Review

Systematic Review of Contaminants of Emerging Concern (CECs): Distribution, Risks, and Implications for Water Quality and Health

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Abstract: The introduction of contaminants of emerging concern (CECs) into the environment has raised concerns due to the significant risks they pose to both ecosystems and human health. In this systematic review, we investigate research trends on CECs worldwide over the past 10 years, focusing on four critical aspects: (i) the identification and distribution of typical CECs across various media, (ii) the sources and environmental behavior of CECs, (iii) the implications of CECs exposure on human health, and (iv) risk assessment and control measures for CECs. The review re-views a comprehensive understanding of the typical types and distribution of CECs in different environmental media, shedding light on their prevalence and potential impact on ecosystems. Furthermore, insights into the sources and behavior of CECs provide crucial information for devising effective strategies to mitigate their release into the environment. By examining the health effects of EC exposure, we highlight the importance of considering potential risks to human well-being. This aspect of the review emphasizes the significance of monitoring and managing CECs to safeguard public health. The review also synthesizes the advancements in risk assessment methodologies and control measures for CECs, which are essential for developing comprehensive regulations and guidelines to manage these contaminants effectively. Drawing from the findings, we identify future research directions for CECs in aquatic environments.

Keywords: contaminants of emerging concern; POPs; microplastics; endocrine disruptor; antibiotic

1. Introduction

Contaminants of emerging concern (CECs) are a group of pollutants that have recently raised concerns due to their potential ecological and human health-related risks. Many of these contaminants have not yet been included in existing management protocols, and current efforts to prevent and mitigate their risks are insufficient. CECs often exhibit widespread distribution, unclear baseline levels, and host a wide array of unforeseen dangers [1,2]. In 2003, Jerald Schnoor, a member of the American Academy of Engineering, proposed the concept of "CECs" and stated that the environmental occurrence of any synthetic or naturally occurring chemicals and microorganisms could cause significant toxic effects and pose health hazards [3]. The number of chemicals registered by the American Chemical Society’s global Chemical Abstracts Service exceeds 142 million [4]. According to a report developed by the United Nations Environment Program and the International Council of Chemical Associations, over 350,000 chemicals and mixtures are used commercially worldwide [5].
To control CECs, it is crucial to conduct investigations, monitoring, and environmental risk assessments for contaminants such as persistent organic pollutants (POPs) and endocrine disruptors. Such efforts are important for establishing and enhancing environmental risk management. This can strengthen our management of pollution sources, help create lists of CECs under control, and advance environmental risk management measures in the context of prohibition, restriction, and emission limitation. On 4 May 2022, China proposed an action plan for the control of CECs with the aim of completing environmental risk screenings for high-yield and high-usage chemical substances by 2025, along with conducting environmental risk assessments for a batch of chemical substances. The management of CECs is closely tied to social security, and without increased control efforts, it could hinder industrial upgrades and impede sustainable development. Consequently, the identification of CECs and the enhancement of product access conditions may have short-term impacts on certain industries. However, in the long run, it can drive and facilitate the entire industry’s green transformation, thereby reducing the harmful effects of CECs on human health.

Research on CECs can be categorized into four aspects: types and distribution, sources and environmental behaviors, exposure and health effects, and risk assessment. At present, the CECs of global concern include POPs controlled by international conventions, endocrine disruptors, antibiotics, and microplastics. Analyzing the research hotspots and evolutionary trends of these CECs has shed light on their dynamics. Moreover, many studies have explored the relationships and distributions of these four typical CECs in different countries worldwide. These findings provide valuable theoretical insights for the screening, treatment, and control of CECs, allowing for more effective strategies to safeguard the environment and human health.

