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Mini Review

Persistent Organic Pollutants (POPs): Historical Risks, Current Challenges and Emerging Solutions

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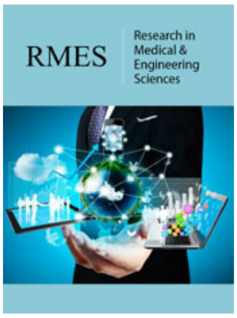

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Abstract

Following World War II, the surge in economic activity and scientific advancements led to the global production and widespread use of synthetic organic chemicals. Although many of these chemicals have been beneficial, some have posed significant environmental and health risks. Landmark studies, including Rachel Carson's 1962 research on dichloro-diphenyl-trichloroethane, and the Yusho and Yucheng poisonings, have highlighted the severe impacts of persistent organic pollutants. In response to these issues, the Stockholm Convention, effective from May 2004, was established to regulate and phase out persistent organic pollutants. Despite these international efforts, improper storage and historical contamination continue to pose health risks, such as endocrine disruption, immune system disorders, reproductive issues, and increased obesity rates. Current disposal methods, primarily incineration, face limitations due to inefficiencies and the potential formation of new pollutants (e.g., dioxin-like substances). Biotechnological solutions have been explored but struggle with challenges related to environmental conditions and the high toxicity of persistent organic pollutants. Thus, there is a growing need for new technologies in managing POPs worldwide. Novel technologies, such as mechanochemical degradation, present a promising alternative by breaking down persistent organic pollutants into less harmful or inorganic materials. Mechanochemical degradation operates in the solid state, eliminating the need for solvent regeneration or disposal and offering a simpler and more efficient approach compared to conventional methods. Thus, mechanochemical degradation holds significant potential as a reliable technology for environmental applications, particularly for addressing contaminated sites. This mini review provides a comprehensive overview of the historical impact, health effects, regulatory responses, and the role of mechanochemical degradation technology in managing persistent organic pollutants. By exploring these facets, the review sheds light on the ongoing challenges and advancements in POPs management, offering valuable insights into how emerging technologies like MCD can contribute to more effective environmental solutions.

Keywords: Persistent organic pollutants; Environmental and health risks; Disposal methods; Mechanochemical degradation

Abbreviations: SOCs: Synthetic Organic Chemicals; POPs: Persistent Organic Pollutants; DDT: Dichloro Diphenyl Trichloroethane; MCD: Mechanochemical Degradation; PCBs: Polychlorinated Biphenyls; PCDFs: Polychlorinated Dibenzofurans; α-HCH: Alpha-Hexachlorocyclohexane; β-HCH: Beta-Hexachlorocyclohexane; γ-HCH: Lindane (≥90%); PFOS: Perfluorooctane Sulfonic acid

Introduction

In 1962, Rachel Carson's observations revealed that birds consuming DDT and other pesticides produced thin-shelled eggs, leading to morbidity and mortality in embryos [1,2]. And in 1968, it was reported that over 1,850 people were poisoned by PCBs in Yusho, Japan, and more than 2,000 people were poisoned by PCDFs in Yucheng, Taiwan, in 1979 due to consuming contaminated food [3-5]. Additionally, in 1999, the use of chemically contaminated animal feed on farms in Belgium led to a major food safety crisis involving poultry and eggs, resulting in the disposal of thousands of chickens and hundreds of thousands of eggs in accordance with EU procedures [6]. These incidents have underscored the need for international measures to protect global public health and the environment. In response, the Stockholm Convention on POPs was adopted during a diplomatic conference held on May 22-23, 2001, in Sweden and entered into force on May 17, 2004. Initially, 12 chemicals known as the "dirty dozen" were classified as POPs, with their production and use restricted and/or banned [7]. Subsequently, the list has been updated several times to include additional chemicals, totaling 16 more.

