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Biotic and abiotic degradation of illicit drugs, their precursor, and by-products in soil

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ABSTRACT

This study presents the first systematic information on the degradation patterns of clandestine drug laboratory chemicals in soil. The persistence of five compounds – parent drugs (methamphetamine, 3,4-methylenedioxymethamphetamine (MDMA)), precursor (pseudoephedrine), and synthetic by-products N-formylmethylamphetamine and 1-benzyl-3-methylnaphthalene) – were investigated in laboratory scale for 1 year in three different South Australian soils both under non-sterile and sterile conditions. The results of the degradation study indicated that 1-benzyl-3-methylnaphthalene and methamphetamine persist for a long time in soil compared to MDMA and pseudoephedrine; N-formylmethylamphetamine exhibits intermediate persistence. The role of biotic versus abiotic soil processes on the degradation of target compounds was also varied significantly for different soils as well as with the progress in incubation period. The degradation of methamphetamine and 1-benzyl-3-methylnaphthalene can be considered as predominantly biotic as no measureable changes in concentrations were recorded in the sterile soils within a 1 year period. The results of the present work will help forensic and environmental scientists to precisely determine the environmental impact of chemicals associated with clandestine drug manufacturing laboratories.

1. Introduction

The use of illicit drugs has gained worldwide concern due to their significant adverse impacts on human health and wellbeing of the society (Sloan, 2008; Rieckermann and Christakos, 2008). Illicit drugs are those whose nonmedical use is prohibited by the international law, and mainly belong to the classes of opiates, cocaine, cannabis, amphetamines and ecstasy-group substances (UNODC, 2007; Hall et al., 2008). Amphetamine, methamphetamine, and 3,4-methylenedioxymethamphetamine currently demand the most attention of all the synthetic illicit drugs (EMCDDA, 2008).

The amphetamines and ecstasy-group of illicit drugs (ATSs) are usually manufactured in clandestine laboratories. The chemicals associated with these illegal laboratories including precursors and by-products as well as the synthesized drugs are often illegally buried in soil or public waste management facilities, or disposed of into sinks or toilets after which they enter the sewerage system (Janusz et al., 2003; Scott et al., 2003). The degradation pattern of an illicit drug and a related precursor and manufacturing by-product in soil was initially reported by our research group (Janusz et al., 2003). In this study, the persistence behavior of methylamphetamine sulfate (MAS) and phenyl-2-propanone (P2P, a key precursor and by-product) in South Australian agricultural soils were presented. It was reported that P2P was rapidly degraded in all the test soils but the degradation of MAS was very slow with the level remaining practically constant over a period of 6 weeks.

Recently, the potential impacts of these toxic chemicals are being recognized as a growing concern among environmental scientists and it is necessary to investigate the behavior of these compounds in the environment. The majority of work so far has focused on analytical detection techniques (Castiglioni et al., 2006; Sach and Woo, 2007), and chemical impurity profiling of the illicit drugs (Qi et al., 2006; Waddell-Smith, 2007). A series of reports have been published on the presence of illicit drugs in surface and waste waters from several countries (Jones-Lepp et al., 2004; Zuccato et al., 2005; Hummel et al., 2006; Castiglioni et al., 2006, 2007; Bones et al., 2007; Boleda et al., 2007; Huerta-Fontela et al., 2007, 2008; Kasprzyk-Hordern et al., 2008). Kaleta et al. (2006) reported the presence of amphetamine in the low ppb range in sewage sludge from Austria. There is a lack of information on the behavior of these compounds in the environment and there is no information available in the scientific literature on the fate of these compounds in soil.

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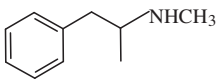
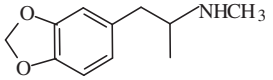
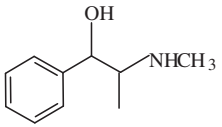
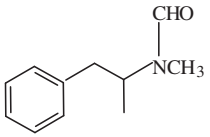
Table 1
General information on the target compounds in the present study.

Target compound full name	Short name	IUPAC nomenclature	Molecular formula	Molecular weight	Molecular structure	Solubility in H_2O(mg L^{-1})	log K_{ow}	pKa
Methamphetamine	MAP	N-methyl-1 -phenyl-propan-2-amine	$C_{10}H_{15}N$	149.24		1.33E + 04	2.07	9.87
3,4-methylenedioxy-methamphetamine	MDMA	1 -(benzo [1,3] dioxol-5 -yl-N-methylpropan-2-amine	$C_{11}H_{15}NO_2$	193.25				
Pseudoephedrine	PSE	(1*S*,2*S*)-2-methylamino-1 -phenylpropan-1-ol	$C_{10}H_{15}NO$	165.23		1.06E + 05	0.89	10.3
N-formylmethylamphetamine	FMA	N,N-dimethyl-1 -phenyl-propan-2-amine	$C_{11}H_{15}NO$	177.25				
l-benzyl-3-methylnaphthalene	BMN	l-benzyl-3-methylnaphthalene	$C_{18}H_{16}$	232.32