2. Types and Distribution of CECs

CECs are a heterogeneous set of pollutants that includes pharmaceuticals, personal care products, insecticides, flame retardants, industrial additives, surfactants, plasticizers, and nanomaterials [6–8]. Based on the current global research trends on CECs, the CECs discussed in this study can be classified as follows: POPs (Persistent Organic Pollutants), antibiotics, EDCs (Endocrine-Disrupting Chemicals), and microplastics. With the wide application of chemicals in industry, agriculture, etc., the introduction of CECs into the environment is inevitable. Although we know some of the chemical structures of CECs, this is only the tip of the iceberg, and there is limited understanding of their structure and content and even less of their toxicity [9,10]. Compared to other nations, China’s CECs pose more critical pollutant crises. China is the largest user of antibiotics in the world, with a total production of 248,000 tons, of which 52 percent is used in animals and 48 percent in humans, according to a 2013 survey [11]. The average concentration of antibiotics in China’s rivers is 303 ng/L, which is three times that of the United States and 15 times that of Germany. And the density of antibiotic discharge in the eastern basin is more than six times that of the western basin [12–15]. Furthermore, the abundance of microplastics detected in freshwater is 2–3 times higher than that reported in other nations [16,17]. In the five major river basins in China, the ecological risks caused by antibiotics are ranked in descending order: Jianghan Plain > Yangtze River Delta > Chaohu River Basin > Yellow River Delta > Pearl River Delta, and the main types of antibiotic pollution are sulfamethoxazole and erythromycin [18].

In developing countries, a higher quantity of CECs is released into the environment due to inadequate post-treatment of pollutants. For instance, in Brazilian rivers, the concentration of acetylsalicylic acid was measured at 20,960 ng/L, caffeine at 14,955 ng/L, and the concentration of acetaminophen exceeded 30,000 ng/L [19]. India is one of the largest pharmaceutical suppliers globally, accounting for 20% of global exports [20]. However, due to the lack of CECs management strategies, the concentrations of certain antibiotics in Indian wastewater treatment plants were found to be 40 times higher than in European, Australian, and other North American countries [21]. CECs are typically detected in densely populated catchment areas, often associated with wastewater treatment plants [22,23].
However, CECs have also been found in rural areas far from known sources of pollution. In the water and sediments of 21 sites in eight US national parks located in the northern Colorado Plateau, CECs were detected, indicating that CECs can be transported through atmospheric deposition to relatively pristine high-altitude and high-latitude regions [24]. Masoner et al. conducted CECs testing in 19 landfill sites across the United States, where bisphenol A was the most detected CEC, and areas with higher levels of precipitation had higher CEC concentrations in leachate compared to lower-precipitation areas [25]. Gao et al. measured 15 types of organochlorine pesticides in Xiamen, China. Among them, HCHs (hexachlorocyclohexane and isomers) showed an increasing trend with depth, while the concentrations of DDT (dichlorodiphenyldichloroethane and its isomers) and OCPs (organochlorine pesticides) decreased with depth, potentially due to the properties of the contaminants [26]. In terms of horizontal distribution, heavier pollution was found in Tong’an District and Xiang’an District, where irrigation was the primary cultivation method, and higher pollution levels were observed in the northeastern part of Xiamen City, possibly due to atmospheric transport and deposition in the region [26].

Moreover, CECs like tetrabromodiphenol A and its derivatives are commonly found in drinking water, rivers, and lakes [27]. China’s sludge contains 749 pollutants across 35 categories, and a significant portion of these are CECs [28,29]. Unfortunately, these chemicals not only affect the environment but also find their way into the human body through bioaccumulation in the food chain, even reaching the bloodstream [30].

Based on the search conducted in the core database of Web of Science with a limited retrieval time from 2013 to 2023, the following results were obtained for each search term: (1) “Antibiotic” (Figure 1): 1646 articles retrieved; (2) “Persistent Organic Pollutants” (Figure 2): 4902 articles retrieved; (3) “Microplastic” (Figure 3): 938 articles retrieved; and (4) “Endocrine Disruptor” (Figure 4): 2957 articles retrieved. These numbers represent the total count of articles related to each specific search term within the given time frame. Please note that these figures may change as new research is published or as the database is updated.

**Figure 1.** Co-occurrence map of keywords in studies on antibiotics environmental contamination from 2013 to 2023.
Figure 2. Keyword co-occurrence map of studies on POPs and environmental pollution from 2013 to 2023.