These include α-HCH, β-HCH, chlordecone, decabromodiphenyl ether, hexabromobiphenyl, hexabromocyclododecane, hexabromodiphenyl ether and heptabromodiphenyl ether, hexachlorobutadiene, γ-HCH, pentachlorobenzene, pentachlorophenol and its salts and esters, PFOS and its salts, perfluorooctane sulfonyl fluoride, polychlorinated naphthalenes, short-chain chlorinated paraffins, technical endosulfan and its isomers and tetrabromodiphenyl ether and pentabromodiphenyl ether [8]. These chemicals are generally characterized by their toxicity, low solubility in water, and high solubility in lipids [9,10].

But, despite international restrictions and prohibitions, numerous stocks of POPs have emerged globally in recent years. Improper storage conditions and environmental contamination from historical use of these chemicals have led to continued hazardous exposures. Even at low doses, these chemicals can cause endocrine disruption, immune system disorders, reproductive diseases, and an increase in obesity rates [11,12]. Current disposal methods, primarily incineration, face limitations due to inefficiencies and the potential formation of new pollutants, such as dioxin-like substances [13]. While biotechnological solutions have been explored as alternatives, challenges remain due to ideal environmental conditions (pH, salinity, temperature, etc.) for microbial species, low solubility of POPs in water, and high toxic concentrations in stockpiles [14]. Therefore, there is a growing need for new technologies for managing POPs. MCD is emerging as a promising technology for the degradation of POPs into less harmful or inorganic materials. MCD occurs in the solid state, eliminating the need for solvent regeneration or disposal and offering a simpler and more efficient alternative to conventional processes [15,16]. However, comprehensive and systematic basic research and evaluations of this technology are also needed. Therefore, this paper focuses on these aspects to highlight the mechanochemical degradation ability to degrade POPs. Overall, this paper reviews important specific information about mechanochemical treatment technology.

Discussion

Mechanochemical degradation

MCD was first employed in the environmental field by Rowlands in 1993 for the degradation of DDT, achieving notable results after a 12-hour reaction [17]. Subsequently, MCD has been applied to the degradation of various POPs, including PFOS, mirex, PCBs, and PCDD/F [18-21]. Additionally, Japan's Ministry of Agriculture, Forestry and Fisheries was the first to recognize mechanochemical degradation as a non-incineration alternative technology (Nomura et al., 2011). Therefore, MCD offers a more economical and environmentally sustainable approach for managing POPs with a greener method. Schematic representation of mechanochemical degradation is given in Figure 1 [22].

Figure 1: Mechanochemical degradation of organic pollutants [22].

Moreover, the European Cooperation in Science and Technology (COST) has funded the COST Action CA18112-Mechanochemistry for Sustainable Industry (MechSusInd), which has been running since 2019. This initiative promotes research and collaboration aimed at advancing environmentally friendly industry practices. It emphasizes mechanochemical protocols that do not require solvents, offering a new perspective on sustainable industry practices [23].

Conclusion

The historical instances of environmental and health crises caused by POPs highlight the urgent need for effective and innovative management strategies. Despite the significant progress made through international regulations like the Stockholm Convention, ongoing issues with improper storage and environmental contamination from these chemicals persist, posing continued risks to public health and ecosystems. Current disposal methods, including incineration and biotechnological solutions, face notable challenges and limitations. As such, there is a critical need for advanced technologies to address the degradation of POPs. MCD has emerged as a promising alternative, offering a simpler and more environmentally sustainable method for breaking down POPs into less harmful or inorganic materials. However, to fully realize its potential, further comprehensive and systematic research and evaluation are necessary.

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Declarations

Conflict of interest

The authors declare no competing interests.

Ethics approval

This article does not contain any studies on animals performed by any of the authors.

