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Review

A review of new and current-use contaminants in the Arctic environment: Evidence of long-range transport and indications of bioaccumulation

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HIGHLIGHTS

- The literature has been reviewed regarding potential new contaminants in the Arctic.
- For several novel brominated flame retardants long-range transport has been shown.
- Dechlorane plus and short-chain chlorinated paraffins accumulate in Arctic biota.
- Ice cores document increasing levels of some current-use pesticides, e.g. endosulfan.
- Long-range transport and bioaccumulation might also occur for octachlorostyrene.

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ABSTRACT

Systematic monitoring of persistent organic pollutants (POPs) in the Arctic has been conducted for several years, in combination with assessments of POP levels in the Arctic, POP exposure and biological effects. Meanwhile, environmental research continues to detect new contaminants some of which could be potential new Arctic pollutants. This study summarizes the empirical evidence that is currently available of those compounds in the Arctic that are not commonly included in chemical monitoring programmes. The study has focused on novel flame retardants, e.g. alternatives to the banned polybrominated diphenyl ethers (PBDEs), current-use pesticides and various other compounds, i.e. synthetic musk compounds, siloxanes, phthalic acid esters and halogenated compounds like hexachlorobutadiene, octachlorostyrene, pentachlorobenzene and polychlorinated naphthalenes. For a number of novel brominated flame retardants, e.g. 2,3-bibromopropyl-2,4,6-tribromophenyl ether (DPTE), bis(2-ethylhexyl)tetrabromophthalate (TBPH), 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB), 1,2-bis(2,4,6-tribromophenoxy)-ethane (BTBPE), decabromodiphenyl ethane (DBDPE), pentabromoethylbenzene (PBEB) and hexabromobenzene (HBBz), transport to the Arctic has been documented, but evidence of bioaccumulation is sparse and ambiguous. For short-chain chlorinated paraffins and dechlorane plus, however, increasing evidence shows both long-range transport and bioaccumulation. Ice cores have documented increasing concentrations of some current-use pesticides, e.g. chlorpyrifos, endosulfan and trifluralin, and bioaccumulation has been observed for pentachloroanisole, chorpyrifos, endosulfan and metoxychlor, however, the question of biomagnification remains unanswered.

Contents

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1. Introduction

In the last 30 years, the long-distance transport of organic chemicals to the Arctic has received increasing attention (AMAP, 2004). Persistent organic chemicals emitted in areas of production and use outside the Arctic can enter Arctic food chains and thus become an issue of exposure for those people who rely on traditional Arctic food items. Comprehensive international regulations of persistent organic pollutants (POPs) accompanied by voluntary phase-out and emission control programmes, have led to decreasing levels of most POPs in Arctic wildlife although exceptions exist (Rigét et al., 2010; Vorkamp et al., 2011).

Parallel to this documented success, new organic compounds are regularly developed and produced, which if emitted to the environment and similar to POPs in their physical–chemical properties, could cause new Arctic problems. Several initiatives in environmental policy deal with the identification of potentially problematic compounds, listing compounds to be phased out, monitored or studied further. The Stockholm Convention on POPs and the UN-ECE Convention on Long-Range Transboundary Air Pollution (LRTAP) with their compound lists are of direct relevance for the protection of the Arctic environment. Lerche et al. (2002) presented the criteria used for the selection of polychlorinated naphthalenes (PCNs), dicofol, hexachlorobutadiene and pentachlorobenzene as candidates for the UN-ECE POP protocol, combining predictions of persistence, bioaccumulation and long-range transport with empirical toxicity data.

Focussing on the marine environment, the Oslo-Paris Commission (OSPAR) for the protection of the North-East Atlantic has established lists of Chemicals for Priority Action and Substances of Possible Concern. The selection and priorisation procedures used in this context were described by Wiandt and Poremski (2002). Priority Substances and Priority Hazardous Substances were recently revised in connection with the Water Framework Directive (WFD) covering freshwater and coastal waters in the European Union (EU) (EU, 2013). For a number of countries, further lists exist at the national level, e.g. the List of Undesirable Substances in Denmark (Danish EPA, 2011). National lists were summarized by Stiehl et al. (2008).

Within environmental research, several studies have approached the identification of potential new Arctic contaminants by way of mathematical modelling of the likelihood of long-range transport and bioaccumulation, taking into account the compounds' physical–chemical properties and production volumes. Based on the Canadian Domestic Substances List and the US Environmental Protection Agency (USEPA) Toxic Substances Control Act Inventory Update Rule as well as relevant physical–chemical properties like partition coefficients, bioconcentration factors, vapor pressure and atmospheric half-lives, an original catalogue of >22 000 compounds was reduced to a list of 610 prioritised compounds (Howard and Muir, 2010). Many of these compounds contained halogen atoms or were siloxanes, i.e. known to be environmentally stable. Muir and Howard (2006) had previously published a list of 30 persistent compounds with the potential of long-range transport and bioaccumulation.

Based on a data set of >100 000 chemicals, 120 were selected as potential Arctic contaminants in a study by Brown and Wania (2008). In addition to the compounds' physical–chemical properties and production amounts, the authors studied molecular structures with regard to their similarity to known Arctic contaminants. Walker and Carlsen (2002) predicted values for bioconcentration and persistence from quantitative structure–activity relationships (QSAR) to select 56 compounds from a USEPA list of >8000 compounds, which were further characterized and ranked according to bioaccumulation and toxicity. With a view to revising an atmospheric monitoring programme, a Swedish study recently selected 15 priority compounds (Cousins et al., 2012). Unlike other approaches, this method combined empirical data on atmospheric occurrence and deposition with an assessment of persistence, long-range transport and bioaccumulation. Compounds of highest priority were short-chained chlorinated paraffins (SCCP), perfluorooctane sulfonate (PFOS) and octachlorostyrene (OCS).

The actual occurrence of contaminants in Arctic food chains and Arctic air is monitored in national monitoring programmes coordinated by the Arctic Monitoring and Assessment Programme (AMAP). Within AMAP, circumpolar spatial and temporal trends are assessed on a regular basis, combining data from national Arctic monitoring programmes and research studies (e.g. de Wit et al., 2010; Hung et al., 2010; Rigét et al., 2010). The objective of this article was to review the information available on potential new pollutants in the Arctic environment, not usually included in systematic monitoring of Arctic pollutants. Thus, the study aimed to identify compounds or compound groups for which further studies of their occurrence, bioaccumulation and biomagnification in the Arctic should be considered. The study has focused on experimental data from measurements in the Arctic. It has included results from abiotic media, showing the transport of contaminants to the Arctic, and from biota, suggesting a certain extent of bioaccumulation.

2. Materials and methods

New potential POPs in the Arctic environment have been defined as those in this study that are not currently included in