A pediatric health risk assessment of children's toys imported from China into Nigeria

Zelinjo Nkeiruka Igweze a, Osazuwa Clinton Ekhatob, Orish E. Orisakwe c,d,*

a Department of Pharmacology & Toxicology, Faculty of Pharmacy, Madonna University Elele, Rivers State, Nigeria
b Department of Science Laboratory Technology, Faculty of Life Sciences, University of Benin, Nigeria
c Department of Experimental Pharmacology & Toxicology, Faculty of Pharmacy, University of Port-Harcourt, Rivers State, Nigeria
d World Bank Africa Centre of Excellence in Public Health and Toxicological Research (PUTOR), University of Port Harcourt, PMB, 5323 Port Harcourt, Rivers State, Nigeria

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ABSTRACT

Trade liberalization led to the flooding of the Nigerian markets with “made in China” children's toys. Information about metal contamination in toys is vital to ensure the safety of children's product. This is a pediatric health risk assessment of three toxic metals (Pb, Cd and As) in children toys purchased from Nigerian market. Thirty cheap “made in China” toys were purchased from stores in Port Harcourt, Nigeria. Three toxic metals (Pb, Cd and As) in the thirty toys samples were determined by absorption spectrophotometry. Pb, Cd and As were present in all the toys at levels below the limits set by EU. The oral and dermal exposure risk assessment showed no significant non-carcinogenic and carcinogen health risks of public health concern. Some “made in China” toys imported into Nigeria may not add to the body burden of these metals in children.

1. Introduction

Trace metals have been detected in toys and baby products (Levin et al., 2008). Lead and cadmium are used as stabilizers in certain plastics, paint color enhancers, or anti-corrosion agents in children's toys (Kumar and Pastore, 2007; Greenway and Gerstenberger, 2010; Al-Qutob et al., 2013). The restrictions on the lead has justified substitution with cadmium since it also prevents formation of hydrochloric which can degrade the polymer (Kumar and Pastore, 2007) but the justification for the use of arsenic in toys remain unclear although some suggest it may be due to certain color dyes. Metals may be released from toys through saliva during mouthing, sweat during dermal contact, or gastric fluids after partial ingestion (i.e., scraped coatings, fibers or textile, or broken sections) (Guney and Zagury, 2012).

Mouthing in children is one important behavior that has been identified to expose them to environment chemicals. Babies and young children frequently mouth objects, including toys, resulting in saliva mobilization and oral exposure to toxic chemicals (Moya et al., 2004). Children and particularly infants are more vulnerable to heavy metal toxicity with compromised renal function, bone deformities, neurological disorders, gastrointestinal complications, cancer etc associated with exposure to these metals (Jarup, 2003; Habeler, 2008; MFMER, 2011). A “risk triangle” with metal-tainted children's toys, accessibility of the toys to children, and their vulnerability to exposure has been identified (IFCS, 2006).

Young children and the developing fetus are especially vulnerable to the neurotoxic effects of Pb, and subtle effects on intelligence and attention occur even at very low exposure levels (Attina and Trasande, 2013). Fatal acute poisoning in a child was reported following ingestion of a charm with very high lead content (Levin et al., 2008). Even with the regulation of Pb and Cd contamination in children's products, recent research still showed ongoing contamination in toys (Guney and Zagury, 2013; Hillyer et al., 2014).

Inorganic As is a carcinogen implicated in several cancers of the skin, lungs, liver, and bladder. Lower level of exposure can cause nausea and vomit, decreased production of red and white blood cells, abnormal heart rhythm, and damage to blood vessels. Chronic exposure to As can cause skin darkening and the appearance of small warts on the palms, soles, and torso (Ismael et al., 2017).