References

1. Carson R (1962) Silent spring, Houghton Mifflin Company, New York, USA.
2. Scheer R, Moss D (2018) How important was Rachel Carson's silent spring in the recovery of bald eagles and other bird species.
3. Kuratsune M, Yashimura T, Matsuzaka J, Yamaguchi A (1972) Epidemiologic study on Yusho, a poisoning caused by ingestion of rice oil contaminated with a commercial brand of polychlorinated biphenyls. Environmental Health Perspectives 1: 119-128.
4. Schecter A (2012) Dioxins and health: Including other persistent organic pollutants and endocrine disruptors, John Wiley and Sons Inc, New Jersey, USA.
5. Stamati PN, Hens L, Howard CV (2001) Endocrine disrupters: Environmental health and policies. Environmental Science and Technology Library, Volume 18.
6. Kupferschmidt K (2011) Dioxin scandal triggers food debate in Germany. CMAJ 183(4): E221-E222.
7. Sharma BM, Bharat GK, Tayal S, Nizzetto L, Larssen T (2014) The legal framework to manage chemical pollution in India and the lesson from the Persistent Organic Pollutants (POPs). Science of The Total Environment 490: 733-747.
8. UN (2018) The 16 New POPs, an introduction to the chemicals added to the Stockholm Convention as Persistent Organic Pollutants by the Conference of the Parties.
9. Teran T, Lamon L, Marcomini A (2012) Climate change effects on POPs' environmental behaviour: a scientific perspective for future regulatory actions. Atmospheric Pollution Research 3(4): 466-476.
10. Xu FL, Jorgensen SE, Shimizu Y, Silow E (2013) Persistent organic pollutants in fresh water ecosystems. The Scientific World Journal pp: 1-2.
11. Lee YM, Kim KS, Jacobs DR, Lee DH (2016) Persistent organic pollutants in adipose tissue should be considered in obesity research. Etiology and Pathophysiology/Toxicology 28 (2): 129-139.
12. Schug TT, Janesick A, Blumberg B, Heindel JJ (2011) Endocrine disrupting chemicals and disease susceptibility. The Journal of Steroid Biochemistry and Molecular Biology 127(3-5): 204-215.
13. Cagnetta G, Liu H, Zhang K, Huang J, Wang B, et al. (2016) Mechanochemical conversion of brominated POPs into useful oxybromides: A greener approach. Sci Rep 6: 28394.
14. Bajaj S, Singh DK (2015) Biodegradation of persistent organic pollutants in soil, water and pristine sites by cold-adapted microorganisms: Mini Review. Int Biodeterior Biodegrad 100: 98-105.
15. Boldyrev VV, Tkácová K (2000) Mechanochemistry of solids: Past, present, and prospects. J Mater Synth Process 8(2-4): 121-132.
16. Wieczorek-Ciurowa K, Gamrat K (2007) Mechanochemical syntheses as an example of green processes. J Therm Anal Calorim 88: 213-217.
17. Rowlands SA, Hall AK, Mccormick PG, Street R, Hart RJ, et al. (1993) Destruction of toxic materials. Nature 367: 223.
18. Zhang K, Huang J, Yu G, Zhang Q, Deng S, et al. (2013) Destruction of Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA) by Ball Milling. Environmental Science and Technology 47(12): 6471-6477.
19. Yu Y, Huang J, Zhang W, Zhang K, Deng S, et al. (2013) Mechanochemical destruction of mirex co-ground with iron and quartz in a planetary ball mill. Chemosphere 90(5): 1729-1735.
20. Nah IW, Hwang YK, Shul YG (2008) Effect of metal and glycol on mechanochemical dechlorination of polychlorinated biphenyls (PCBs). Chemosphere 73(1): 138-141.
21. Birke V, Mattik J, Runne D, Benning H, Zlatovic D (2003) Dechlorination of recalcitrant polychlorinated contaminants using ball milling. In: Proceedings of the NATO ARW on ecological risks associated with the destruction of chemical weapons, Luneburg, Germany.
22. Cagnetta G, Huang J, Wang B, Deng S, Yu G (2016) A comprehensive kinetic model for mechanochemical destruction of persistent organic pollutants. Chemical Engineering Journal 291: 30-38.
23. Hernández JG, Halasz I, Crawford DE, Krupicka M, Baláž M, et al. (2020) European research in focus: Mechanochemistry for sustainable industry (COST Action MechSustInd). European Journal of Organic Chemistry 2020(1): 8-9.

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