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REVIEW

Uptake and translocation of organic pollutants in plants: A review

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Abstract

Organic pollutants, such as polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), antibiotics, herbicides, and bisphenol A (BPA), are commonly found in agricultural environments. They are released into the environment as a result of their use for human health purposes and farm management activities, and are often discharged as waste-water effluents. Most of these organic pollutants are taken up by plants through roots and leaves, and when they enter the tissue, they cause serious damage to the plants. Although the toxicity of organic pollutants to plants, especially to plant cells, has been intensively studied, a systematic review of these studies is lacking. Here we review researches on the toxicity of organic pollutants, their uptake, and translocation in plants. Our objective is to assemble existing knowledge concerning the interaction of organic pollutants with plants, which should be useful for the development of plant-based systems for removing pollutants from aquatic and agricultural environments.

Keywords: organic pollutants, plant, uptake, cytotoxicity

1. Introduction

Normal development and productivity of plants depends upon internal and external factors. Natural and man-made chemicals are important external factors that exert detrimental effects on plants. Some organic pollutants, such as hormones and persistent organic pollutants (POPs), including polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), and antibiotics, herbicides and bisphenol A (BPA), have drawn significant attention in environmental science and engineering research. Several countries and international organizations have published lists of harmful pollutants, which need to be controlled urgently. For example, the World Wildlife Fund listed 67 types of environmental hormones in 1997 that were considered harmful (Karissa 2002). Under the Stockholm Convention, countries agreed to reduce or eliminate the production, use, and/or release of 12 key POPs, and as specified under the Convention, a scientific review process led to the addition of other POP chemicals of global concern in 2001 (Anonymous 2008). Although most of these chemicals are beneficial, they may have unforeseen effects on the environment (Myöhänen *et al.* 2009). Many studies have been conducted on the toxicity of organic pollutants to plants cells and on the up-

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take of organic pollutants by plants. Here we review these studies, focusing primarily on (1) the uptake of organic pollutants by plants and their detrimental effects on plant cells, particularly irreversible cytotoxicity and (2) recent progress on the negative impacts of PCDD/Fs, PCBs, antibiotics, herbicides, and BPA on plant growth, reproduction, and crop productivity. This review could be useful in the development of plant based systems for removing organic pollutants from environments.

2. Uptake and translocation of organic pollutants by plants

The uptake pathway of organic pollutants in plants

Most organic pollutants are absorbed by plants either from soil or air. As shown in the Table 1 and Fig. 1, the organic pollutants, including PCBs and PCDD/Fs can be absorbed by plants from soil (through roots) or air (through leaves directly from the air or after these pollutants evaporate from

Table 1 Pathway of plant uptake of organic pollutants

Organic pollutant[1)]	Tissue tested	Species	Reference
PCBs (PCB3, PCB15, PCB28, PCB52, PCB73)	Root	Hybrid poplar	Liu and Jerald (2008)
	Foliage	Bluegrass, *Luzula*, and *Betula*	Pier *et al*. (2002)
PCDD/Fs	Root	Cucurbita, rouzi grass (*Thylacospermum caespitosum*), lettuce, potato, apple, pear, rice, pea, and oilseed rape	Engwall and Hjelm (2000); Zhang *et al*. (2009); Li *et al*. (2014)
	Foliage	Rice and radish	Stefan and Michael (1997); Wu *et al*. (2002)
Antibiotics (tetracyclines, polyether, semisynthetic and macrolides, aminoglycosides, sulfa, and β-lactams antibiotics)	Root	Spinach, lettuce, carrot, radishes, potatoes, onion and garlic, wheat, cucumber, pinto beans	Migliore *et al*. (2003); Alistair *et al*. (2006); Grote *et al*. (2007); Bassil *et al*. (2013); Kang *et al*. (2013); David *et al*. (2016)
BPA	Root	Rice, tobacco	Nakajima *et al*. (2002); Noureddin *et al*. (2004)
Herbicides (sulfonylurea, imidazolinone, triazines, phenylureas, uracilsand, and sulfonamide families)	Root and foliage	Pea, coffee plant, orange plant	Sterling (1994); Jurado *et al*. (1999); Papiernik *et al*. (2012); Goncalves (2016)

[1)] PCBs, polychlorinated biphenyls; PCDD/Fs, polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans; BPA, bisphenol A.

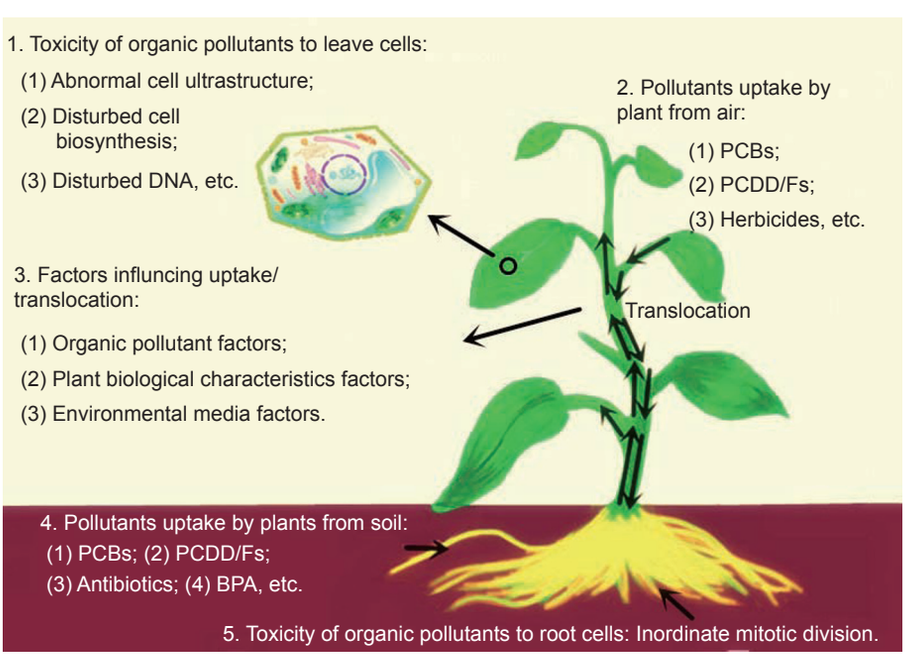

Fig. 1 Uptake and translocation of organic pollutants in plants, factors influencing uptake, and the toxic effects of organic pollutants in plants. PCBs, polychlorinated biphenyls; PCDD/Fs, polychlorinated dibenzofurans; BPA, bisphenol A.