Science of the Total Environment 635 (2018) 817–827

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

Concentration and factors affecting the distribution of phthalates in the air and dust: A global scenario

Durba Kashyap, Tripti Agarwal *

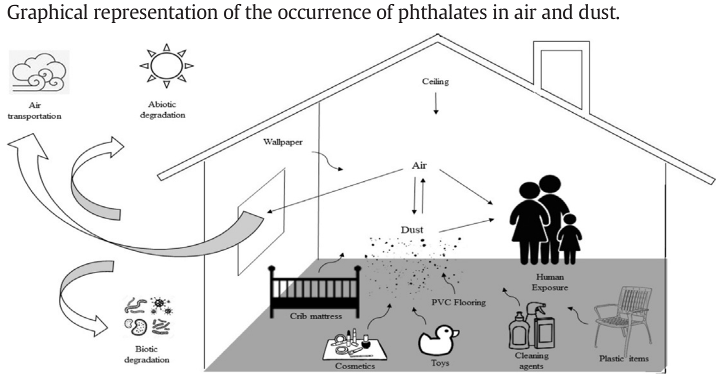
National Institute of Food Technology Entrepreneurship and Management, Kundli, Sonipat, Haryana 131028, India

HIGHLIGHTS

- Global phthalate levels in the air and dust along with factors associated with their presence were reviewed.
- Asian countries were found to contain the highest level of phthalates.
- DEHP and DBP were found to be predominant in both air and dust.
- Temperature, air exchange rate and use of PVC materials were found to be strongly associated with presence of phthalates.

GRAPHICAL ABSTRACT

Graphical representation of the occurrence of phthalates in air and dust.



ARTICLE INFO

Article history:
Received 14 December 2017
Received in revised form 10 April 2018
Accepted 11 April 2018
Available online xxxx

Editor: Lidia Morawska

Keywords:
DBP
DEHP
Plasticizer
PVC
Indoor pollution

ABSTRACT

Phthalates are ubiquitously present environmental contaminants. Air and dust are the most important mediums of exposure to phthalates. The present study reviews the presence of phthalates in the air and dust reported from different countries in the last ten years (2007–2017). The phthalate concentrations revealed wide heterogeneity with a mean and median value 6 ± 19 μg/m^3 and 0.5 μg/m^3 respectively in the air and $1.5 \times 10^3 \pm 2.2 \times 10^3$ μg/g and 7.8x10^{2}μg/g respectively in the dust. The highest phthalates levels in the air were reported from India (1.1×10^2 μg/m^3) and in dust from Bulgaria (1.2×10^4 μg/g). Overall higher levels were reported from developing countries as compared to developed countries. Di (2-ethylhexyl) phthalate (DEHP) and Di-*n*-butyl phthalate (DBP) were found to be predominant in both air and dust. Temperature, humidity, air exchange rate, building material and indoor maintenance were reported as the important factors influencing the levels of phthalates in the air and dust. In addition to policy level interventions, reducing the use of phthalate containing materials and controlling the factors which enhance the emission from existing sources can help in reducing human exposure to phthalates.

Contents

* Corresponding author at: Department of Agriculture and Environmental Sciences, National Institute of Food Technology Entrepreneurship and Management, Kundli, Sonipat, Haryana 131028, India.
E-mail address: tripti.niftem@gmail.com. (T. Agarwal).

https://doi.org/10.1016/j.scitotenv.2018.04.158

1. Introduction

Phthalates are esters of ortho-phthalic acids (1, 2-benzenedicarboxylic acid), that is produced by the reaction between alcohol and phthalic anhydrite. The hydrocarbon chain derived from alcohols ranging from methanol and ethanol to tridecanol imparts specific properties to each of the phthalates (Fernandez et al., 2012). Phthalate esters can be broadly divided into two groups based on the length of the ester groups' main carbon chain, namely high molecular weight (HWM) phthalates (7–13 carbon atoms) and low molecular weight (LMW) phthalates (3–6 carbon atoms). These are primarily used as plasticizers in polyvinyl chlorides (PVCs) and consumer products such as toys, building material, electronics and medical devices (Sampath et al., 2016). DEP and DMP with <3 carbon atoms are not used as plasticizers and not classified in any group. These are used as solvents and fixatives in fragrances, additives in cosmetics, medical devices, household and personal care products (Katsikantami et al., 2016).

