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Current status of persistent organic pesticides residues in air, water, and soil, and their possible effect on neighboring countries: A comprehensive review of India

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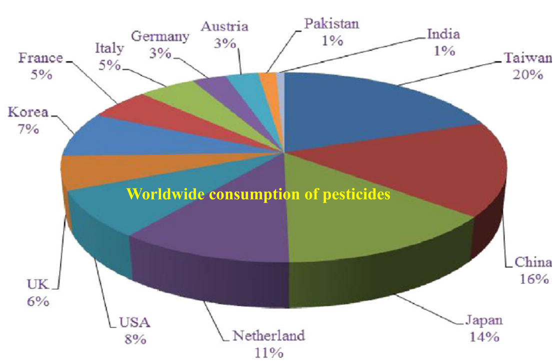
HIGHLIGHTS

- Every environmental component in India is contaminated with POPs.
- Residue level of pesticide is high in air, water and soil despite low consumption.
- Tibetan Plateau in Southwest China is affected with POP emission from India.
- India is one of the major contributors of global POP distribution.

GRAPHICAL ABSTRACT



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ABSTRACT

Though the use of pesticides has offered significant economic benefits by enhancing the production and yield of food and fibers and the prevention of vector-borne diseases, evidence suggests that their use has adversely affected the health of human populations and the environment. Pesticides have been widely distributed and their traces can be detected in all areas of the environment (air, water and soil). Despite the ban of DDT and HCH in India, they are still in use, both in domestic and agricultural settings. In this comprehensive review, we discuss the production and consumption of persistent organic pesticides, their maximum residual limit (MRL) and the presence of persistent organic pesticides in multicomponent environmental samples (air, water and soil) from India. In order to highlight the global distribution of persistent organic pesticides and their impact on neighboring countries and regions, the role of persistent organic pesticides in Indian region is reviewed. Based on a review of research papers and modeling simulations, it can be concluded that India is one of the major contributors of global persistent organic pesticide distribution. This review also considers the health impacts of persistent organic pesticides, the regulatory measures for persistent organic pesticides, and the status of India's commitment towards the elimination of persistent organic pesticides.

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Contents

1. Introduction

The use of chemical pesticides has provided a valuable aid to agricultural production, increasing crop protection and yield. However, the discovery of pesticidal residues in various sections of the environment has raised serious concerns regarding their use; concerns which well-outweigh the overall benefits derived from them (Ali et al., 2014; Sharma et al., 2014). Organochlorine pesticides (OCPs) have been in wide usage across the world to control agricultural pests and vector-borne diseases (Abhilash and Singh, 2009; Zhang et al., 2011). Amongst the OCPs in regular usage, dichlorodiphenyltrichloroethane (DDT), hexachlorocyclohexane (HCH), endosulfan, aldrin, chlordane, dieldrin, endrin, heptachlor, mirex, hexachlorobenzene (HCB) and toxaphene, metoxychlor, and metolachlor are persistent organic pesticides. OCPs are very stable compounds and their half-lives can range from a few months to several years; in some cases decades (Cremlyn, 1991). It has been estimated that the degradation of DDT in soil ranges from 4 to 30 years, while other chlorinated OCPs may remain stable for many years after their use (Afful et al., 2010). Because of their inability to break down in the environment, their degradation is restricted by chemical, physical, biological and microbiological means (Afful et al., 2010; Darko and Acquaah, 2007; NCEH, 2005; Swackhamer and Hites, 1988). They are liposoluble compounds and are capable of bio-accumulating in the fatty parts of biota such as breast milk, blood and fatty tissues (William et al., 2008) in the food chain. As a result, human beings are exposed to the effects of these micropollutants by eating foods in contact with contaminated soil or water (Belta et al., 2006; Raposo and Re-Poppi, 2007). These pesticides not only cause serious diseases in humans but are also highly toxic to most aquatic life (Aiyesanmi and Idowu, 2012) and soil microflora (Megharaj, 2002).

According to a joint report produced by WHO and UNEP, roughly 200,000 people die and around three million are poisoned each year by pesticides, all over the world, though the vast majority (95%) of cases are from developing nations (WHO/UNEP, 1990; FAO/WHO, 2000; Pope et al, 1994). As a result of the severe health effects associated with pesticides, most notably DDT and HCH, their use has been either banned or restricted in many countries (Jit et al., 2011; van den Berg, 2009). In India, pesticide use was banned in 1985, with the exemption of DDT which is still being used to control malaria (UNEP, 2003). Though the use of HCHs was banned for agricultural use in 1997, the Indian government still allows the use of HCHs on specific crops as well as in the health sector (Mukherjee and Gopal, 2003; Tanabe et al., 1994). There are few countries besides India who are still engaged in the production, usage and export of γ-HCH on a large scale (Abhilash and Singh, 2009).

India is home to approximately 16% of the total world's population, but has just less than 2% of the total landmass. Rapid population growth, together with a high emphasis on achieving food grain self-sufficiency has compelled Indian farmers to resort to the substantial use of pesticides. It is estimated that more than 100,000 tons of DDTs has been applied in India alone, primarily for agricultural use and malaria eradication programs, due to their low cost and broad-spectrum toxicity, making them effective in the control of pests and diseases (Kannan et al., 1995; Voldner and Li, 1995; Abhilash and Singh, 2009; Arora et al., 2013). However, some characteristics, such as persistency, volatility and atmospheric distribution through long range transportation (Bentzen et al., 2008; Caldas et al., 1999) has resulted in the contamination of air, water, soil and food (Caldas et al., 1999; Hans et al., 1999; Kim and Smith, 2001; Kumar et al., 1995; Singh, 2002; K.P. Singh et al., 2005; V.K. Singh et al., 2005).

Persistent organic pesticide residues have been broadly distributed in Indian soil (Al-Wabel et al., 2011; Devi et al., 2013; Hoai et al., 2010; Kata et al., in press; Kumar et al., 2014; Kumari et al., 2008; Liu et al., 2009; Senthilkumar et al., 2009), water (Huang et al., 2013; Lari et al., 2014; Malik et al., 2009; Mutiyar et al., 2011; Mutiyar and Mittal, 2012; Singh et al., 2012), air (Chakraborty et al., 2010; Devi et al., 2011; Huang et al., 2013; Srimural et al., in press; Syed et al., 2013; Zhang et al., 2008), living creatures (Bhuvaneshwari and Rajendran, 2012; Devanathan et al., 2009; Subramaniam and Solomon, 2006), and crops (Bajpai et al., 2007; Chowdhury et al., 2011). The fate of OCPs in soils in the areas of land use and cropping patterns has also been extensively studied. The concentrations of these pollutants observed in many agricultural soil samples were very high (Al-Wabel et al., 2011; Hoai et al., 2010; Kumari et al., 2008; Liu et al., 2009; Senthilkumar et al., 2009; Xu et al., 2013a,b). A number of studies revealed the prevalence of OCPs and PCBs in various environmental matrices, including food commodities in India (Aktar et al., 2009; Chakraborty et al., 2010; Chowdhury et al., 2007; Devanathan et al., 2009; Guzzella et al., 2005; IPEN, 2006; Kole et al., 2001; Kumar et al., 2009; Prakash et al., 2004; Senthilkumar et al., 2001; Someya et al., 2009; Zhang