New
Contaminants

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Perspective

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# New contaminants in indoor environments: occurrence, transformation, and health risks

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## Abstract

People spend the majority of their time indoors, making indoor environmental quality a critical determinant of human health. With the extensive use of chemical products, new contaminants have increasingly attracted public attention due to their potential health risks. Differences in chemical use across indoor settings result in diverse sources and types of new contaminants. Moreover, the higher surface-to-volume ratio indoors, compared with that in outdoor environments, leads to more complex surface chemistry and transformation processes of these contaminants. Therefore, identifying emission sources and pollutant profiles specific to different indoor environments is essential for effective pollution control. Considering the substantial health risks posed by new contaminants, there is an urgent need for systematic investigations into their occurrence and transformation across diverse indoor environments, along with comprehensive health risk assessments. These efforts will generate critical data to inform the management of indoor new contaminants, support the formulation of relevant environmental standards, and ultimately protect human health.

**Keywords:** New contaminants, Indoor environment, Occurrence, Transformation, Health risks

## Introduction

People spend approximately 90% of their time in various indoor environments, such as homes, offices, schools, and shopping malls[1]. Therefore, understanding and predicting indoor environmental quality is crucial for human health. In indoor environments, the composition and sources of harmful pollutants are complex and diverse, and long-term or repeated exposure to these pollutants can lead to serious adverse health effects[2]. For instance, previous studies have shown that indoor air pollution can contribute to cardiovascular diseases and respiratory disorders, including cancers of the lung, bronchus, and trachea[3]. According to the World Health Organization, millions of people die prematurely each year due to indoor air pollution[4]. In China, indoor air pollution contributed to 14.1% of the total disease burden in 2017, ranking third among all identified health risk factors. The associated economic losses were estimated at CNY¥2.88 trillion, representing approximately 3.45% of the national GDP[5]. Therefore, improving indoor environmental quality is crucial for protecting human health.

Indoor environmental quality has attracted increasing public attention in recent years. For example, the Chinese government has actively advanced initiatives to improve indoor air quality[6]. In 2022, China officially implemented a new national indoor air quality standard, which introduced threshold values for trichloroethylene, tetrachloroethylene, and fine particulate matter, while lowering the permissible limits for nitrogen dioxide, carbon dioxide, formaldehyde, benzene, and inhalable particulate matter[7]. This revision represents a significant step toward the establishment of high-quality indoor environments. Although the new standard introduced three additional compounds, limit values have been established for only 18 substances in total. With growing awareness of the health risks associated with chemical products, the presence of new contaminants has been reported, including persistent organic pollutants, endocrine-disrupting chemicals (EDCs), antibiotics, and microplastics[8]. Compared with traditional pollutants, these new contaminants are diverse in type and characterized by latent risks, posing potential threats to human health[9]. Furthermore, due to their environmental persistence and mobility, they tend to accumulate and persist in indoor environments, resulting in long-term human exposure[10,11]. Therefore, exposure to new contaminants in indoor settings warrants considerable attention.

Indoor environments contain a wide range of chemical products, many of which can serve as sources of new contaminants[12,13]. For example, common personal care products such as shampoos, body

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washes, sunscreens, and nail polishes contain EDCs like bisphenol A and phthalates[14]. Plastic products, including packaging materials, garbage bags, and beverage bottles, are rich in microplastics such as polyethylene, polypropylene, and polystyrene[15]. In addition, materials such as carpets, flooring, and wall paints are significant sources of perfluorinated compounds[16]. These new contaminants can be released into the indoor environment through the regular use, volatilization, abrasion, or aging of chemical products, leading to their widespread presence in indoor air, dust, and surface materials[17]. They can subsequently enter the human body via ingestion, dermal contact, or inhalation, posing potential risks to human health[18].

