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Heavy metals in children's toys and baby items commonly sold in Trinidad and Tobago

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Children's toys and baby items are a unique source of exposure to heavy metals in young children. It is a global health concern because of the potential risk heavy metals pose during the early years of childhood development. This study assessed the levels of six heavy metals (lead (Pb), manganese (Mn), nickel (Ni), chromium (Cr), cadmium (Cd) and copper (Cu)) in eleven toys and seven baby items currently sold in Trinidad and Tobago. Samples were analysed using Flame Atomic Absorption Spectrophotometry (FAAS). The concentrations of Pb, Mn, Ni, Cr, Cd and Cu ranged from 2.63 to 34.45 mg/kg, 0.03 to 4.22 mg/kg, 2.28 to 16.95 mg/kg, 0.95 to 14.10 mg/kg, 0.002 to 4.14 mg/kg and 0.03 to 2.15 mg/kg, respectively. Two samples exceed the regulatory limit for lead and one exceeded the regulatory limit for cadmium set by the EU. The ingestion risk (ADD) for lead, nickel and chromium in toys and baby items ranged between 3×10^{-5} and 1.0×10^{-4}, 3.1×10^{-5} and 2.3×10^{-4} and 1.0×10^{-5} and 2.0×10^{-4} respectively. The HQ values for lead, nickel and chromium in toys and baby items ranged between 0.0070-0.1150, 0.0015-0.0113, and 0.0036-0.0627, respectively, while the hazard index (HI) ranged between 0.0156 and 0.1447. The results suggest that these toys and baby items generally posed a low risk to children.

Key words: Children toys, Trinidad and Tobago, health risk.

INTRODUCTION

Plastics toys contain a variety of additives such as plasticizers, antioxidants, stabilizers, curing and colouring agents. Stabilizers impart characteristics such as softness, stability, brightness and flexibility to toys. However, these may contain heavy metals such as lead, cadmium, chromium and zinc, which may be released as dust on the surface of toys that can be easily transferred to children through hand-to-mouth action. Lead and cadmium are also added to Polyvinyl chloride (PVC) or other plastic products as colouring agents in the paints

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used. The presence of heavy metals in toys can pose a significant risk to young children due to long-term toxicological effects as these can migrate from the toys if they are chewed or sucked.

Toys are an important part of early childhood development and each age group interacts and handles toys in different ways. This provides different exposure pathways for heavy metals such as: direct ingestion or interactions such as licking, sucking, mouthing and hand to mouth behaviour which can result in metals leaching from the toys through saliva (Abhay and Prashant, 2007; Kelly et al., 1993). Once ingested the metals can be released by gastric and intestinal fluids and then absorbed by the digestive system. The digestive system of children can absorb up to 50% of the lead they ingest (NRCLPI, 2009).

The potential risk of heavy metal contamination in toys resulted in the United States of America recalling an estimated 20 million Chinese-made toys in 2007 (Allen et al., 2008; CFA, 2008). Previous studies have also reported heavy metal contamination in various toy around the world. Weidenhamer and Clement (2007) reported that 43% of metallic jewellery from the USA was contaminated with Pb, averaging 440 mg kg^{-1}. Guney and Zagury (2013) also reported that the concentrations of Ni, Cd, Pb, As and Sb were 140, 367 and 653, 0.43 and 1.02 mg kg^{-1} respectively in children's jewellery bought in north America. Cui et al. (2015) reported that the total concentration of As, Cd, Sb, Cr, Ni, and Pb were ND-24, ND-6.7, ND-239, ND-846, ND- 2.1 and ND-44 mg kg^{-1} respectively. Some of the samples exceeded the EU limit for As = 47, Sb = 560, Cd = 23 and Pb = 90 mg/kg in toys. Additional work on leachates from plastic toys in India showed that the concentrations of Pb, Cd, Ni, Zn, Cr, Co and Mn ranged from 0.219-1.12, 0.005-0.110, 0.251-1.090, 0.119-1.111, 0.219-1.040, 0.000-0.531and 0.990-1.070 (ppm) respectively (Ahmad et al., 2012). In Nigeria, the concentration of heavy metals in soft plastic toys imported from china ranged from 2.50 - 1445.00, 0.50 - 373.33, 31.17 - 119.67, 12.00 - 93.67, 266.67 - 2043.33, 5.00 - 191.67, 1.00 - 73.33 and 6.17 - 36.67 µg g^{-1}, for Pb, Cd, Ni, Cu, Zn, Cr, Co and Mn respectively (Omolaoye et al., 2010). About 17% of these toy samples were reported to have concentrations of Pb, Cd, Cr and other metals above regulatory limit. Low priced toys in Malaysia also had varied levels of heavy metals such as As (23.4 ppm), Cd (26.1 ppm), Cr (94.4 ppm), Pb (109.9 ppm) and Hg (7.1 ppm) (Ismail et al., 2017).

