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Review

Current use pesticides in Arctic media; 2000–2007 ☆

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ABSTRACT

This review will summarize the levels of selected current use pesticides (CUPs) that have been identified and reported in Arctic media (i.e. air, water, sediment, and biota) since the year 2000. Almost all of the 10 CUPs (chlorothalonil, chlorpyrifos, dacthal, diazinon, dicofol, lindane, methoxychlor, pentachloronitrobenzene (PCNB), pentachlorophenol, and trifluralin) examined in the review currently are, or have been, high production volume chemicals i.e. >1 M lbs/y in USA or >1000 t/y globally. Characteristic travel distances for the 10 chemicals range from 55 km (methoxychlor) to 12,100 km (PCNB). Surveys and long-term monitoring studies have demonstrated the presence of 9 of the 10 CUPs included in this review in the Arctic environment. Only dicofol has not been reported. The presence of these chemicals has mainly been reported in high volume air samples and in snow from Arctic ice caps and lake catchments. There are many other CUPs registered for use which have not been determined in Arctic environments. The discovery of the CUPs currently measured in the Arctic has been mainly serendipitous, a result of analyzing some samples using the same suite of analytes as used for studies in mid-latitude locations. A more systematic approach is needed to assess whether other CUPs might be accumulating in the arctic and ultimately to assess whether their presence has any significance biologically or results in risks for human consumers.

Contents

1. Introduction

The Arctic is a region that is largely free from direct inputs of industrial and agricultural chemicals. Increasing urbanization in high latitude areas combined with atmospheric transport from lower latitude regions, however, provides for deposition of persistent organic pollutants (POPs) and other anthropogenic contaminants

☆ This paper is a contribution to the AMAP POPs assessment.

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into this unique part of the world. POPs are defined within the Stockholm Convention in terms of persistence, bioaccumulation, and adverse effects including human and ecotoxicity, as well as potential for long-range transport (LRT) (UNEP, 2001). Traditionally this definition has referred to legacy chlorinated organic contaminants, which are no longer in use or have much reduced global emissions as a result of past national and regional bans on use. Furthermore, Arctic monitoring data suggest that the environmental residues of legacy chlorinated organic chemicals are leveling off or declining (de Wit et al., 2004). In contrast, increasing levels of large-scale application agro-chemicals (current use pesticides; CUPs) have been found in regions isolated from their use and production, e.g. in the Arctic and in some alpine regions. By current use, we mean pesticides (acaricides, insecticides, herbicides, fungicides) which are currently registered for use by regulatory authorities worldwide although our emphasis is on products used in the USA, Canada, Russia, and western Europe. Not included here are banned organochlorine insecticides such as chlordane, DDT, mirex, and toxaphene. The CUPs most relevant to monitoring efforts are those exhibiting characteristics similar to those of POP substances currently listed in the Stockholm Convention. As of 2009 endosulfan has been proposed for inclusion in the Stockholm Convention while trifluralin, dicofol and pentachlorophenol (PCP) have been proposed to be added to the UNECE list of POPs (Rasenberg and van de Plassche, 2003; UNECE, 2007, 2008).

CUPs of concern in the Arctic have high production volumes and widespread current or past use, in temperate regions, relatively high air–water partitioning, and potential to bioaccumulate and biomagnify in fish and wildlife. When coupled with the fact that significant populations of arctic subsistence food users are reliant on high trophic level wildlife as part of their traditional diet, the relevance of these contaminants in Arctic monitoring activities becomes apparent. This review will summarize the levels of selected CUPs (Table 1) that have been identified and reported in Arctic media (i.e. air, water, sediment, and biota) since the year 2000. Endosulfan, an important CUP found in the Arctic, is reviewed in another article in this series (Weber et al., 2010-this issue).

1.1. CUP production and long-range transports

Production volume and use profile are important considerations in evaluating the arctic contaminant potential of CUPs (Muir and Howard, 2006). Almost all of the 11 CUPs listed in Table 1 currently are, or have been, high production volume chemicals i.e. >1 M lbs/y in USA or >1000 t/y globally. For two chemicals, methoxychlor and lindane, production and use have recently ceased in the USA, Canada, and the EU (US Environmental Protection Agency, 2004; UNEP, 2006). According to the UNEP lindane dossier, lindane production and use continues in Russia although other reports suggest that it has been banned along with other hexachlorocyclohexane (HCH) isomers (Li et al., 2005). PCP remains in use in the USA for wood treatment (US EPA, 2008) and is also permitted for wood treatment in Europe (UNECE, 2008) but has been phased out in Canada. Dicofol is a major acaricide in China and also has relatively wide use in the USA and Europe. Pentachloronitrobenzene (PCNB), chlorpyrifos, diazinon, and chlorothalonil remain high production CUPs and have undergone re-evaluation in the USA (US EPA, 1999, 2004, 2006b,a) although chlorpyrifos was phased out for residential and termite uses in the USA in 2000 (US EPA, 2006a). Dacthal underwent re-registration in the USA in 1998 (US EPA, 1998) and its use continues today (USGS, 2004). In general, quantities of PCNB, chlorphyrifos, chlorothalonil, diazinon, and dacthal used in other circumpolar countries and globally are not publically available to our knowledge.