The information about metal contamination in toys is vital to ensure the safety of children's product. Trade liberalization in Nigeria led to the flooding of the markets with all and sundry items including cheap children's toys from China. There have been earlier reports of high lead and cadmium levels in children's toys from China. There have been earlier reports of high lead and cadmium levels in children's toys from China.
Table 1. Description of the variables in Health Risk Assessment.

| Parameters | Description | Value | Unit | Source |
|------------|-------------|-------|------|--------|
| THQ | Target Hazard Quotient | - | - | - |
| TTHQ | Total Target Hazard Quotient | - | - | - |
| ADI | Average Daily Intake | - | - | - |
| CS | Concentration of Metal | - | mg/kg | From this study |
| ING | Ingestion Rate (Child) | 0.0002 | kg/day | |
| EDnc | Exposure Duration for Non-Carcinogenic | 6 | years | RAIS 2013 |
| EDc | Exposure Duration for Carcinogenic | 70 | years | USEPA (2007) |
| EF | Exposure Frequency | 365 | Days/years | USEPA (2007) |
| ATnc | Average Time of Exposure for Non-Carcinogenic Element | EDnc × 365 = 2190 | days | RAIS 2013 |
| ATc | Average Time of Exposure for Carcinogenic Element | EDc × 365 = 25550 | days | RAIS 2013 |
| BW | Body Weight | 15 | kg | RAIS 2013 |
| SA | Surface Area | 2100 | cm² | |
| ABS | Absorption Factor | 0.001-0.03 | mg/cm² | USEPA (2004) |
| CF | Conversion Factor | 1 × 10⁻⁶ | kg/mg | USEPA (2004) |
| AP | Adherence Factor | 0.2 | mg/m² | - |
| RFD | Reference Dose | - | mg/kg-day | RAIS 2013 |
| CSF | Cancer Slope Factor | - | mg/kg-day | RAIS 2013 |

(Omolayo et al., 2010; Oyeyiola et al., 2017). There were recalls of low-cost toys and jewelries by US. Consumer Protection Safety Commission (USCPSC) in 2007 and strict regulation for Pb in children products. This is pediatric health risk assessment of the levels of Pb, Cd and As in some “made in China” children’s toys sold in Nigeria.

2. Materials and method

2.1. Sample collection

Using a market-basket method, thirty ‘made in China’ low cost toys were purchased from supermarket and street vendors in Port Harcourt, Nigeria from January–February 2018. The plastic toys included teethers, balloon, toy cars/planes, and rattles. The brittle/pliable toys consisted of playdough, crayon, and watercolor pen. The paint coating was scrapped from plastic toy car and building blocks.

2.2. Heavy metal assay

Toy’s surface paint was removed by scraping with clean razor blades. In all sample mass ranged from 15–25mg. To avoid cross-contamination of samples, fresh razor blades were used for scraping of each toy new gloves and underlying paper on the lab bench to prevent contamination.

Samples were placed in test tubes and 5 mL trace metal grade nitric acid was added, along with two small boiling chips. After initial heating at 90–100 °C until fuming stopped, samples were placed in an oil bath or heating block for vigorous digestion at more than 120 °C for 3 h (Weidenhammer, 2009). Samples were cooled and diluted to 25 mL in volumetric flasks, rinsing 4 times with 4 mL portions of water, transferring as much residue as possible. After dilution to volume, samples settled at least 0.5 h before analysis. If needed, samples were diluted further with 5% trace metal grade nitric acid. The concentrations of Pb, Cd and As in toy samples were analyzed in triplicates using an Atomic Absorption Spectrophotometer (Perkin Elmer AAS-700).

2.3. Quality control

The range of the calibration curve was used to calculate the range of application. Samples were also diluted and reanalysed when necessary to fit within the range of the calibration curve. The accuracy of the method was determined by analysis of a soil Certified Reference Material (CRM) (TraceCERT® 16595 for Pb, 51994 for Cd and 39436 for As). The results of this CRM analysis are required to be within the 95% confidence interval of the corresponding certified values. Furthermore, the relative standard deviation (RSD) was measured in triplicate analyses of the CRM under repeatability conditions. The CRM was also used as quality control sample in each series of measurements. The RSD between replicate analyses was less than 4%.