Exposure to heavy metals can lead to long-term risk because of their potential to bio-accumulate. Heavy metals such as lead can cause learning disabilities, kidney failure, anaemia and irreversible brain damage as well as mortality in children. Other metals such as cadmium can cause a wide variety of acute and chronic effects in the neurological system, the gastrointestinal system and respiratory system. Cadmium is a known carcinogen and has been linked to lung cancer, prostate cancer and kidney cancer (Al-Qutob et al., 2014).

In Trinidad and Tobago and the wider Caribbean there has been increased importation of cheap plastic toys for which there are no local regulations. There have been no investigations to determine whether these toys can be a potential source of heavy metal contamination in children. Therefore, analysis of such elements and preventive action is important to ensure toy safety, which is the joint responsibility among governments, manufacturers, regulatory bodies and parents.

MATERIALS AND METHODS

A total of 18 plastic children's toys and baby items for the age group less than 5 years were obtained from the Trinidad and Tobago Bureau of Standards. These included: Children's jewellery, building blocks, dolls, play sets, pacifiers, teething rings, soft plastic animals, cars and sippy cups. Soft plastic samples were cut into pieces (approximately 0.5 cm) while brittle samples were crushed into a powder. Approximately 0.5-3 g of sample were weighed into porcelain crucibles and charred on a hot plate until fuming ceased. This was followed by complete ashing in a furnace at 550-600°C for 2 h. The crucibles were cooled and 10 ml of analar grade nitric acid (70%) was added and left to pre-digest at room temperature for 24 h. Samples were digested at 130°C for 2 h, and then cooled to room temperature. This was then filtered using Whatman No. 541 and made up to 50 ml with deionized water. The mixture was then filtered using Whatman No. 541 Hardened Ashless paper and made up in 50 ml volumetric flask to the mark. Samples were then analysed for Pb, Ni, Mg, Cd, Cr, and Cu by Flame Atomic Absorption Spectrophotometry (FAAS).

Quality control

All glassware used were grade "A" quality and were washed using laboratory detergent followed by rinsing with tap water then deionized water. Glassware were soaked in a 10% (v/v) Nitric Acid bath overnight and rinsed multiple times with deionized water before being allowed to air dry. Method blanks and spiked sample recoveries were used to validate the methodology. The spiked samples were treated and processed identically to the samples as described previously. All samples were prepared in triplicate as well as a method blank and a spiked sample. The method blank was included to ensure there was no contamination of samples. The spike sample contained 1 mg/L of Cd, Cr, Ni, Pb, Cu and Mn and was used to determine a percentage recovery. The percentage recovery was calculated using the following equation:

$$Recovery\ \% = \frac{(Spiked\ Concentration\ Sample - Unspiked\ Concentration\ Sample)}{Concentration\ added}$$

The coefficient (R^2) was used to evaluate the linearity of the calibration curves.

Health risk assessment

Non-carcinogenic health risk (Ingestion exposure)

The non-carcinogenic health risk was calculated as average daily

dose of ingestion (ADD) (Ismail et al., 2017):

$$ADD = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Where ADD - the average daily dose of ingestion (mg/kg/day),
C - concentration of the heavy metal (mg/kg),
IR - the intake rate (0.0002 kg/day (Grżetic and Ghariani, 2008)
BW - the body weight of exposed individual (15 kg),
EF - the exposed frequency (365 days/years),
ED - the exposure duration (5 years),
AT - the averaging time (days) (ED years × 356 days/years = 1825)

Non-carcinogenic risks (Ingestion exposure)