The presence of CUPs in the Arctic environment suggests sufficient stability for transport to remote areas (Stocker et al., 2007). A degree of persistence is necessary for a pesticide's effectiveness. However, compared to the legacy organochlorine pesticides, most CUPs have

Table 1
Technical data for CUPs reviewed in this article.

Common name (acronym)	Class	IUPAC name	Production (t/y)[a]	Soil half-life (days)[b]	Water solubility (mg/L)[b,c]	Log Kow[c]	Log Kaw[c]	Log Koa[c]	AC-BAP[d]	CTD (km)
Chlorpyrifos	Organothiophosphate insecticide	Diethoxy-sulfanylidene-(3,5,6-trichloropyridin-2-yl)oxy-phosphorane	5000–7300[e]	30	0.4	4.96	−3.47	8.43	NA	430
Chlorothalonil	Organochlorine fungicide	2,4,5,6-Tetrachloro-1,3-benzene-dicarbonitrile	3600–5000[e]	30	0.6	4.81	−4.87	7.92	No	4420
Dacthal	Organochlorine herbicide	Dimethyl 2,3,5,6-tetrachlorobenzene-1,4-dicarboxylate	200[e]	100	0.5	4.28	−4.05	8.33	No	2690
Diazinon	Organothiophosphate insecticide	Diethoxy-(6-methyl-2-propan-2-yl-pyrimidin-4-yl) oxy-sulfanylidene-phosphorane	1820–3200[e]	40	60	3.81	−4.43	8.24	NA	130
Dicofol	Organochlorine insecticide	2,2,2-Trichloro-1,1-bis(4-chlorophenyl) ethanol	5500[f]	45	0.8	5.02	−5.01	10.03	Yes	640
Lindane	Organochlorine insecticide	(1*r*,2*R*,3*S*,4*r*,5*R*,6*S*)-1,2,3,4,5,6-hexachlorocyclohexane	3220[g]	400	7	4.14	−4.76	7.77	Yes	2500
Methoxychlor	Organochlorine insecticide	1-Methoxy-4-[2,2,2-trichloro-1-(4-methoxyphenyl)ethyl]benzene	193–2500[h]	120	0.1	5.08	−5.08	10.16	NA	55
Pentachlorophenol (PCP)	Chlorinated herbicide/fungicide	Pentachlorophenol	8500–50,000[i]	10–100	14	5.12	−6.0	11.1	NA	1320
Pentachloroanisole (PeCA)	PCP transformation product	1-Methoxy-2,3,4,5,6-pentachlorobenzene	–	55	0.35	5.45	−2.35	7.98	NA	2110
Pentachloronitrobenzene (PCNB)	Organochlorine fungicide	Pentachloronitrobenzene	350–450	189	0.44	4.64	−2.74	11.1		12,100
Trifluralin	Dinitroaniline herbicide	2,6-Dinitro-N,N-dipropyl-4-(trifluoromethyl)aniline	8700–10,500[j]	60	0.18	5.34	−2.38	7.72	NA	110

[a] Global for lindane and dicofol or for USA only as indicated below.
[b] ARS database.
[c] EPI Suite database (US Environmental Protection Agency, 2008).
[d] Arctic accumulation potential (Brown and Wania 2009). NA = not analyzed for AC-BAP.
[e] Kiely et al. (2004). USA production only – 2001.
[f] Global dicofol production (Rasenberg and van de Plassche, 2003) including China (Belfroid et al., 2005); USA estimated at 160 t/y for the period 1999–2004 (USGS, 2004).
[g] Global lindane usage, 1990–1995 (UNEP, 2006).
[h] Last produced in the USA in late 1990s. Production in 1975 estimated at 2500 t/y and in 1991 at 193 t/y (US Environmental Protection Agency, 2004).
[i] Range of global production estimates during the 1990s (UNECE, 2008).
[j] Combined USA and EU production based on Kiely et al. (2004) for 2001 in USA and UNECE (2007) for the EU.