known to increase the production of Reactive Oxygen Species (ROS), which causes oxidative damage to cell lipids, proteins, and DNA. It triggers cellular dysfunction, chronic inflammation, and even apoptosis²³. Antioxidants neutralize Reactive Oxygen Species (ROS) either indirectly by enhancing the activity of endogenous antioxidant enzymes such as Superoxide Dismutase (SOD), Catalase (CAT), and Glutathione Peroxidase (GSHPx) or directly by donating electrons to free radicals. This donation converts antioxidants into free radicals, but with significantly lower toxicity²⁴. These 'new radicals' are then easily neutralized by other antioxidant mechanisms in the body.

Based on the results table, the three studies on the role of antioxidants in mitigating the health effects of BPA exposure may offer different approaches to evaluating the impact of antioxidants on the toxic effects of Bisphenol A (BPA). The study by Meli et al.²⁵ presents a comprehensive review of the various types of antioxidants that reduce oxidative stress resulting

from BPA exposure. The study focused on the role of antioxidants in maintaining the balance of redox enzymes, such as Superoxide Dismutase (SOD), catalase, Glutathione Reductase (GR), and Glutathione Peroxidase (GSH-Px), as well as the inhibition of inflammatory pathways. In contrast, Santiago et al.²⁶ focused their study on BPA-induced male infertility by reviewing several antioxidants that have been shown to improve sperm quality and reduce DNA damage, as well as mitochondrial dysfunction caused by oxidative stress. On the other hand, Maczka et al.²⁷ emphasized the role of natural antioxidants from vegetables, fruits, and herbal medicines in reducing the negative impact of BPA on cancer risk. They showed that phenolic compounds, such as punicalagin and ellagic acid, are not only able to reduce the levels of Reactive Oxygen Species (ROS) and lipid peroxidation but also normalize the expression of inflammatory and apoptotic genes. Thus, the three studies share a commonality in their focus on the role of antioxidants in mitigating the toxic effects of BPA; however, they differ in their target organs, the types of antioxidants examined, and the depth of biological mechanisms investigated. This comparison suggests that we can tailor protection strategies against BPA based on the context of exposure and the specific target organs affected.

CONCLUSION

Bisphenol A (BPA) is a synthetic chemical compound widely used in plastic products and is a known disruptor of the human endocrine system. Based on the literature review, preventive approaches to health risks associated with BPA exposure should be comprehensive, encompassing public education, strengthening and updating regulations, lifestyle modifications, and biological interventions through the consumption of antioxidants. Research has shown that education increases public awareness of the dangers of BPA and encourages behavioral changes in plastic use. However, policymakers need to strengthen this educational approach with stricter, science-based regulations. This approach addresses the need for comprehensive preventive measures to reduce the long-term health impacts of BPA exposure.

Additionally, adopting a lifestyle that prioritizes the consumption of fresh food and minimizes plastic packaging can help lower the risk of exposure. The role of antioxidants is also crucial in neutralizing the toxic effects of BPA by reducing oxidative stress. Therefore, effective prevention requires cross-sector collaboration, including the involvement of individuals, robust public policies, ongoing education, and an integrated scientific approach to creating a safer and healthier living environment that mitigates the dangers of BPA.

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