Current research on new contaminants has primarily focused on outdoor environments, while studies on indoor environments are still relatively limited[19]. Notably, to reduce energy consumption and enhance comfort, modern buildings are designed with higher airtightness and lower indoor–outdoor air exchange. As a result, pollutants from indoor sources can easily accumulate, resulting in prolonged human exposure[20]. More severe air pollution indoors compared to outdoors has also been frequently reported[21]. Given the substantial contribution of indoor exposure to total human exposure and the tendency of new contaminants to accumulate indoors, research should focus on the pollution characteristics and health risks of these contaminants in indoor environments to improve indoor environmental quality and protect human health.

## Identifying key sources and types of indoor new contaminants

Similar to traditional pollutants, the emission sources of new contaminants vary considerably among different types of indoor environments, resulting in substantial differences in their composition and concentrations (Fig. 1)[22]. Therefore, identifying the major emission sources in different indoor environments is a fundamental prerequisite for effective control of new contaminants. Common building and decorative materials in indoor environments, such as furniture, paints, and wallpapers, can release phthalates, polybrominated diphenyl ethers, and organophosphate esters (OPEs), resulting in generally high levels of these compounds, particularly in newly renovated buildings[23−25]. Occupational environments often contain high concentrations of specific pollutants. For example, cooking processes and tobacco smoke are the primary sources of nitrosamines[26]. Therefore, higher concentrations of indoor nitrosamine pollution are likely to occur in places with intensive cooking activities, such as restaurants and kitchens, as well as in smoking environments like mahjong parlors[27]. Pharmaceuticals and personal care products are important new contaminants in residential environments, as they are widely used in cosmetics, therapeutic drugs, and household pest control products[28]. In daycare centers, polyvinyl chloride floor mats, foam cushions, and toys contain substantial amounts of antioxidants, plasticizers, and flame retardants, which can be gradually released into the indoor environment as these products age[29]. In offices, computer rooms, and other fire-sensitive areas, building materials typically contain high levels of flame retardants and plasticizers[30]. The high density and frequent replacement of electronic devices further contribute to the emission of OPEs and alternative halogenated flame retardants, making these environments significant sources of such contaminants[31]. Variations in chemical product usage across occupational settings result in differences in the types and concentrations of dominant new contaminants indoors. Therefore, identifying the characteristic new contaminants specific to each type of workplace can support the development of targeted prevention and control strategies, thereby enhancing the efficiency of pollution management in various indoor environments. Furthermore, the diverse sources of new contaminants and the wide variation in indoor layouts make it challenging to accurately model indoor new contaminant pollution. Accurate simulation of indoor new contaminant pollution requires comprehensive identification of key pollutants across different functional indoor environments.

## Investigating the transformation of indoor new contaminants

In outdoor environments, high photochemical activity, abundant oxidants, and a complex composition of substances contribute to the transformation of new contaminants into more persistent and toxic secondary products through multiple pathways[32]. Similar characteristics have also been observed in indoor environments. Ultraviolet radiation from indoor lighting and ozone produced during ventilation or appliance use, can induce photooxidation[33]. Consequently, chemicals released from consumer products, including organophosphorus flame retardants emitted from furniture, electrical appliances, and