The potential health risks posed by contaminated toys were assessed based on hazard quotient (HQ), which is the ratio of the ADD of a pollutant to the reference dose (RfD). The HQ was calculated for the cosmetic samples based on the following equation:

$$HQ = ADD/RfD$$

The RfD can be used as a reference point to identify the potential impacts of the chemical at different doses. Doses less than the RfD are not likely to be associated with adverse health effects, while doses more than the RfD are likely to be associated with adverse health effects (USEPA, 2015). The RfD for Pb, Ni, Cr, Cd, Cu, and Mn are 0.0004, 0.02, 0.003, 0.001, 0.04 and 0.014 mg/kg/day (Ismail et al., 2017; Patrick-Iwuanyanwu and Udowelle, 2017). HQ ≤ 1 indicates that there would be no adverse health effects whereas HQ ≥ 1 indicates possible adverse health effects. An estimation of the risk of mix heavy metal contaminates can be determined by the sum of HQs to generate a hazard index (HI) ($HI = \sum$ HQ) (Guerra et al., 2010). HI ≤ 1 specifies no adverse health effects while HI ≥ 1 specifies the possibilities of adverse health effects.

RESULTS AND DISCUSSION

Quality control

The percent recoveries from spiked recoveries for lead, cadmium, chromium, nickel, copper and manganese ranged between 102.9 and 114.4%. The calibrations curves showed acceptable linearity, with correlation coefficients (R^2) ranging between 0.9944 and 0.9999.

Concentration of heavy metals in toys and baby items

The concentration of metals in children's toys and baby items commonly sold in Trinidad are given in Table 1. Six metals were investigated, however, only three metals (Pb, Ni, Cr)) were detected in all samples while Cd, Cu and Mn were present in less than 40% of the samples (Table 1). The concentration of lead, nickel and chromium in toys ranged between 2.5-34.5, 2.3-17 and 0.9-14.1 mg/kg respectively. The concentration of these metals in the baby items ranged between 2.1-14.7, 2.6-14.3 and 0.8-12.4 mg/kg respectively. There was no significant difference (P>0.05) in the concentration of these metals found in the toys and baby items. Metals such as Pb, Ni and Cd are often used as thermal stabilizers in plastics to enhance characteristics such as softness, brightness, and flexibility. The lead levels for both the toys and baby items were higher that the EN 71-3: 2013 Category I limit of 2 mg/kg. It is likely that the levels of lead will be of concern and may pose a risk to young children over a long exposure time. The levels of lead were similar to that reported by Ismail et al. (2017) (109.8 ppm); Vo et al. (2017) (0.86-440 mg/kg); Ahmad et al. (2012) (1.12 ppm); Al-Qutol et al. (2014) (2.8-96.7 mg/kg) and Omolaoye et al. (2010) (2.5-1445 mg/kg) (Table 2). Chromium (III) and nickel levels were below the recommended limit of 37.5 and 75 mg/kg respectively and were generally lower than the levels reported by some other studies (Table 2). Cadmium, copper and manganese were only detected in only a few of the toys and baby items. The concentration of Cd, Cu and Mn for the samples ranged between BDL- 4.1, BDL-2.2 and BDL-4.2 mg/kg respectively (Table 1) which were all lower than the EN 71-3: 2013 Category I limits for these metals. Presently, there is no global coherent system for safe acceptable limit of heavy metals in toys. The current safe acceptable limits of heavy metals in toys and baby items differ among countries or organizations.

Health risk assessment

Heavy metal in children's toys and baby items is an emerging global concern because of the risks posed during the early childhood development, when they are most susceptible to the effects. Heavy metals such as lead have been linked to learning disabilities, kidney failure, anemia, impairment of cognitive development and brain damage in children exposed during early childhood. Heavy metals can migrate from toys because of the chewing, licking, sucking and swallowing behaviours of children and thus pose toxic effects in the long term (Grynkiewicz-Bylina, 2011; Kang and Zhu, 2015; Al-Qutol et al., 2014). Though the total concentration of metals in toys and baby items may be low, the potential health risk should not be overlooked since children use these toys continuously and often play with many toys at the same time, which can lead accumulation and over time metal concentrations may exceed the maximum allowable limits. The extent of heavy metal migration from toys can be assessed using common test methods such as EN 71–3:2019- Safety of toys- Migration of certain elements; ASTM F963 - 17 Standard Consumer Safety Specification for Toy Safety and ISO 8124-3:2020 Safety of - Part 3: Migration of certain elements all of which

Table 1. Concentration of heavy metals in children's toys and baby items commonly sold in Trinidad and Tobago.