2.4. Human health risk assessment

Human Health Risk Assessment was undertaken using methodologies proposed by the United States environmental protection (U.S. EPA, 1991). This USEPA model as described in the Risk Assessment Information System (RAIS), 2007 (http://rais.orl.gov/), supported by the Toxicological profiles developed by the USEPA Integrated Risk Information System (IRIS) (http://cfpub.epa.gov/ncea/iris/index.cfm) and by the US Agency for Toxic Substances and Disease Registry – Toxicological profiles (ATSDR) (http://www.atsdr.cdc.gov/toxfaq.html) were all employed in the pediatric health risk assessment Table 1.

2.5. Oral exposure to heavy metal in toys

\[ \text{ADI}_{\text{ing}} = \frac{C \times IR \times EF \times ED \times CF}{BW \times AT} \]  

2.6. Dermal exposure to heavy metal in toys

\[ \text{ADI}_{\text{dermal}} = \frac{C \times SA \times SL \times ABS \times EF \times ED \times CF}{BW \times AT} \]  

2.7. Non-carcinogenic risk assessment

Non-carcinogenic hazards are characterized by a term called hazard quotient (HQ). HQ is a unitless number that is expressed as the probability of an individual suffering an adverse effect. It is defined as the quotient of ADI or dose divided by the toxicity threshold value, which is referred to as the chronic reference dose (RfD) in mg/kg/day of a specific heavy metal as shown in Eq. (3) (U.S. EPA, 2004).

\[ \text{THQ} = \frac{\text{ADI}}{\text{RfD}} \] (3)

The non-carcinogenic effect to the population is as a result of the summation of all the THQs due to individual heavy metals or Hazard
Index (HI) as described by USEPA document (U.S. EPA, 2004). Eq. (4) shows the mathematical representation of this parameter:

$$HI = \sum_{k=1}^{n} HQI$$

(4)

2.8. Carcinogenic risk assessment

The lifetime cancer risk was calculated using:

$$Riskpathway = \sum_{k=1}^{n} ADIkCSFk$$

(5)

Where Risk is a unitless probability of an individual developing cancer over a lifetime. ADIk (mg/kg/day) and CSFk (mg/kg/day) are the average daily intake and the cancer slope factor, respectively for the k heavy metal, for n number of heavy metals. The slope factor converts the estimated daily intake of the heavy metal averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer (U.S. EPA, 2004).

The total excess lifetime cancer risk for an individual is finally calculated from the average contribution of the individual heavy metals for all the pathways using the following equation:

$$Risk(\text{total}) = Risk(\text{ing}) + Risk(\text{dermal})$$

(6)

where Risk (ing) and Risk (dermal) are risks contributions through ingestion and dermal pathways. Both non-carcinogenic and carcinogenic risk assessment of heavy metals are calculated using RfD and CSF values derived are shown in Table 2.

3. Results

Metal levels in the toys sample are shown in Table 3. All the 30 toy samples analyzed were found to contain Pb (4.16–9.747), Cd (1.942–6.50) and As (1.459–6.318 mg/kg). The highest Pb, Cd and As levels are shown in Table 3.
levels were found in samples A11 (Donkey - 9.747 mg/kg), A13 (Ball - 6.10 mg/kg) and A19 (Toy rabbit - 6.318 mg/kg) respectively. Whereas the lowest levels of Pb, Cd and As were detected in A12 (Teddy bear - 4.16 mg/kg), A10 (Bird - 1.942 mg/kg) and A13 (Fishepine rattle - 1.459 mg/kg) respectively.

The oral and dermal Chronic Daily Intake CDI target hazard Quotient (THQ) and total target hazard Quotient (TTHQ) of Pb, Cd and As are shown in Table 4. The THQ and TTHQ of Pb, Cd and As were less than 1 which indicates no significant health risk from heavy metal exposure in toys.

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Table 5 show the oral and dermal cancer risk, total cancer risk (TCR) and hazard Index (HI). The HI of Pb, Cd and As from via oral and dermal routes ranged from 0.126-0.409 indicating es no significant health risk from heavy metal exposure in toys.

