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Waste dumping sites as a potential source of POPs and associated health risks in perspective of current waste management practices in Lahore city, Pakistan

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HIGHLIGHTS

- The pioneer study provides the baseline data from waste dumping site from Lahore.
- Dump site of Lahore is the potential source of PCBs, PBDEs and DPs in nearby environment.
- Fugacity fractions indicated air to soil deposition of PCBs and PBDEs.

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ABSTRACT

Persistent organic pollutants (POPs) including polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and dechloran plus (DP) were analyzed in air, dust, soil and water samples from waste dump site, Lahore, Pakistan. It was revealed that PCB levels were detected higher in all matrices than PBDEs and DPs. Principal Component Analysis (PCA) showed higher usage of BDE-47, -99 and di-CBs, tri-CBs, tetra-CBs and penta-CBs. Health risk assessment of PCBs and PBDEs from soil and dust indicated low to moderate risk to the local population via different exposure pathways. It is recommended to improve current waste management practices in order to avoid emissions of contaminants and open dumping grounds should be modified into sanitary landfill.

1. Introduction

Economic development and population growth lead to the production of huge amounts of solid waste in urban areas (Krishnamurti and Naidu, 2003) as shown in SI Table 1 which describes the increasing waste generation rates in different regions of the world. The composition of this waste may comprised of plastics, electronics, paper, glass, metals, and textiles etc. (Idris et al., 2004) which are potentially the source of persistent organic pollutants (Minh et al., 2006). Persistent organic pollutants (POPs) are toxic and persistent chemicals that have the ability to transport into long distances in the environment. POPs accumulate to such levels that become harmful to biota and human. The persistence of such chemicals in different environmental matrices gives rise to their ubiquitous distribution in the environment and eventual penetration into the food chain. Public concern about contamination by POPs increased recently because several of these compounds are identified as hormone disrupters, which can alter the normal function of endocrine and reproductive systems in humans and wildlife (Ali et al., 2014).

Developing world lacks the state of art facilities for proper waste management and recycling and even some countries lack proper laws and regulatory guidelines for waste management while waste production is increasing day by day mostly in urban areas. Mostly waste is dumped in open grounds and burning is common practice to reduce the volume and to recover metals and plastics (Adriano, 2001; Idris et al., 2004; Korhonen et al., 2004; Liamsanguan and Gheewala, 2008). Previous studies by Chrysikou et al. (2008) and Persson et al. (2005)

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showed that dumping sites are direct potential sources of POPs. In Pakistan, like other developing countries municipal solid waste which consists of a wide variety of materials such as food waste, paper, plastic, building material and metal scrap is openly dumped on waste sites. Burning of waste is a common practice to decrease the volume of waste and recover valuable items such as metals from e waste (Haydar et al., 2012b; Ahmed, 1998). Though municipalities are responsible for proper management of this waste but they lack up to date treatment and disposal technologies (Mahar et al., 2007). About 5000 tons per day waste is generated in Lahore city. Per capita waste generation ranges 0.5–0.65 kg/day which is higher as compared to other cities of Punjab. Administratively, there are 9 towns of Lahore among which Ravi town generated highest waste i.e., about 607 tons per day followed by Samanabad and Allama Iqbal towns with waste generation of 593 and 591 tons/day, respectively (Haydar et al., 2012b). Lahore Waste Management Company under City District Lahore Government is responsible for collection of this waste from the city and disposes it off at two dumping sites i.e., Mahmood Booti and Lakhodaer. Both of these dumping sites does not fulfill sanitary landfill requirements and only used as open dumping grounds without pollution controlling facilities and leachate treatment. Invasive smell, flies, insects and impacts on ground water, soil and nearby population are common issues (KOICA, 2007). Burning of waste on site contribute towards release of toxic contaminants in the air while leachate contaminate the groundwater. As Mahmood Booti is main official dumping site in Lahore and receives most of the waste, where waste is dumped without any treatment so this site could potentially be a direct source of POPs (flame retardants and PCBs).

Keeping in view the above scenario and current waste management practices in Lahore, this study was designed to determine the levels of selected POPs (PBDEs, DP and PCBs) from and in the vicinity of Mahmood Booti dumping site Lahore. The main objectives of this study were to: (i) provision of baseline data regarding PCBs, PBDEs and DPs in air, water, soil and dust samples from and in the vicinity of Mahmood Booti dumping site; (ii) assessing soil air exchange fluxes; (iii) health risk assessment (carcinogenic and non-carcinogenic) of dust and soil through different pathways (ingestion, dermal contact and inhalation) based on concentration of studied compounds.

