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Review

Emerging contaminants in Indian environmental matrices – A review

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HIGHLIGHTS

- A baseline data on the current status of Emerging Contaminants (ECs) in Indian Environmental matrices is presented.
- A stepwise progress of Indian research on ECs is explored.
- The country is categorized into six zones based on climatic, geographical and cultural factors.
- The presence of ECs in various matrices, occurrence of antibiotic resistance bacteria/genes and the toxic effects are discussed in each zone.
- The gap areas were identified and provided suitable recommendations for future research works.

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ABSTRACT

The emergence of issues related to environment from ECs is a topic under serious discussions worldwide in recent years. Indian scenario is not an exception as it is tremendously growing in its rate of production and consumption of compounds belongs to ECs categories. However, a comprehensive documentation on the occurrence of ECs and consequent ARGs as well as their toxic effects on vertebrates on Indian context is still lacking. In the present study, an extensive literature survey was carried out to get an idea on the geographical distribution of ECs in various environmental matrices (water, air, soil, sediment and sludge) and biological samples by dividing the entire subcontinent into six zones based on climatic, geographical and cultural features. A comprehensive assessment of the toxicological effects of ECs and the consequent antibiotic resistant genes has been included. It is found that studies on the screening of ECs are scarce and concentrated in certain geological locations. A total of 166 individual compounds belonging to 36 categories have been reported so far. Pharmaceuticals and drugs occupy the major share in these compounds followed by PFASs, EDCs, PCPs, ASWs and flame retardants. This review throws light on the alarming situation in India where the highest ever reported values of concentrations of some of these compounds are from India. This necessitates a national level monitoring system for ECs in order to assess the magnitude of environmental risks posed by these compounds.

Contents

Abbreviations: APIs, Active pharmaceutical ingredients; ARGs, Antibiotic resistant genes; ARI, Antibiotic resistance index; ASWs, Artificial sweeteners; BBP, Butylbenzyl phthalate; BPA, Bisphenol A; CBZ, Carbamazepine; DBP, Dibutyl phthalate; DEHP, Diethylhexyl phthalate; DEP, Diethyl phthalate; DMP, Dimethyl phthalate; DOP, Dioctyl phthalate; ECs, Emerging contaminants; EDCs, Endocrine disrupting compounds; EROD, Ethoxyresorufin-O-deethylase; ETEC, Enterotoxigenic *E. coli*; FOSAs, Fluorooctane sulfonamides; FOSEs, Fluorooctane sulfonamidoethanols; FTAs, Fluorotelomer acrylates; FTOs, Fluorotelomer olefins; FTOHs, Fluorotelomer alcohols; GOT, Glutamate oxaloacetate transaminase; GPT, Glutamate pyruvate transaminase; HQ, Hazard quotient; LDH, Lactate dehydrogenase; MLD, Million liters per day; ND, Not detected; NSAIDs, Non-steroidal anti-inflammatory drugs; NP, Nonylphenol; OP, Octylphenol; PETL, Patancheru Enviro Tech Ltd.; PFASs, Per- and polyfluoroalkyl substances; PFBA, Perfluorobutanoic acid; PFBS, Perfluorobutane sulfonate; PFDA, Perfluorodecanoic acid; PFDoDA, Perfluorododecanoic acid; PFDS, Perfluorodecane sulfonate; PFHxA, Perfluorohexanoic acid; PFHxS, Perfluorohexanesulfonate; PFNA, Perfluorononanoate; PFOA, Perfluorooctanoic acid; PFOS, Perfluorooctane sulfonate; PFOSA, Perfluorooctanesulfonamide; PFPA, Perfluoropentanoic acid; PFUnDA, Perfluoroundecanoic acid; STEC, Shiga toxin-producing *E. coli*; STPs, Sewage treatment plants; TCC, Triclocarban; TCPP, Tris-2-chloroisopropylphosphate; TCS, Triclosan; WWTPs, Wastewater treatment plants.

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1. Introduction

The issue of ECs has gained global attention and several government and non-government organisations have taken up active research in this area. But contamination due to ECs is not a new phenomenon; this has been existing for several millenia. Its increase is proportional to the development of industries and technologies. The world wars and subsequent warfares have resulted chemical, nuclear and biological contamination of the environment to an unimaginable extent. Contaminations from different origins may be caused by intentional or unintentional means. This began with biological contamination of water bodies with human excreta and carcasses, global lead contamination through mining and smelting from the Romans, moves on to arsenic-based pesticides and DDT issues and presently reaches up to pharmaceuticals, personal care products, nanoparticles, flame retardants etc. (Sauvé and Desrosiers, 2014). It will remain as an enduring target of scientific and research community as new compounds are being synthesized and introduced into the environment every year. It does not mean that only synthetic chemicals are considered as ECs. As per the definition given by the United States Geological Survey, ECs are “any synthetic or naturally occurring chemical or any microorganism that is not commonly monitored in the environment but has the potential to enter the environment and cause known or suspected adverse ecological and/or human health effects” (USGS, 2017). In fact, microbial contaminants including antibiotic resistance bacteria/genes are also considered as ECs (Pruden et al., 2006; Fatta-Kassinos and Michael, 2013; Czekalski et al., 2014; Petrie et al., 2015; Sanderson et al., 2016; Glassmeyer et al., 2017). A contaminant may also be “emerging” because a new source or a new pathway to humans has been discovered or a new detection method or treatment technology has been developed (DoD, 2009). However, better understanding of ECs is a real challenge as currently only sparse information is available on their behavior in the environment and their toxic effects on human health or the environment. To a great extent, the rapid development of mass spectrometric analytical methods during the past 25 years has opened the way for identification of these ECs at trace levels (Larsson, 2014). Consequently, a large number of research works are now going on in this area world over, which has resulted in numerous publications (Suter and Giger, 2000; Petrović et al., 2003; Stackelberg et al., 2004; Westerhoff et al., 2005; Gros et al., 2006, 2008; Feitosa-Felizzola et al., 2007; Pedrouzo et al., 2009; Pitarch et al., 2010; Borkar et al., 2012; Blair et al., 2013; Padhye et al., 2014; Carvalho et al., 2015; Lai et al., 2016; Westhof et al., 2016; Cowell et al., 2017; McGrath et al., 2017). However, as compared to developed countries, developing countries in general