Figure 3. Keyword co-occurrence of research on microplastics and environmental pollution from 2013 to 2023.
Over the past 10 years, research on antibiotics has mainly focused on sample types, identification methods, environmental behaviors, pollution behavior, and the interaction between antibiotic types and other related pollutants (such as those found in personal care products and pharmaceuticals) (Figure 1). Mass spectrometry, liquid chromatography, and solid-phase extraction were used to identify the antibiotics. The study samples mainly included wastewater and aquatic environments (Figure 1). The research on antibiotics has shown a trend towards multidisciplinary and integrated studies. Researchers no longer focus solely on the drugs themselves, but also pay greater attention to the behavior of antibiotics in the environment and their relationship with other pollutants. They are increasingly interested in the interactions between different substances and are approaching actual environmental conditions. This means that future research on antibiotics may involve more interdisciplinary collaboration. Research on POPs has focused on their type, identification methods, biohazards, and environmental impacts (Figure 2). Polychlorinated biphenyls and organochlorine pesticides were the main POP types, accounting for more than 30% of the total. Passive sampling, mass spectrometry, and stable isotope analysis were used to identify the types and their environmental behaviors (Figure 2). In the case of MPs (Figure 3), the research primarily focuses on the types of plastics, environmental media, qualitative and quantitative characteristics, biological toxicity, composite pollution, and environmental behavior. Through studies on the generation and decomposition of different plastic types in the environment, the forms and migration behaviors of microplastics in environmental media such as water, soil, and sediment, particle size, morphology, concentration analysis of microplastics, toxic effects on organisms, composite pollution with other pollutants, and environmental behavior processes of microplastics, a comprehensive understanding of the sources, distribution characteristics, and environmental effects of microplastics can be achieved. This helps to evaluate the ecological risks and develop suitable management and control measures. The research on EDCs mainly focuses on the types, identification methods, hazards and mechanisms, and environmental media (Figure 4). Researchers identify and quantify endocrine-disrupting chemicals through various techniques, such as chemical analysis, biological detection, molecular sieves, and
mass spectrometry. They investigate the harm and potential carcinogenic risk effects of endocrine disruptors on human reproductive, immune, and nervous systems. Currently, research mainly focuses on endocrine disruptors in wastewater, and further studies are needed to strengthen research on drinking water in order to better protect drinking water hygiene and food safety.

3. Sources and Environmental Behavior of CECs

CiteSpace 6.2 was used for keyword co-occurrence analysis of the obtained literature (Figure 5). In the field of microplastics, research clustering has mainly focused on the ecological risks of polyvinyl chloride and plastic pollution over the past 10 years (Figure 5a). In the past decade, many studies have focused on POPs contained in personal care products, polychlorinated biphenyls, and bisphenol A, as well as environmental disturbances and endocrine disorders caused by POPs (Figure 5b). Recently, endocrine disruptors and biochar-related processes have garnered a lot of attention in the context of research (Figure 5c). The main research on antibiotics focuses on the study of resistance genes, especially in the context of adsorption and photocatalysis (Figure 5d).

**Figure 5.** Landscape view of each keyword from 2013 to 2023 ((a): microplastics; (b): POPs; (c): EDCs; (d): antibiotics on the right side represents the cluster, and the smaller the antibiotics number, the larger the cluster. Landscape view can be used to intuitively show the research hotspots and evolutionary trajectory).

The production and use of toxic and harmful chemicals are the primary sources of CECs [31,32]. CECs may originate from industrial waste, municipal waste, agricultural waste, hospital, and laboratory wastewater [33]. They can enter the environment through various point sources (i.e., industrial, municipal, and hospital wastewater treatment plants), nonpoint sources (such as atmospheric deposition and stormwater runoff), or unexpected scenarios [19,34,35]. For example, perfluorooctane sulfonyl compounds (PFOs) are typical...
perfluorinated compounds mostly derived from textiles, leather antifouling coatings, semiconductor paper products, synthetic detergents, foam extinguishing agents, food additives, pesticides, and cosmetics. PFOSs have been widely detected in environmental media and the human body. Owing to the toxic effects of PFOSs, they were included in the Stockholm Convention in 2009 and have been gradually banned in numerous countries.