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4. Discussion

Children's toys may be source of heavy metals. Lead exposure has been implicated in the impairment of cognitive development in children (Jusko et al., 2008; Kaufman et al., 2014) whereas exposure to cadmium and arsenic may give rise to neurodevelopment problems and behavioral disorders in children (Rodríguez-Barranco et al., 2013). These metals are used in stabilizing and recycling of the plastics in addition to being applied in the attractive paint colours of the toys (Guney and Zagury, 2012; Rastogi and Pritzl, 1996). Mouthing of non-food item which peaks at 6-12-month age (39-66 min/day) is a common behavior of children plays the unwanted role of children exposure to these metals (Guney and Zagury, 2014; Smith and Norris, 2003).

Another study by Oyeyeola et al. (2017) also in Nigeria detected high levels of Pb and Cd in a range of 36.1–106 mg/kg and 3.55–40.7 mg/kg respectively.

According to US CPSC, 0.06% Pb by weight, or 600 ppm was chosen as the permissible limit of Pb in paint on items intended for children (United states Consumer Product Safety Commission, 2019) but was further reduced to 0.009% (Library of Congress, 2008).

The Pb, Cd and As levels in all the toys in this study were below the limit set by the European Union migration units for toy safety which includes Pb (90 mg/kg), Cd (23 mg/kg) and As (47 mg/kg) (European Council, 2009). There were higher Pb levels than Cd and As probably due to the preference for Pb because of its better stabilizing property than the other metals preventing free chlorine radicals in polyvinyl chloride PVC from reacting with hydrogen radicals to form hydrochloric acid (Tuczai and Cortolano, 1992). Although some manufactures have substituted Pb for Cd in stabilizing PVC in children products because of reported Pb toxicity, the substitution of Pb with Cd in children's toys may also pose a health threat.

Pb, Cd and As levels in this study were lower than previously reported data by other researchers in Nigeria and other countries. Studies by Omolayole et al. in 2010 from Nigeria reported higher lead level Pb and Cd in the range of 2.50–1445.00 mg/kg and 0.50–373.3 mg/kg respectively. Another study by Oyeyeola et al. (2017) also in Nigeria detected high levels of Pb and Cd in a range of 36.1–106 mg/kg and 3.55–40.7 mg/kg.
respectively. Elsewhere other studies have reported higher levels of Pb, Cd and As than values detected in our study Hillyer et al. (2014); Mateus-Garcia and Ramos-Bonilla (2014); Cui et al., (2015), Ismail et al., (2017) and Negev et al., (2018).

The metal levels in our study coupled with reports from studies done by Oyeyeola et al., (2017) (Pb-36.1-106 mg/kg) and Ismail et al., 2017(Pb- 1.50-171.67 mg/kg) show there is a decrease in the levels of these metals in children toys when compared with studies before and immediately after the recalls of low-cost toy and jewelry in 2007 by US CPSC in 2007 and strict regulation for Pb in children products. In 2007 alone nearly 6 million toys were recalled in the US (Schmidt, 2008). In 2010, 12 million Mcdonald’s cups were recalled due to Cadmium content in the painted coating (CPSC, 2010). Also, in 2010 bracelet were voluntarily recalled due to high levels of Cd.

The THQ, TTHQ, and HI of Pb, Cd and As in the children toys, via oral and dermal exposures were below the threshold of 1. The carcinogenic health risks of these metals were within the acceptable limit $1/C_2 1/C_0 4/C_0 1/C_2 1/C_0 6$. Although Pb, Cd and As determined in this study did not show any significant health risk but bioaccumulation after chronic exposure may pose health risk in children especially for Pb which has no safe levels in blood.