2. Materials and methods

2.1. Study area and sampling

Mahmood Booti is the only official municipal waste dumping site in Lahore located on 31°36′33.00″N/74°23′10.24″E and 5 km from the River Ravi situated on north of Ring Road Lahore. Dumping site is in use since 1997 and operates round the year. The total area of dumping site is about 0.32021 km^2 (KOICA, 2007). For sampling, study area was divided into three major zones including main dumping site and Lahore compost zone, adjacent agricultural zone and residential zone. Zonation was done on the basis of different land use areas around dumping site and to evaluate impact of Mahmood Booti dumping site on vicinity area. From each zone air, soil, dust and water samples were collected. SI Fig. 1 shows the sampling points for different matrices. A total of 6 passive air, 19 soil, 17 dust and 12 water samples were collected (SI 1 and SI 2). All samples were transported to Environmental Biology Laboratory, Quaid-i-Azam University Islamabad and stored at 4 °C till further analysis. Details of experimentation have been provided in the SI 3.

2.2. Chromatographic analysis

A total of 30 PCBs (PCB-8, -28, -37, -44, -49, -52, -60, -66, -70, -74, -77, -82, -87, -99, -101, -105, -114, -118, -126, -128, -138 + 153, -153, -156, -166. -170, -179, -180, -183, -187 and PCB-189), eight BDE congeners (BDE-28, -35, -47, -99, -100,-153, -154, and -183) and two DP isomers (*syn*- and *anti*-DP) were analyzed. Detailed analytical procedures and QA/QC data are provided in the Supporting Information. Briefly, after adding surrogates, soils (20 g) were Soxhlet extracted with DCM. Clean-ups were done by column chromatography. PCBs were detected by GC–MS (GC–EI-MS) using 50 m capillary column while PBDEs and DPs were detected by GCECNI-MS (Agilent GC7890 coupled with 5975C MSD) applied with a DB5-MS capillary column (30 m × 0. 25 mm i.d., and 0.25 lm film thickness).

2.3. QA/QC

All analytical procedures were monitored using strict quality assurance and control measures. Field, procedural and solvent blanks were analyzed by the similar methodology, adopted for original samples. Detection limits were estimated as three times the standard deviation of the blank. Reported values were corrected according to the recovery ratios and blank values. Average surrogate recoveries in all samples for TCmX ranged between 51–67% and PCB-209 average recoveries ranged between 73–85%.

2.4. Health risk assessment

Carcinogenic and non-carcinogenic health risk assessment for PCBs and PBDEs was calculated through different pathways. Estimated daily intake through ingestion, dermal contact and inhalation was calculated using equations described by Man et al. (2011) and Ge et al. (2013). The detailed methodology, equations and calculations of fugacity fractions and health risk assessment are presented in supporting information (SI 4).

2.5. Statistical analysis

Basic descriptive statistics was done using Microsoft Excel 2013. One-way ANOVA was done by IBM SPSS 20 to study the variance of different land use types to identify the differences in POPs levels. PCA was performed for source identification on log transformed data using MultiVariate Statistical Package (MVSP) among and first two axes were discussed on the basis of Eigen values.

3. Results and discussion

3.1. Environmental levels and global comparison of POPs

Table 1 shows the descriptive statistics for PCBs, PBDEs and DPs in studied environmental matrices for Mahmood Booti dumping site and surrounding areas, while following sections discussed abovementioned POPs in each studied environmental compartment. The detailed concentration levels for each POP can be seen in SI Tables 2 and 3.

3.1.1. Air

$\sum_{30}$PCBs were ranged between 456 − 996 pg/m^3 among which PCB-70 were dominant with 37.8% followed by PCB-8 (18.5%) > PCB-28 (9.57%) and PCB-44 (6.75%). Overall, tetra-PCBs were dominant (51.6%) among analyzed homologues followed by di- and tri-PCBs (18.5 and 11.6%, respectively). Compositional patterns (SI Fig. 2) were similar to those reported by Syed et al. (2013b). This homologues pattern in air was similar to previously reported in the Asian atmosphere, where tetra-PCBs were found dominant (Jaward et al., 2005; Li et al., 2012; Zhang et al., 2008) while Manodori et al. (2007) and Sundqvist et al. (2004) reported higher levels of tri-CBs in the atmosphere. $\sum_8$PBDEs and $\sum$ DPs ranged 53.8–454 and 0.02–1.50 pg/m^3, respectively. Congener profile showed dominance of BDE-47 and -99 (39.2 and 26.6% respectively (SI Fig. 3). Tetra- and penta-BDEs were dominant among BDE homologues (SI Fig. 4). The pattern of chemical concentration by land use area was as follows (mean; pg/m^3): residential (834) > dumping site (709) > roadside (561) > agricultural (510) for PCBs, dumping site (212) > agricultural (175) > roadside (98.3) > residential (79.4) for PBDEs and dumping site