Environmental concentration and Sources of Halogenated Flame Retardants in Nepal
ネパールのハロゲン系難燃剤の環境濃度と発生源

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Introduction : Elevated level of brominated- and chlorinated- flame retardants (FRs) have been accounted in ambient air across the globe. Despite what might be expected, restricted information is available on PBDEs and other halogenated FR contained indoor air in whole of Indian sub-continent especially in case of Nepal, sandwiched between two most populous countries i.e. India and China. It was conjectured that the level of halogenated flame retardant (HFRs) in Nepalese air would be high because they have not been liable to control in Nepal; and henceforth there is more plausibility of HFRs to be available in a diverse array of goods and consumer products. This study therefore aims to measure the occurrence, spatial distributions and sources of 15 brominated- and 2 chlorinated-FRs in indoor air from four major cities of Nepal.

Materials and methods : Four major urban areas (i.e. Kathmandu, Pokhara, Birgunj and Biratnagar) of Nepal were chosen for collection of air samples. A total of 34 polyurethane foam passive air sampling (PUF-PAS) samplers (8 each in Pokhara, Birgunj, Biratnagar and 10 in Kathmandu) were deployed in open region of every urban area > 3m over the ground at various areas. After exposure of two months, from August-October, 2014, all PUF disks were recovered, resealed and transported to the laboratory and stored at −20 °C until investigation. All the 34 PUFs were spiked with 20 ng PCB 209 as surrogate standard and were soxhlet extracted for 24 h with DCM. The concentrate was concentrated to 2-3 mL (approx.) by rotary evaporator after extraction, followed by multilayer silica gel/alumina column cleanup. Later, the eluent was concentrated to 0.2 mL under gentle nitrogen stream and injected to Agilent 7890 gas chromatograph coupled to an Agilent 5975C mass selective detector (Mississauga, ON) working in electrochemical negative ionization (ECNI) mode. A known measure of 13C-PCB141 (10 ng) was included as internal standard before GC-MS analysis.

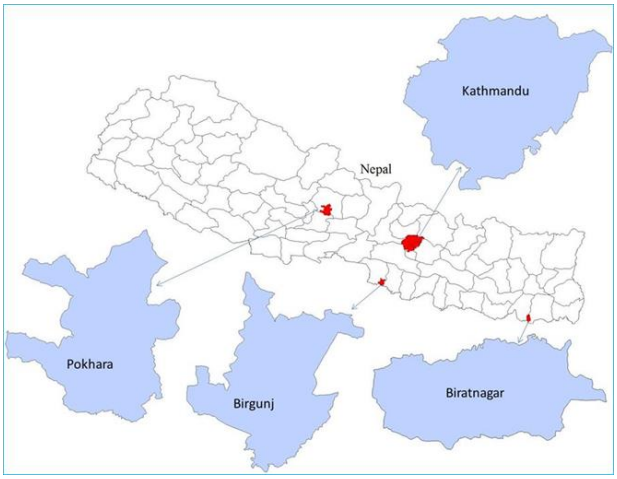

Fig. 1. Map of Nepal showing four Nepalese cities

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Results and discussion : The overall concentrations of HFRs ranged from 16.1-6750 pg/m^3(median 334 pg/m^3).The total concentrations of novel brominated fire retardants (NBFRs) were 20 and 100 times (13.2-6270 pg/m^3) higher than PBDEs (2.2-353 pg/m^3) and DPs (0.67-129 pg/m^3), respectively indicating much higher usages of NBFRs in Nepal. The most abundant NBFR was DBDPE while BDE 209 was the most imperative contributor to ∑PBDEs. Spatially, higher concentrations of ∑PBDEs were observed in Birgunj (16.4-271 pg/m^3) and Kathmandu (5.67-103 pg/m^3) than Pokhara (6.5-58 pg/m^3) and Biratnagar (8.6-19 pg/m^3). The ∑DPs were more prevalent in Kathmandu (2-129 pg/m^3) and Birgunj (2-60 pg/m^3) than those in Pokhara (0.8-4 pg/m^3) and Biratnagar (0.9-11 pg/m^3). Generally, syn-DP (56%) was most identified isomer than anti-DP (44%). Likewise, higher level of ∑NBFRs was measured in Kathmandu (67-4080 pg/m^3) and Birgunj (309-5760 pg/m^3) than Pokhara (22-2350 pg/m^3) and Biratnagar (18-1140 pg/m^3). Among NBFRs, DBDPE was identified as the most abundant chemical followed by TBPH, TBB and BTBPE, and accounted for 98%, 0.8%, 0.4% and 0.3% of ∑NBFRs, respectively. The penta-BDEs (BDE-47, -99, -100, -154, -153) were significantly and positively inter-correlated ($p<0.01$). The level of octa-BDE was essentially connected ($p<0.01$) with deca-BDE (BDE-209).Likewise, octa-BDE was further significantly correlated with BTBPE.

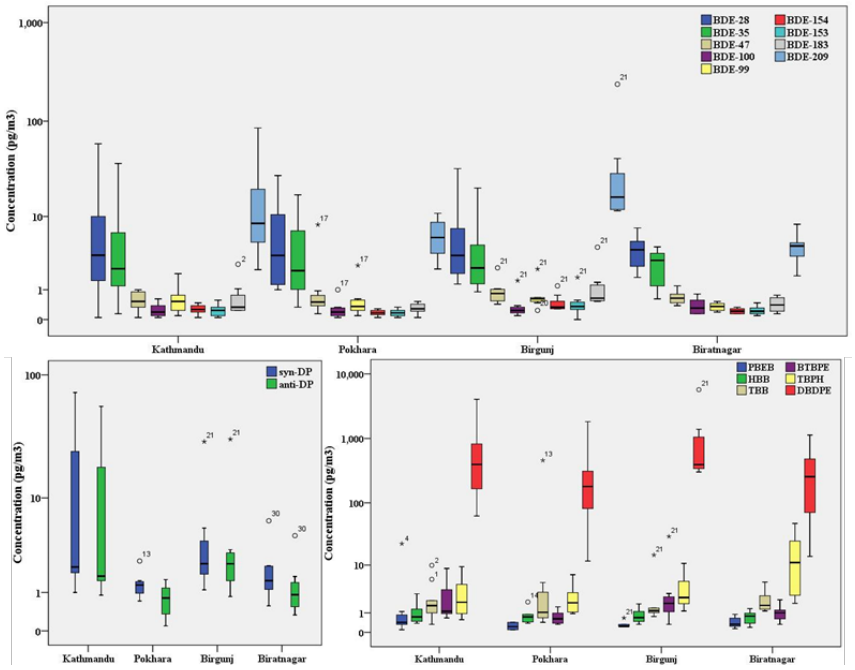

Fig. 2. Concentration of PBDEs, DPs and NBFRs in air (pg/m^3) of four Nepalese cities

Conclusions : NBFR was most abundant chemical measured in air among all HFRs studied. The most inexhaustible NBFR was DBDPE while BDE 209 was the most vital supporter to ∑PBDEs. The sources of PBDEs was identified with utilization of wide variety of consumers products and building materials in Nepalese houses, while higher concentration of BDE-209 were subject to emission from materials containing deca-BDE formulation. The lower f_{anti} ratios suggests the DP level in this study was essentially affected by the long range atmospheric transport from remote DP source instead of commercial products. The estimated low inhalation exposure suggested insignificant risk to Nepalese population. However, other modes of human exposure might still be significant in Nepal.