5. Conclusion

There were low levels of Pb, Cd and As in some “made in China” toys lately imported into Nigeria.

| Sample | Oral Cancer Risk | Dermal Cancer Risk | Total Cancer Risk | Hazard index |
|--------|------------------|-------------------|------------------|-------------|
|        | Pb               | Cd                | As               |             |
| A1     | 7E-07            | 2.1E-05           | 4.2E-05          | 2.6E-06     | 6.6E-05     | 0.188 |
| A2     | 7.8E-07          | 2E-05             | 7E-05            | 4.4E-06     | 9.6E-05     | 0.262 |
| A3     | 6.1E-07          | 3.2E-05           | 6.8E-05          | 4.3E-06     | 0.0001      | 0.281 |
| A4     | 5.6E-07          | 2.1E-05           | 4.9E-05          | 3.1E-06     | 7.4E-05     | 0.202 |
| A5     | 7E-07            | 1.7E-05           | 3.3E-05          | 2.1E-06     | 5.2E-05     | 0.155 |
| A6     | 5E-07            | 1.1E-05           | 8.2E-05          | 5.1E-06     | 9.8E-05     | 0.256 |
| A7     | 8.5E-07          | 2.5E-05           | 5.3E-05          | 3.6E-06     | 8.3E-05     | 0.234 |
| A8     | 7.1E-07          | 2.1E-05           | 4.8E-05          | 3E-06       | 7.3E-05     | 0.205 |
| A9     | 5.9E-07          | 9.5E-06           | 6.2E-05          | 3.9E-06     | 7.5E-05     | 0.203 |
| A10    | 5.1E-07          | 1.6E-05           | 8.4E-05          | 5.3E-06     | 0.00011     | 0.276 |
| A11    | 1.1E-06          | 3E-05             | 6.1E-05          | 3.8E-06     | 9.6E-05     | 0.276 |
| A12    | 4.5E-07          | 1.2E-05           | 3E-05            | 1.9E-06     | 4.5E-05     | 0.126 |
| A13    | 9.3E-07          | 1.1E-05           | 8.9E-05          | 5.6E-06     | 0.00011     | 0.289 |
| A14    | 7.9E-07          | 2.6E-05           | 8.3E-05          | 5.2E-06     | 0.00011     | 0.309 |
| A15    | 9.5E-07          | 1.9E-05           | 9.8E-05          | 6.2E-06     | 0.00012     | 0.335 |
| A16    | 1E-06            | 2.6E-05           | 8.4E-05          | 5.3E-06     | 0.00012     | 0.32 |
| A17    | 8.9E-07          | 3.1E-05           | 7.3E-05          | 4.6E-06     | 0.00011     | 0.302 |
| A18    | 8.3E-07          | 2E-05             | 5.1E-05          | 3.2E-06     | 7.5E-05     | 0.213 |
| A19    | 8.9E-07          | 2.5E-05           | 0.00012          | 7.6E-06     | 0.00015     | 0.409 |
| A20    | 9.1E-07          | 2.3E-05           | 8.2E-05          | 5.2E-06     | 0.00011     | 0.304 |
| A21    | 7E-07            | 1.7E-05           | 2.8E-05          | 1.8E-06     | 4.8E-05     | 0.143 |
| A22    | 6.8E-07          | 1.1E-05           | 9.8E-05          | 6.2E-06     | 0.00012     | 0.303 |
| A23    | 8.5E-07          | 1.8E-05           | 4.3E-05          | 2.7E-06     | 6.5E-05     | 0.189 |
| A24    | 6.8E-07          | 1.4E-05           | 7E-05            | 4.4E-06     | 8.9E-05     | 0.24 |
| A25    | 8.9E-07          | 2.3E-05           | 0.0001           | 6.6E-06     | 0.00014     | 0.361 |
| A26    | 6.2E-07          | 2.6E-05           | 6.1E-05          | 3.9E-06     | 9.1E-05     | 0.247 |
| A27    | 7.9E-07          | 1.8E-05           | 2.9E-05          | 1.8E-06     | 5E-05       | 0.15 |
| A28    | 6.7E-07          | 1.7E-05           | 8.4E-05          | 5.3E-06     | 0.00011     | 0.286 |
| A29    | 5E-07            | 2.2E-05           | 4.2E-05          | 2.6E-06     | 6.7E-05     | 0.185 |
| A30    | 5.8E-07          | 2.6E-05           | 5.7E-05          | 3.6E-06     | 8.7E-05     | 0.236 |

**Declarations**

**Author contribution statement**

O. Orisakwe: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper

Z. Igweze: Performed the experiments; Contributed reagents, materials, analysis tools or data.

O. Ekhator: Analyzed and interpreted the data; Wrote the paper.

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The authors declare no conflict of interest.