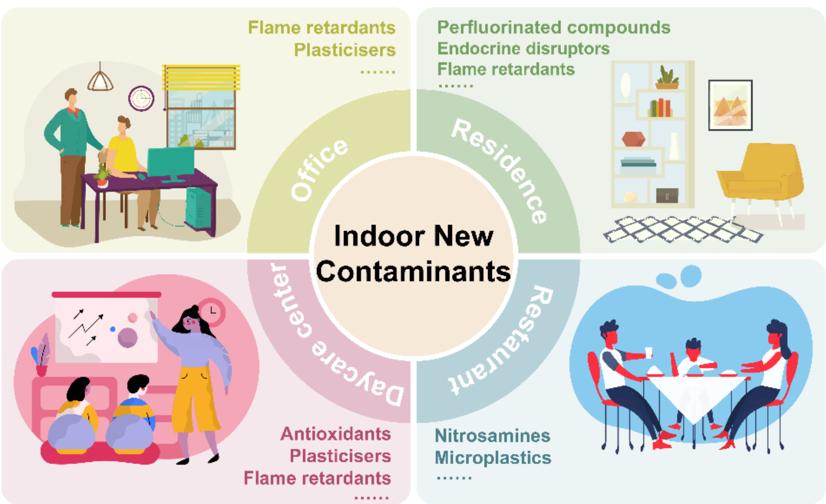


**Fig. 1** Schematic diagram of new contaminants in indoor environments.

building materials, may be transformed into oxidized derivatives with greater neurotoxic potency[34]. In addition to photooxidation, gas-phase oxidation reactions within the indoor atmosphere are also a common transformation pathway[35,36]. For example, linalool, a new contaminant released from chemicals such as cleaning agents, disinfectants, and cosmetics, can undergo gas-phase oxidation reactions with ozone or hydroxyl radicals to produce a variety of oxidative products, including carbonyl compounds and secondary organic aerosols. These oxidative derivatives often exhibit greater oxidative reactivity and toxicity potential than the parent compound, thereby increasing the risk of respiratory and systemic adverse effects[37].

A key characteristic of indoor environments is their high surface-to-volume ratio, which not only enhances heterogeneous reactions but also increases the chemical complexity of indoor pollutants[20]. For instance, di(2-ethylhexyl) phthalate, a plasticizer extensively released from polyvinyl chloride flooring, vinyl materials, and consumer plastics, can generate gas-phase hydroxyl radicals on indoor surfaces and within dust films, thereby initiating heterogeneous oxidation processes that yield numerous oxygen-containing derivatives[38]. These oxidation products have higher chemical stability and a stronger endocrine-disrupting potential than the parent compound, resulting in elevated health risks[39]. The transformation of new contaminants is both a key source of indoor pollution and a major factor in heightened human health risks. Therefore, research on indoor contaminants should consider the distinctive features of indoor environments, such as the high surface-to-volume ratio, to differentiate indoor from outdoor processes better.

# Evaluating the health risks of indoor new contaminants

New contaminants in indoor environments can enter the human body through inhalation, ingestion, or dermal absorption, thereby posing potential health risks[40]. For example, EDCs contained in personal care products such as sunscreens and skin-whitening agents can penetrate the skin barrier and enter systemic circulation[41]. New contaminants have been widely detected in various human tissues and biological matrices, such as bone marrow, blood, urine, hair, breast milk, nails, and adipose tissue[11]. For instance, microplastics have been identified in human bone marrow samples, while urinary analyses have frequently revealed the presence of bisphenol A, OPEs, phthalates, and organophosphate pesticides[42−44]. The adverse health effects of new contaminants have been extensively reported, including but not limited to: endocrine-disrupting toxicity, developmental toxicity, neurotoxicity, reproductive toxicity, and potential carcinogenicity[45,46]. For example, Whyatt et al. reported that prenatal exposure to monobutyl phthalate and monobenzyl phthalate may negatively affect children's cognitive and behavioral development[47]. Importantly, sensitive populations, such as the young (under 18 years old), and the elderly (over 80 years old), typically spend over 90% of their time indoors[29]. Consequently, exposure to indoor new contaminants may pose significant health risks for these vulnerable groups. For example, studies have shown that exposure to new contaminants in indoor environments can adversely affect the health of subsequent generations[42,43]. During pregnancy, these contaminants can cross the placental barrier and directly disrupt fetal development and may also indirectly impact fetal growth and increase the risk of adult diseases by modifying maternal intrauterine factors[48]. For instance, Kim et al. found that maternal urinary concentrations of diethyl phthalate were positively correlated with adverse neurodevelopmental performances in children aged 1–2 years[49].

