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Lead-based paint in children's toys sold on China's major online shopping platforms☆

Zhengtao Shen [a, b], Deyi Hou [a, *], Ping Zhang [a], Yinan Wang [a], Yunhui Zhang [c], Peili Shi [a], David O'Connor [a]

[a] School of Environment, Tsinghua University, Beijing, 100084, China
[b] Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, T6G 2E3, Canada
[c] Department of Engineering, University of Cambridge, Cambridge, CB2 1PZ, United Kingdom

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ABSTRACT

Lead in paint is a major public health concern and has drawn much attention from international organizations such as the World Health Organization (WHO) and the United Nations Environmental Programme (UNEP). However, there is limited research on lead-based paint, especially its use in toys, which poses an explicit health risk to vulnerable children. The present study sampled 100 different toys purchased from the three largest online shopping platforms in China: JD, Taobao (TB) and Tmall (TM). These selected toys have been sold nearly 3 million times in total, suggesting that they may have reached the dwellings of millions of children. It was found that the toys sold by JD and TM, which are considered organized sellers, had average lead concentrations of 25 mg/kg and 32 mg/kg, respectively, much lower than that of toys sold by unorganized sellers on the TB platform, at 219 mg/kg. Approximately 12% of the toys purchased from TB contained paint with total lead concentrations exceeding China's regulatory standard for paints in toy manufacturing, and nearly 36% of the toys purchased from TB exceeded the equivalent US regulatory standard and EU standard. These results suggest that further action is needed to verify the health and safety standards of toys sold by such unorganized sellers. Moreover, this study found that China's regulatory standard (90 mg/kg) based on soluble lead may underestimate the risk posed by lead in paints, and it is suggested that future regulatory thresholds for lead levels in paints for toy manufacture be based on total rather than soluble lead concentrations. The present study also explored various influencing factors on lead concentration, and found that lead concentrations were related to toy price, age group, color, and sales volume.

1. Introduction

Lead (Pb) is one of the 10 chemicals of highest public health concern. In 2016, lead exposure accounted for nearly half a million deaths and over 9 million disability-adjusted life years (DALYs) (WHO, 2017). The toxic effect of lead exposure on IQ is irreversible and persists for a lifetime (Gilbert and Weiss, 2006). Children are most vulnerable to lead exposure; moreover, children's mouthing behavior has been identified as an important exposure pathway (Lanphear and Roghmann, 1997). Previous studies in the United States (US) show that two major sources of lead exposure for children were airborne lead from leaded gasoline and chips or dust containing deteriorated lead-based paint (Committee on Environmental Health, 2005). After the ban of leaded gasoline, the primary source of children's lead poisoning became deteriorating lead paint (Lofgren et al., 2000). Currently, lead exposure in children incurs an enormous economic cost for developing countries, amounting to approximately $977 billion dollars per year for low-income and middle-income countries, representing 1.9%, 2.0%, and 4.0% of the GDPs of Asia, Latin America, and Africa, respectively (IPEN, 2016).

Lead in paint can cause elevated lead concentrations in toys, deteriorated paint chips, dusts and soils, resulting in lead exposure to children at home and in playgrounds. In 2011, the United Nations Environment Programme (UNEP) and World Health Organization (WHO) formed the Global Alliance to Eliminate Lead Paint (GAELP), with a mission to eliminate lead in paint globally by 2020. The

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* Corresponding author.
E-mail address: houdeyi@tsinghua.edu.cn (D. Hou).

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GAELP aimed to have a minimum of 70 countries to have adopted legally binding controls on the production, import, sale, and use of lead based paints by 2015, and get all countries to have such legally binding measures by 2020 (UNEP, 2013).

Despite regulatory bans of lead-based paint for toy manufacture in many countries, lead exceedance in painted toys has been observed in China (Lin et al., 2009), the US (Greenway and Gerstenberger, 2010), Columbia (Mateus-Garcia and Ramos-Bonilla, 2014), etc. China is the largest exporter of toys in the international market (Anwar, 2014). The US Consumer Product Safety Commission issued recalls of millions of units of lead contaminated toys in 2007, most of which were manufactured in China (Meyer et al., 2008). The use of lead based paint in toys has been the target of criticism, causing damage to the reputation of Chinese manufacturers (Beamish and Bapuji, 2008). On the other hand, the Chinese government has introduced increasingly stringent regulatory thresholds for paint used in toy manufacture (GAQSIQ, 2003, 2009; 2014a; b). The latest regulatory standard became effective on January 1, 2016. However, to our knowledge, although several other countries conducted studies on lead concentrations in toys' paint recently (Table S1), China has not examined this since 2009. Toys sold on China's market generally have higher lead concentrations than those sold in other countries (Table S1). Therefore, it is important to address this problem and find potential solutions.