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**References**

Al-Qutob, M., Asafra, A., Nashashibi, T., Qutob, A.A., 2014. Determination of different trace heavy metals in children’s plastic toys imported to the West Bank/Palestine by ICP/MS - environmental and health aspects. J. Environ. Protect. 5 (2), 1104.
Attina, T.M., Trasande, L., 2013. Economic costs of childhood lead exposure in low and middle-income countries. J. Environ. Health Perspect. 121 (9), 1097–1102.

PSC U.S. Consumer Product Safety Commission, 2010. Claire’s recalls children’s metal charm bracelets due to high levels of cadmium (cited 10 May 2010) Available from: https://www.cpsc.gov/Recalls/2010/claires-recalls-childrens-metalcharm-bracelets-due-to-high-levels-of-cadmium [Accessed 16 April 2019].

Cui, X., Li, S., Zhang, S., Fan, Y., Ma, L., 2015. Toxic metals in chil-dren’s toys and jewellery: coupling bio accessibility with risk assessment. J. Environ. Pollut. 200, 77–84.

European Council, 2009. Directive of the European Parliament and of the Council of June 18, 2009 on the Safety of Toys. Brussels. Belgium.

Greenway, J., Gerstenberger, S., 2010. An evaluation of lead contamination in plastic toys collected from day care centers in the Las Vegas Valley, Nevada. Bull. Environ. Contam. Toxicol. 85, 363–366.

Guney, M., Zagury, G.J., 2012. Heavy metals in toys and low-cost jewelry: critical review of U.S. and Canadian legislations and recommendations for testing. J. Environ. Sci. Technol. 46, 4265–4274.

Guney, M., Zagury, G.J., 2013. Contamination by ten harmful elements in toys and children’s jewelry bought on the North American market. Environ. Sci. Technol. 47 (11), 5921–5930.

Guney, M., Zagury, G.J., 2014. Children’s exposure to harmful elements in toys and low-cost jewelry: characterizing risks and developing a comprehensive approach. J. Hazard Mater. 271, 321–330.

Habler, J., 2008. States Take the Lead for Safer Toys. The american nurse, p. 13.

Hillyer, M., Finch, I., Cerel, A., Dattelb, J., 2014.

Habeler, J., 2008. States Take the Lead for Safer Toys. The american nurse, p. 13.

Hillyer, M., Finch, I., Cerel, A., Dattelb, J., 2014. ‘Multi-technique quantitative analysis and socioeconomic considerations of lead, cadmium and arsenic in children’s toys and toy jewelry’. Chemosphere 108, 205–213.

Intergovernmental Forum on Chemical Safety (IFCS), 2006. Toys and chemical safety, A thought starter forum Hungary. Available from: http://www.oicf.org/en/conferences/IFCS/2006/events/documents

Ismail, S.N.S., Mohamad, N.S., Karuppiath, K., Abidin, E., Rasdi Paeena, S.M., 2017. Heavy metals content in low priced toys. J. Eng. Appl. Sci. 12, 5.

Jarup, L., 2003. Hazards of heavy metal contamination. Bull. Br. Med. 68, 167–182.

Juszko, T.A., Henderson, C.R., Lanphear, B.P., Cory-Slechta, D.A., Parsons, P.J., Canfield, R.L., 2008. Blood lead concentrations <10 mu g/dL and child intelligence at 6 years of age. J. Environ. Health Perspect. 116, 243–248.

Kaufman, A.S., Zhou, X.B., Reynolds, M.R., Kaufman, N.L., Green, G.P., Weiss, L.G., 2014. The possible societal impact of the decrease in US blood lead levels on adult IQ. J. Environ. Res. 132, 413–420.

Kumar, A., Pastore, P., 2007. Lead and cadmium in soft plastic toys. Curr. Sci. 93 (6), 818–822.