Given the importance of the indoor environment for human health, especially for sensitive populations, future research should emphasize new contaminants in diverse indoor environments, such as residential, educational, medical, commercial, recreational, and sports facilities, which will support the establishment of a comprehensive database of indoor new contaminants. In addition, future studies should employ high spatiotemporal-resolution sampling to disclose shared pollutant characteristics and summarize pollution patterns from extensive datasets. A comprehensive understanding of the mechanisms and contributions of secondary formation processes is essential for developing effective pollution control strategies. Finally, toxicological and cellular studies should be conducted to evaluate the health risks of new contaminants, providing a scientific foundation for their regulation and the development of indoor environmental standards.

# Author contributions

The authors confirm their contributions to the paper as follows: Wei Du, Bo Pan: study conception and design, data collection, analysis and interpretation of results, manuscript preparation, and approval of the final version of the manuscript; Jinze Wang, Xinyi Zhou: first manuscript draft preparation; Nan Fu, Shan Zhou, Shuo Yang, Jiangping Liu: manuscript reviewing. All authors reviewed the results and approved the final version of the manuscript.

# Data availability

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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# Declarations

## Competing interests

The authors declare that they have no conflict of interest.

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# References

[1] Ageel HK, Harrad S, Abdallah MAE. 2022. Occurrence, human exposure, and risk of microplastics in the indoor environment. *Environmental Science: Processes & Impacts* 24:17−31

[2] González-Martín J, Kraakman NJR, Pérez C, Lebrero R, Muñoz R. 2021. A state–of–the-art review on indoor air pollution and strategies for indoor air pollution control. *Chemosphere* 262:128376

[3] Radbel J, Rebuli ME, Kipen H, Brigham E. 2024. Indoor air pollution and airway health. *Journal of Allergy and Clinical Immunology* 154:835−846