CECs are released into the surrounding environment during the production, use, and disposal of related products. For example, China’s plastic ocean waste in 2011 was approximately 547–752,000 tons and it continued to expand at a rate of 4.55% per year until 2017, and then it had decreased to 257–353,000 tons by 2020 [36]. In the Hetao Plain of Inner Mongolia, China, the agricultural film remains in the soil, and the residue coefficient is as high as 40% [37,38]. CECs migrate, transform, agglomerate, degrade, and exhibit other environmental behaviors in environmental media, which affect their return to the environment. For example, water in the atmosphere inhibits the degradation of organophosphorus flame retardants caused by hydroxyl radicals [31]; perfluorooctanesulfonamides are converted to PFOS in earthworms; and perfluorohexane sulfonic acid and perfluorobutanesulfonate are converted in wheat [39]. Organophosphorus flame retardants exhibit biomagnification effects during food chain transfers [40]. When exposed to a mixture of o,p′-DDE and p,p′-DDE, the reduction in the ratio of estradiol to testosterone is greater than that observed with individual exposures. Northern bobwhite survival rates were lower when exposed to a mixture of TCDD and ethynyl estradiol or coumestrol compared to individual chemical exposures [41]. Smaller microplastics (i.e., 500 nm) can exacerbate the toxicity of POPs, where larger microplastics (30 µm) are less toxic, possibly due to size-dependent interactions between microplastics and POPs [42]. However, research on the effects of CECs mixtures is still in infancy, and current risk assessments are primarily based on concentration addition, which may lead to inaccurate risk estimates [43].

Currently, the primary focus of CECs removal technologies is on upgrading wastewater treatment plants. In line with this focus, membrane bioreactor (MBR) technology has shown improved removal performance of CECs before disinfection in conventional wastewater treatment plants [44,45]. In addition, activated carbon has demonstrated high adsorption capacity for CECs removal, although it has drawbacks such as slow adsorption kinetics and poor adsorption efficiency for hydrophilic pollutants [46,47]. Advanced oxidation processes based on ozone oxidation, ultraviolet radiation, gamma radiation, and electrooxidation have also been widely applied in CECs treatment [48–51].

CECs can persist in sediments for prolonged periods, resulting in the bioaccumulation of CECs in benthic organisms. Since the benthic organisms are consumed by fish, this food-web-driven bioaccumulation of CECs culminates in top predators having accumulated CECs to concentrations several orders of magnitude higher than that of the surrounding water [52,53]. The fate of CECs in soils may be influenced by interrelated processes [54]. Chemical substances with strong hydrophobicity or positive charges often exhibit high adsorption capacity, thereby reducing their potential for biodegradation, long-range transport, or plant accumulation [55–57]. Photodegradation of CECs represents a significant non-biological transformation process. For instance, under aerobic conditions, the half-life of bisphenol A in soil and sediment is estimated to be 3–37 days, whereas no degradation was observed in anaerobic or hypoxic estuarine sediments during a 120-day incubation experiment [58–60]. Microorganisms in soils also have the capability to degrade CECs, primarily occurring in the rhizosphere [61–63]. Consequently, it is necessary to conduct more detailed and systematic research on the pollution sources and environmental behaviors of CECs to provide a scientific basis for the accurate and scientific promotion of the prevention and control of pollutant health risks, and it is extremely important to treat and control their sources.
4. Exposure and Health Effects of CECs