Another aspect of concern is the emergence of online selling of children's toys. In recent years, consumers are rapidly shifting to online shopping. High Street sellers like Toys”R”Us are forced to bankruptcy (Rizzo and Kapner, 2017), with the closure of many retail stores (Thompson, 2018). Online shoppers usually rely upon user-generated ratings to assess product approval (Flanagin et al., 2014); however, user-generated knowledge tends to be related to physical attributes, and it is unlikely to include information regarding risks associated with lead based paint. Product quality in online shopping has become a serious concern, especially with the fast-growing e-commerce market in China (Li et al., 2015).

In the present study, we assessed a variety of toy products purchased from different online shopping platforms. The objectives of this study included: 1) to determine the lead levels in lead-based paint in toys assess whether lead-based paint is an issue for toys sold on Chinese online shopping platforms; 2) compare the exceedance of regulatory thresholds, among products purchased from platforms of organized versus unorganized sellers; and 3) explore the various influencing factors which may relate to the lead contents in toys.

2. Methods

2.1. Selection of online shopping platforms

The three largest online shopping platforms in China were selected for the present study: JD, Taobao (TB), and Tmall (TM). Among these three platforms, JD (https://www.jd.com/) and TM (https://www.tmall.com/) are considered organized sellers and are analogous of the US counterpart Amazon, while TB (https://www.taobao.com/) hosts third party small businesses and individual entrepreneurs (i.e. unorganized sellers) on their platform, and is often considered China's counterpart of eBay. JD had net revenues of ￥362 billion RMB (US$55.7 billion) in 2017, a 40.3% increase from 2016 (JD, 2018). The revenues of TB and TM (both owned by Alibaba Group Holding Ltd) reached ￥3 trillion RMB (US$462 billion) in 2016 (Lee, 2016). Given the large volumes of consumer products being sold on these platforms, the quality of these products undoubtedly raises a concern. In the context of the present study, we intend to examine and compare the occurrence of lead-based paint on children's toys. We hypothesized that lead based paint is less often found in products sold by organized sellers JD and TM in comparison with products sold by unorganized sellers on TB.

2.2. Sample selection and processing

A total of 100 toys were randomly selected and purchased from JD ($n = 24$), TM ($n = 43$) and TB ($n = 33$). The following criteria were used in selecting toys for purchase: 1) the toys should cover a wide range of colors, to include more than 10 yellow, red, and black toys each (note: previous studies have indicated that these colors tend to have higher lead content than lighter colors); 2) the toys should cover a wide range of costs and sales volumes; and 3) the selected toys should be intended for various age groups.

It should be noted that there are myriad of toy products sold on these online platforms. The sample size of the present study ($n = 100$) is only a tiny fraction of their huge inventory, and by no means would our samples provide a representative picture of the overall quality of products sold on these platforms. Nevertheless, because of the targeted sampling regime used, we believe our study results may provide meaningful insights.

Upon delivery, the toys were unwrapped, and the paints were manually scrapped into a receptacle using stainless steel knives. A sufficient quantity of paint (>0.4 g) was collected to meet the analysis need as described in Section 2.3.

2.3. Chemical analyses

The paint scrapings were crushed and passed through a 0.5 mm mesh. The soluble lead content was determined by the method specified in GB 6675.4–2014 Safety of toys - Part 4: Migration of certain elements. The procedure involved heating HCl (0.07 mol/L) to $37 \pm 2\,^{\circ}C$, to which the paint sample (0.2 g) was added (50:1 m:m). The mixture was magnetically stirred at 600 rpm for 1 min to reach a pH of 1.0–1.5; if the pH remained >1.5, stirring was continued and HCl (2 mol/L) was added dropwise until pH 1.0–1.5 was reached. The acidified mixture was then stirred in darkness at $37 \pm 2\,^{\circ}C$ for 1 h. The mixture was allowed to settle for 1 h, centrifuged at 5000 rpm, and then passed through a 0.22 μm filter. The lead concentration in solution was quantified using Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) (Thermo Fisher XSERIES 2), and the soluble lead concentration was calculated.

There is a total lead regulatory standard for paints used in toy manufacturing in China. Therefore, we measured the total lead content by using the method specified in GB 24613-2009 Limit of harmful substances of coatings for toys. The procedure involved: paint scrapings (0.2 g) were crushed and then placed in a polytetrafluoroethylene tube; 5 mL of 65% (m/m) HNO_3 and 2 mL of 30% (m/m) H_2O_2 were added for microwave digestion; the tubes were heated to 180 °C and held for 30 min, and then cooled down to room temperature. After digestion, the solution was diluted to 50 mL and passed through a 0.22 μm filter. The lead concentration of the filtrate was measured by ICP-MS, and the total lead concentration in paint was calculated based on mass balance.

2.4. Quality control and statistical analyses

The effects of the matrix on the chemical analysis were investigated. Specifically, for the total lead concentrations in the paints, acid digestion without paint was performed as blank, and its influence was calculated as 0.45 mg/kg. Similarly, the influence of the matrix on soluble lead concentrations in the paints was tested as 0.52 mg/kg. All the presented data are subtracted by the concentrations of the matrix (blank).

The limit of detection (LOD) of the ICP-MS for Pb is calculated as 0.07 μg/L by testing 10 blank samples. When testing, each