Compared to the long duration of their use in the plasticizer industry, concerns over possible adverse effects of phthalates on human health are relatively recent, dating back to the 1980s (Kamrin and Lansing, 2009). Today, phthalates are known to be reproductive and developmental toxicants (EU, 2005; WHO, 2013). Human bio-monitoring studies have indicated that exposure to phthalates can cause adverse health outcomes like fertility problems, respiratory diseases, childhood obesity and neuropsychological disorders (Katsikantami et al., 2016). Consequently, six phthalates, namely, Di-methylphthalate (DMP), Di-ethylphthalate (DEP), Di-*n*-butyl phthalate (DBP), Butyl-benzyl phthalate (BBP), Di (2-ethylhexyl) phthalate (DEHP), and Di-*n*-octylphthalate (DnOP) have been identified as priority pollutants by the United States Environmental Protection Agency (U.S. EPA) and the European Union (EU). Usage of DEHP, DBP, BBP & DnOP has been limited to ≤0.1% in toys and childcare articles by EU (Directive 2005/84/EC), US (Consumer Product Safety Improvement Act of 2008 (CPSIA, 2008), China (China National Standard GB 6675, 2014), India (BIS, 2011) and Japan (Japan Toy Safety Standard ST-2002 Part 3, 2011). Recently in 2015, DEHP, DBP and BBP were classified as reproductive toxicant category 1B and completely banned for any application without prior approval from EU (ECHA, 2016).

Owing to the strict regulations on the use of phthalates because of human health concerns, there has been a reduction in their production and alternative plasticizers are being manufactured and employed by the plastic industry (Katsikantami et al., 2016). This is clearly visible in declining contribution of phthalates to world consumption of plasticizers from 88% in 2005 to 70% in 2014, forecasted to be 65% in 2019 (IHS Markit, 2015). Bui et al. (2016) reported an increasing trend in use of alternate plasticizers in Sweden over the past decade. However, even with the shift towards the use of alternate non–phthalate plasticizers and higher molecular weight phthalates, the exposure risk from products already containing high levels of phthalates prior to regulation cannot be neglected (Larsson et al., 2010). Large-scale and diverse use of phthalates in consumer products combined with their property of volatilization and leaching have made these chemicals ubiquitously present in the environment in all kinds of media including air, water, dust, sediment and food (Cao, 2010). Phthalates dwell in a state of dynamic flux in the environment, through the processes of emission, transportation, degradation, deposition and exchange between different environmental media. These processes depend upon environmental factors and their physicochemical properties like vapor pressure (Vp), air-water partition coefficient (K_{AW}), octanol-air partition coefficient (K_{OA}), and octanol-water partition coefficient (K_{OW}), organic carbon partition coefficient (K_{OC}) (Teil et al., 2006; Net et al., 2015). The vapor pressure of a particular phthalate and its concentration in a source determines the equilibrium gas-phase concentration of that phthalate, which in turn is a key parameter in influencing source emission rates of phthalates (Liang and Xu, 2014b; Afshari et al., 2004). Octanol-air partition coefficient (K_{OA}), an indicator of hydrophobicity, is another among the key factors which determines partitioning between the gas phase and indoor surfaces/dust (Sukiene et al., 2016). The ability to partition between gas and particle phase leads to a dynamic distribution of phthalates in the air and on surfaces like particles, dust and human skin, which leads to direct exposure through dust ingestion, inhalation and dermal absorption (Bergh et al., 2011; Blanchard et al., 2014). Ingestion of dust and inhalation of indoor air and re-suspended dust are the most important non-food sources of exposure to phthalate esters (Clark et al., 2003; Clausen et al., 2004). In the present review, peer-reviewed literature published in the last ten years i.e. from 2007 to 2017 from different parts of the world reporting phthalate levels in the air and dust was examined. The status of the worldwide presence of six priority phthalates, in two of the most important environmental media viz. air and dust, and the factors affecting their presence are presented and discussed here.

2. Phthalates in the air and dust samples on a global scale

Phthalates are high production volume chemicals that accounted for 70% of the world consumption of plasticizers in 2014. Of this, Asia, Western Europe and the U.S.A accounted for 59%, 14% and 16% respectively of the world plasticizer consumption in 2014 (IHS Markit, 2015). However, phthalate exposure (phthalate metabolite levels in urine) among countries indicates the highest exposure for people living in Europe (2.1×10^2 μg/l) closely followed by USA (2.0×10^2 μg/l) and least in Asia (1.3×10^2 μg/l) (Katsikantami et al., 2016). There exists a discrepancy between trends for industrial consumption and human exposure. Trade might be a plausible explanation, for instance, a large proportion of articles containing phthalates are brought into Sweden via imports (KEMI, 2015). The highest concentrations of phthalates in