Exposure to CECs occurs through diverse pathways, including industrial production, consumer goods, personal care products, plants and animals, food, and environmental media like soil. These CECs have a tendency to bioaccumulate in organisms and humans, resulting in threats to the environment and human health [64,65]. Scientific studies have highlighted their adverse impact on tissues, organs, and overall health, with a substantial portion of cancer risks linked to chemical use [66]. For example, persistent organic pollutants have been associated with intersexes, and chlorinated paraffins have shown toxic effects on zebrafish metabolism [67]. These contaminants enter the human body through multiple routes, including oral ingestion, respiratory inhalation, and skin absorption. Drinking water remains a primary source for most perfluorinated and polyfluoroalkyl substances (PFCs), while other sources contribute more to PFOA dust and air exposure [68]. Although studies indicate that micro/nanoplastics’ main exposure pathway is ingestion, the contribution of other routes, like dust inhalation, should not be underestimated. However, accurately assessing human exposure to micro/nanoplastics is currently limited by detection methods [69,70].

The cumulative homeostasis of CECs in the human body reflects the synergistic effects of multiple exposure pathways. For example, with the gradual use of bisphenol S (BPS) as a substitute for bisphenol A, the highest levels of BPS are found in the urine of the Japanese population, followed by the United States, China, Kuwait, and Vietnam, and the levels of BPS in the urine of the rest of Asia are an order of magnitude lower than the levels of BPS elsewhere [71]. CECs are enriched in organisms and produce a variety of biological toxicities in organisms and human health, including endocrine disruption, growth and development toxicity, neurotoxicity, immunotoxicity, carcinogenicity, and teratogenicity [72]. Some studies have reported that photolysis will increase the toxic effect of polystyrene microplastics and polystyrene fragments after photodegradation will reduce the particle size and form persistent free radicals on the surface (such as CO· and COO·). Polystyrene fragments after photodegradation have the greatest impact on the growth inhibition and liver damage of grouper, followed by polystyrene fragments before photolysis and commercially available polystyrene particles [73]. It has also been reported that PFOA induces apoptosis in mouse hepatocytes, and the genotoxicity caused by the overproduction of reactive oxygen species (ROS) is due to the inhibition of complex I subunits in the electron transport chain and activation of the peroxide proliferation-activating receptor PPAR [74]. BPA also affects rat metabolism, with BPA exposure interfering with the biosynthesis of valine, leucine, and isoleucine and the metabolism of D-glutamine and D-glutamate, and low doses of BPA may have toxic effects on the nervous system [75]. Some studies have reported that PFOs exposure affects synaptic transmission, cell growth, and development, and mainly acts on calcium ion channels and produces neurotoxic effects [76].

Consumption of contaminated aquatic products is one of the most important pathways of human exposure to CECs; therefore, it is important and necessary to assess the human health risks caused by the intake of aquatic products. Some researchers found a significant positive association between urine levels of organophosphorus flame retardants (DPHP) in pregnant women and the risk of low birth weight in female infants. In the third trimester, the fetus is susceptible to the developmental toxicity of BDCIPP and BBOEP [77]. However, perfluorinated compounds (PFCs) have a serious impact on the occupationally exposed population, and the levels of PFCs in this population are much higher than those in the general population. Metabolomic studies have shown that 14 potential biomarkers are associated with oxidative stress, fatty acid beta-oxidation disorder, and kidney damage; however, the health risks of PFCs in occupational populations cannot be ignored, with as many as 4730 PFCs used in the global market [78,79]. According to incomplete statistics, 62% of CECs have environmental health hazards. For example, owing to the influence of new estrogen-like pollutants, the incidence of intersexes in wild barracudas in Bohai Bay has reached 50% [67]. In addition, the tetrabrombisphenol A derivative had a stronger neurotoxic effect than the parent compound, and exposure to this compound resulted
in significant neuroethological changes in neonatal rats. The Journal of Science reports that antibiotic drugs in CECs increase the resistance of organisms and interfere with the homeostasis of organism populations and ecosystems [80]. Therefore, it is important to study the main driving factors and regulatory mechanism of EC transport for the treatment and control of CECs, and the joint ecological risk assessment of various pollutants needs to be further improved.