[4] World Health Organization. 2024. *Household air pollution*. www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health
[5] Liu N, Liu W, Deng F, Liu Y, Gao X, et al. 2023. The burden of disease attributable to indoor air pollutants in China from 2000 to 2017. *The Lancet Planetary Health* 7:e900−e911
[6] Fang L, Liu N, Liu W, Mo J, Zhao Z, et al. 2022. Indoor formaldehyde levels in residences, schools, and offices in China in the past 30 years: a systematic review. *Indoor Air* 32(10):e13141
[7] National Standard of the People's Republic of China. 2022. *GB/T 18883-2022 indoor air quality standards*. www.ndcpa.gov.cn/jbkzzx/c100201/common/content/content_1666357812062392320.html
[8] Richardson SD, Ternes TA. 2018. Water analysis: emerging contaminants and current issues. *Analytical Chemistry* 90(1):398−428
[9] Kim S, Kim Y, Moon HB. 2020. Contamination and historical trends of legacy and emerging plasticizers in sediment from highly industrialized bays of Korea. *Science of The Total Environment* 765:142751
[10] Annamalai J, Namasivayam V. 2015. Endocrine disrupting chemicals in the atmosphere: their effects on humans and wildlife. *Environment International* 76:78−97
[11] Zhou Y, Wang P, Li J, Luo R, Li J, et al. 2021. Effects of emerging organic contaminants on childhood obesity and neurodevelopment: a review. *Journal of Environmental and Occupational Medicine* 38:1001−1009 (in Chinese)
[12] Covaci A, Harrad S, Abdallah MAE, Ali N, Law RJ, et al. 2011. Novel brominated flame retardants: a review of their analysis, environmental fate and behaviour. *Environment International* 37(2):532−556
[13] Dou M, Wang L. 2023. A review on organophosphate esters: physiochemical properties, applications, and toxicities as well as occurrence and human exposure in dust environment. *Journal of Environmental Management* 325:116601
[14] Wong KH, Durrani TS. 2017. Exposures to endocrine disrupting chemicals in consumer products—a guide for pediatricians. *Current Problems in Pediatric and Adolescent Health Care* 47(5):107−118
[15] Chen J, Wu J, Sherrell PC, Chen J, Wang H, et al. 2022. How to build a microplastics-free environment: strategies for microplastics degradation and plastics recycling. *Advanced Science* 9(6):2103764
[16] Wu Y, Romanak K, Bruton T, Blum A, Venier M. 2020. Per- and polyfluoroalkyl substances in paired dust and carpets from childcare centers. *Chemosphere* 251:126771
[17] Ji X, Liang J, Wang Y, Liu X, Li Y, et al. 2023. Synthetic antioxidants as contaminants of emerging concern in indoor environments: knowns and unknowns. *Environmental Science & Technology* 57(51):21550−21557
[18] Gardner CM, Hoffman K, Stapleton HM, Gunsch CK. 2021. Exposures to Semivolatile Organic Compounds in Indoor Environments and Associations with the Gut Microbiomes of Children. *Environmental Science & Technology Letters* 8(1):73−79
[19] Salthammer T. 2020. Emerging indoor pollutants. *International Journal of Hygiene and Environmental Health* 224:113423
[20] Liu C, Liang L, Xu W, Ma Q. 2024. A review of indoor nitrous acid (HONO) pollution: measurement techniques, pollution characteristics, sources, and sinks. *Science of The Total Environment* 921:171100
[21] Wang J, Du W, Lei Y, Chen Y, Wang Z, et al. 2023. Quantifying the dynamic characteristics of indoor air pollution using real-time sensors: current status and future implication. *Environment International* 175:107934
[22] Bergh C, Torgrip R, Emenius G, Östman C. 2010. Organophosphate and phthalate esters in air and settled dust - a multi-location indoor study. *Indoor Air* 21(1):67−76
[23] Wilke O, Jann O, Brodner D. 2004. VOC- and SVOC-emissions from adhesives, floor coverings and complete floor structures. *Indoor Air* 8:98−107
[24] Schreder ED, La Guardia MJ. 2014. Flame retardant transfers from U. S. households (dust and laundry wastewater) to the aquatic environment. *Environmental Science & Technology* 48(19):11575−11583
[25] Alaee M, Arias P, Sjödin A, Bergman Å. 2003. An overview of commercially used brominated flame retardants, their applications, their use patterns in different countries/regions and possible modes of release. *Environment International* 29(6):683−689
[26] Navruz-Varli S, Bilici S, Ari A, Ertürk-Ari P, Ilhan MN, et al. 2022. Organic pollutant exposure and health effects of cooking emissions on kitchen staff in food services. *Indoor Air* 32(8):e13093
[27] Zhang L, Yuan W, Zhao W, Yang B, Jiao X, et al. 2024. Formation of Nitrosamines from the heterogeneous reaction of nitrous acid and organic amines in indoor environments. *Environmental Science & Technology* 58(42):18881−18891