Levin, R., Brown, M.J., Kashstock, M.E., Jacobs, D.E., Whelan, E.A., Rodman, J., Schock, M.R., Padilla, A., Sinks, T., 2008. Lead exposures in US children: implications for prevention. J. Environ. Health Perspect. 116 (10), 1285.

Library of Congress, 2008. Consumer product safety modernization act. Available from: http://thomas.loc.gov/cgi-bin/query/z?c110:H.R.4040 (August 2008).

Matesu-Garcia, Ramos-Bonilla, J., 2014. Presence of lead in paint toys sold in stores of the formal market of Bogota, Colombia. J. Environ. Res. 128, 92–97.

Mayo Foundation for Medical Education and Research (MFMER), 2011. Lead poisoning. Available from.

Moya, J., Bearer, C.F., Etzel, R.A., 2004. Children’s behavior and physiology and how it affects exposure to environmental contaminants. Pediatrics 113 (3), 996–1006.

Negev, M., Berman, T., Reichers, S., Sadeh, M., Arli, R., Shammai, Y., 2018. Concentration of trace elements, phthalates, bisphenol A and flame retardants in toys and other children’s product in Israel. Chemospex 192, 217–224.

Omolowo, J.A., Uzairu, A., Gimba, C.E., 2010. Heavy metal assessment of some soft plastic toys imported into Nigeria from China. J. Environ. Chem. Ecotoxicol. 2 (8), 126–130.

Oyeyiola, A.O., Akinyemi, M.I., Chinedu, I.E., Fatunsen, O.T., Olayinka, K.O., 2017. ‘Statistical analyses and risk assessment of potentially toxic metals (PTMs) in children’s toys’. J. Taibah Univ. Sci. 11, 842–849.

The Risk Assessment Information System (RAIS). Available from: http://rais.orl.gov/tox/rap/toxsp.html [Accessed on 15 April 2019].

Rastogi, S.C., Pritzl, G., 1996. Migration of some toxic metals from crayons and water colors. Bull. Environ. Contam. Toxicol. 56, 527–533.

Rodriguez-Barranco, M., Lacanana, M., Aguilar-Garduno, C., Alguacil, J., Gil, F., González-Alzaga, B., 2013. Association of arsenic, cadmium and manganese exposure with neurodevelopment and behavioural disorders in children: a systematic review and meta-analysis. J. Sci. Teach. Educ. 454–455, 562–577.

Schmidt, C., 2008. Fact to face with toy safety: understanding an unexpected threat. J. Environ. Health Perspect. 116, A70–A76.

Smith, S.A., Norris, B., 2003. Reducing the risk of choking hazards: moulding behaviour of children aged 1 Month to 5 Years. Inj. Contr. Saf. Promot. 10, 145–154.

Tuccii, E., Cortolano, F., 1992. Reformulating PVC to eliminate heavy metals and protect performance. J. Modern Trends Plast. Surg. 123–124.

United States Consumer Product Safety Commission, 2007. Ban of lead-containing paint and certain consumer products bearing lead-containing paint. available from: (accessed August 2007) [2011]. http://www.cpsc.gov/BUSINFO/regsumlead paint.pdf, http://www.mayoclinic.com/health/lead-poisoning/FL00068. U.S. EPA, 1991. Integrated Risk Information System; Antimony (CASRN 7440-36-0). Washington DC.

U.S. EPA, 2004. Toxicological Review of Boron and Compounds (CAS No.), pp. 7440–7442, Washington DC.

US EPA (United States Environmental Protection Agency), 2004. Toxicological Review of Boron and Compounds (CAS No.), pp. 7440–7442, Washington DC.

US EPA (United States Environmental Protection Agency), 2007. Risk Assessment for Non-cancer Effects, Walkes, M.F., Rehm, S., 1994. Cadmium and prostate cancer. J. Toxicol. Environ. Health. 43, 251–269.

Weidenhamer, J.D., 2009. Lead contamination of inexpensive seasonal and holiday products. Sci. Total Environ. 407 (7), 2447–2450.