5. Risk Assessment and Management of CECs

Geographic visualization analysis of studies published in 2013, 2018, and 2023, and their correlations are shown in Figure 6. Globally, countries have the closest exchanges and cooperation in the field of POP research (Figure 6j–l), followed by antibiotics (Figure 6a–c), especially in Europe, the United States, and China, which have more extensive cooperative research, followed by Australia and South America.

Currently, the risk management and control of CECs is plagued by a few issues, primarily stemming from the lack of comprehensive laws and supervision. The absence of upper-level national laws on chemical management in countries like China hinders the regulation of CECs, leading to unclear numbers, unknown risks, and uncertainty regarding priority control of pollutants in specific industries and regions. Moreover, there is a weak foundation and insufficient reserves for effectively managing CECs, and innovation and governance capabilities need significant strengthening. Notably, existing environmental quality and industrial emission standards do not encompass CECs, despite their international significance. For instance, the “Surface Water Environmental Quality Standard” used in China lacks indicators for new POPs, such as perfluorinated and polyfluorinated compounds, which have been widely detected across various aquatic environments. Local management often focuses on conventional pollutants, with limited attention and supervision given to CECs and their potential health and environmental risks. Compared to conventional pollutants, CECs present more complex and hidden risks, posing greater challenges in terms of scientific understanding and effective governance. Consequently, addressing the risks associated with CECs necessitates urgent attention and comprehensive regulatory measures.

CECs in the environment pose a threat to human health. The derivation of environmental benchmarks and risk assessments of CECs is the only way to conduct risk management. Currently, aquatic water quality standards have been established for 35 pesticides, including organophosphorus pesticides, nicotine pesticides, acaricides, pyrethroids, carbamates, fungicides, and herbicides [81]. In addition, some studies have reported that a combination of the quantitative structure-activity relationship (QSAR), intermediate relationship model (ICE), and species sensitivity distribution model (SSD) can accurately predict the 5% species hazard concentration (HC₅), which is less than two times the actual experimental data concentration. The stratified ecological risk assessment method showed that 14.2% (HC₅) and 76.5% (HC1) of the surface water in China may present reproductive health risks, with the Yangtze River Basin being significantly higher than the other river basins [82]. It has been reported that 50 types of drugs and personal care products (PPCPs) are frequently detected in China’s surface water, and after in-depth research, 12 PPCPs with greater risk to aquatic organisms have been selected using accurate probabilistic risk assessment methods [83]. Studies have also found that the ingestion of organophosphorus flame retardants through drinking water poses a potential carcinogenic risk, with a contribution rate of up to 72.4% [84]. In short, global research on the exposure and effects of CECs has made rapid progress, and it is urgent to determine the impact of CECs on the ecological environment and the risk assessment of human health, as well as to conduct comprehensive and in-depth mechanistic exploration and risk prevention and control of the environmental behavior, migration, transformation, and health effects of CECs.
Figure 6. Geographical visualization of the literature published in 2013, 2018, and 2023 ((a–c): visualizations of antibiotics as the main topic; (d–f): visualizations with EDCs as the main inscription; (g–i): visualizations of microplastics for the title; (j–l): visualizations with POPs as the title. The white lines represent collaborative networks and the red dots represent research institutions).

Currently, in developed countries, there are environmental regulations addressing CECs. For example, the European Union has established an observation list [85] and implemented the Regulation on Registration, Evaluation, Authorization, and Restriction...
of Chemicals [86]. The United Kingdom has its own chemical investigation program and national implementation plans [87]. The United States has designated a candidate pollutant list that specifically focuses on unregulated contaminants in drinking water [88]. On 28 June 2022, China jointly issued the Ecological and Environmental Protection Plan for the Yellow River Basin and the Action Plan for Ecological Protection and Management of the Yellow River, focusing on the mainstream and major tributaries of the Yellow River to carry out environmental investigation, monitoring, and risk assessment of CECs. Various CECs, including endocrine disruptors, POPs, antibiotics, microplastics, and pesticides, have been detected in the agriculture surface water and sediments of the Yellow River Basin, among which the pollution levels of antibiotics and POPs are high according to statistical analysis of big data with the CiteSpace software (Figure 7). Microplastics have special carrier behavior and can absorb CECs such as antibiotics, PFAS, and endocrine disruptors from the environment [5]. With the ongoing battle against pollution, the focus of pollution control has shifted from the short-term and explicit risk management of conventional pollutants to the long-term and invisible risk management of CECs. However, current research has not organically combined the exposure and health impacts of CECs for the health risk assessment and management of CECs. Therefore, it is necessary to make scientific judgments based on scientific experiments and data; implement classification standards, quantitative risk assessment, differentiated assessment, and supervision; and provide scientific and technological support and systematic solutions to support the prevention and control of CECs.