[28] Chakraborty A, Adhikary S, Bhattacharya S, Dutta S, Chatterjee S, et al. 2023. Pharmaceuticals and personal care products as emerging environmental contaminants: prevalence, toxicity, and remedial approaches. *ACS Chemical Health & Safety* 30(6):361−388
[29] Koelmans AA, Besseling E, Foekema EM. 2014. Leaching of plastic additives to marine organisms. *Environmental Pollution* 187:49−54
[30] Vojta Š, Melymuk L, Klánová J. 2017. Changes in flame retardant and legacy contaminant concentrations in indoor air during building construction, furnishing, and use. *Environmental Science & Technology* 51(20):11891−11899
[31] Tao F, Abdallah MAE, Harrad S. 2016. Emerging and legacy flame retardants in UK indoor air and dust: evidence for replacement of PBDEs by emerging flame retardants? *Environmental Science & Technology* 50(23):13052−13061
[32] Liu Q, Li L, Zhang X, Saini A, Li W, et al. 2021. Uncovering global-scale risks from commercial chemicals in air. *Nature* 600:456−461
[33] Wu J, Alipouri Y, Luo H, Zhong LX. 2022. Ultraviolet photocatalytic oxidation technology for indoor volatile organic compound removal: a critical review with particular focus on byproduct formation and modeling. *Journal of Hazardous Materials* 421:126766
[34] Fu Z, Xie HB, Elm J, Liu Y, Fu Z, et al. 2022. Atmospheric autoxidation of organophosphate esters. *Environmental Science & Technology* 56(11):6944−6955
[35] Wang C, Collins DB, Arata C, Goldstein AH, Mattila JM, et al. 2020. Surface reservoirs dominate dynamic gas-surface partitioning of many indoor air constituents. *Science Advances* 6(8):eaay8973
[36] Mattila JM, Arata C, Wang C, Katz EF, Abeleira A, et al. 2020. Dark chemistry during bleach cleaning enhances oxidation of organics and secondary organic aerosol production indoors. *Environmental Science & Technology Letters* 7(11):795−801
[37] Fu Z, Guo S, Yu Y, Xie HB, Li S, et al. 2024. Oxidation mechanism and toxicity evolution of linalool, a typical indoor volatile chemical product. *Environment & Health* 2(7):486−498
[38] Fahy WD, Gong Y, Wang S, Zhang Z, Li L, et al. 2024. Hydroxyl radical oxidation of chemical contaminants on indoor surfaces and dust. *Proceedings of the National Academy of Sciences of the United States of America* 121(45):e2414762121
[39] Chang WH, Herianto S, Lee CC, Hung H, Chen HL. 2021. The effects of phthalate ester exposure on human health: a review. *Science of The Total Environment* 786:147371
[40] Salthammer T, Zhang Y, Mo J, Koch HM, Weschler CJ. 2018. Assessing human exposure to organic pollutants in the indoor environment. *Angewandte Chemie International Edition* 57(38):12228−12263
[41] Matta MK, Zusterzeel R, Pilli NR, Patel V, Volpe DA, et al. 2019. Effect of sunscreen application under maximal use conditions on plasma concentration of sunscreen active ingredients: a randomized clinical trial. *JAMA* 182(6):1345−1347
[42] Guo X, Wang L, Wang X, Li D, Wang H, et al. 2024. Discovery and analysis of microplastics in human bone marrow. *Journal of Hazardous Materials* 477:135266
[43] Oh J, Buckley JP, Kannan K, Pellizzari E, Miller RL, et al. 2025. Exposures to contemporary and emerging chemicals among children aged 2 to 4 years in the united states environmental influences on the child health outcome (ECHO) cohort. *Environmental Science & Technology* 59(27):13594−13610
[44] Zhang D, Liu X, Tu J, Xiao Q, Han L, et al. 2024. Mediating role of glucose-lipid metabolism in the association between the increased risk of coronary heart disease and exposure to organophosphate esters, phthalates, and polycyclic aromatic hydrocarbons. *Environment & Health* 2:170−179
[45] Yadav D, Rangabhashiyam S, Verma P, Singh P, Devi P, et al. 2021. Environmental and health impacts of contaminants of emerging

concerns: recent treatment challenges and approaches. *Chemosphere* 272:129492
[46] Tang KHD, Li R, Li Z, Wang D. 2024. Health risk of human exposure to microplastics: a review. *Environmental Chemistry Letters* 22(3):1155−1183
[47] Whyatt RM, Liu X, Rauh VA, Calafat AM, Just AC, et al. 2011. Maternal prenatal urinary phthalate metabolite concentrations and child mental, psychomotor, and behavioral development at 3 years of age. *Environmental Health Perspectives* 120(2):290−295
[48] Wright ML, Starkweather AR, York TP. 2016. Mechanisms of the maternal exposome and implications for health outcomes. *Advances in Nursing Science* 39(2):E17−E30
[49] Kim S, Eom S, Kim HJ, Lee JJ, Choi G, et al. 2018. Association between maternal exposure to major phthalates, heavy metals, and persistent organic pollutants, and the neurodevelopmental performances of their children at 1 to 2 years of age- CHECK cohort study. *Science of The Total Environment* 624:377−384