Simultaneously, it is necessary to strengthen the top-level design, formulate CECs control strategies and action plans, determine the pollution bottom number, organize investigations and monitoring special actions, strengthen scientific research, and establish a technical system for the collaborative treatment of CECs and conventional pollutants. The control and treatment of CECs are related to social and economic development, ecological civilization construction, and people’s lives and health, and are deep-seated environmental problems that must be solved as soon as possible. This is a long-term systematic project

Figure 7. Various CECs in the agriculture-linked surface water and sediments of the Yellow River Basin.
that should give full play to the leading and forcing role of ecological and environmental protection and coordinate the promotion and joint efforts of science and technology, economy, management, and policy to continuously improve environmental quality and promote the comprehensive green transformation of economic and social development.

6. Research Prospects

Currently, many CECs in the environment cannot be detected due to limitations in detection methods. Therefore, there is a need for the development of robust non-targeted monitoring approaches that can identify unknown compounds using minimal information. It is important to establish priority control lists for CECs to facilitate regulatory measures. Additionally, there should be a focus on the research and development of improved treatment methods for CECs in the environment, such as Advanced Oxidation Processes (AOPs) or other treatment technologies. To address the health risks posed by CECs, detailed research on their sources and behaviors is necessary. Overall, adopting a global approach based on screening, assessment, control, prohibition, reduction, and treatment will enable effective management of CECs and safeguard human health and the environment.

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Abbreviations

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>AOPs</td>
<td>Advanced Oxidation Processes</td>
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<tr>
<td>BBOEP</td>
<td>butyl benzyl ortho-phthalate</td>
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<tr>
<td>BDCIPP</td>
<td>1,2-bis(2,4-dichlorophenyl)isopropanol</td>
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<td>CECs</td>
<td>Contaminants of emerging concern</td>
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<tr>
<td>DDE</td>
<td>Dichlorodiphenyldichloroethylene</td>
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<td>DDT</td>
<td>dichlorodiphenyldichloroethane and its isomers</td>
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<tr>
<td>EDCs</td>
<td>Endocrine-Disrupting Chemicals</td>
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<tr>
<td>HCHs</td>
<td>hexachlorocyclohexane and isomers</td>
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<td>HC5</td>
<td>the 5% species hazard concentration</td>
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<td>ICE</td>
<td>intermediate relationship model</td>
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<td>MBR</td>
<td>Membrane bioreactor</td>
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<td>MPs</td>
<td>microplastic</td>
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<td>OCPs</td>
<td>organochlorine pesticides</td>
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<td>PFCs</td>
<td>perfluorinated compounds</td>
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<td>PFAS</td>
<td>per- and polyfluoroalkyl substances</td>
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<td>PFOS</td>
<td>perfluorooctane sulfonate</td>
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<td>POPs</td>
<td>persistent organic pollutants</td>
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<td>PPAR</td>
<td>peroxide proliferation-activating receptor</td>
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<td>PPCPs</td>
<td>personal care products</td>
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<td>QSAR</td>
<td>quantitative structure-activity relationship</td>
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<td>ROS</td>
<td>reactive oxygen species</td>
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<td>SSD</td>
<td>species sensitivity distribution model</td>
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<td>TCDD</td>
<td>2,3,7,8-tetrachlorodibenzo-p-dioxin</td>
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