Toys	Metals (mg/kg)					
	Pb	Ni	Cr	Cd	Cu	Mn
Jewellery (Yellow)	6.6±3.4	17.0±12.7	14.0±4.4	BDL	BDL	0.03±0.2
Jewellery (Blue)	4.6±1.2	4.9±0.3	1.7±0.8	BDL	1.4±1.3	BDL
Jewellery (Purple)	34.5	5.8	1.7	BDL	0.5	BDL
Jewellery (Pink)	4.6±0.2	12.6±0.1	1.3±0.8	BDL	BDL	BDL
Building Blocks (Pink)	3.4±1.6	3.0±0.2	1.0±0.2	BDL	0.3±0.7	BDL
Building Blocks (Blue)	2.5±0.6	2.5±0.3	1.8±0.9	0.1±0.3	2.2±0.1	BDL
Doctor Set	2.7±0.3	3.4±0.5	1.1±0.5	0.05±0.22	BDL	BDL
Car (yellow)	4.0	2.3	0.9	BDL	0.4	0.13
Princess doll	5.5±0.8	4.5±0.7	2.4±0.5	0.4±0.4	1.2±0.5	2.8±0.6
Pink bear	8.7±0.2	5.0±0.4	14.1±1.0	0.3±0.3	BDL	0.9±0.7
Baby Items						
Sippy cup	4.3±1.3	6.3±0.3	1.1±0.9	BDL	BDL	BDL
Pacifier (brown)	4.8±0.4	4.5±0.03	1.5±0.2	BDL	1.8±1.0	BDL
Pacifier (bright star)	10.3±1.0	8.4±0.1	3.6±0.3	0.3±0.5	BDL	BDL
Pacifier (silicone)	3.1±0.1	2.6±0.7	0.8±0.3	BDL	BDL	BDL
Rattle	2.1±0.4	4.9±0.4	0.8±0.3	BDL	BDL	4.2±0.1
Bottle nipple	2.4	4.2	3.5	BDL	BDL	0.2
Teething ring	14.7	14.3	4.5	0.06	BDL	BDL
Rubber duck	9.0±0.1	5.9±0.3	12.4±0.3	4.1±0.6	0.2±0.1	1.0±0.8

Table 2. Concentration of heavy metals in children's toys from various countries.

Study	Location	Metals (mg/kg)					
		Pb	Ni	Cr	Cd	Cu	Mn
Vo et al. (2017)	Vietnam	0.86-440.5	9.11-210.1	17.5-303,0	0.27-86.5	2.35-642.3	9.68-188.3
Ismail et al. (2017)	Malaysia	109.9	4.99	94.4	26.1	32.9	53.7
Ahmad et al. (2012)	India	1.12	1.09	1.04	0.111	-	1.07
Omolaoye et al. (2010)	Nigeria	2.5-144.5	15.3-119.7	ND-191.67	ND-373.3	14.8-93.7	6.2-36.7
Cui et al. (2015)	China	ND-6100	ND-2894	ND-3212	ND-139	-	-
Al-Qutob et al. (2014)	West Bank/Palestine	2.8-96.7	-	7.2-59	4.5-75.9	-	-

identify specific migration limits for various metals. These limits are based on the average quantities of toy components that are likely consumed by a child on a daily basis which is estimated at 8 mg per day (Kumar and Pastore, 2007).

The risk posed by heavy metals in toys was determined using the ingestion exposure (ADD) pathway and calculating the HQ and HI values for lead, nickel, chromium, cadmium, copper and manganese. If the values obtained from the HQ and HI indices are less than 1, this indicates that there is low risk to the health children. The ingestion risk (ADD) for daily ingestion of lead, nickel and chromium in toys and baby items ranged between 3.0×10^{-5} - 1.0×10^{-4}, 3.1×10^{-5} – 2.3×10^{-4} and 1.0×10^{-5} – 2.0×10^{-4} respectively (Table 3). These values were lower than the reference dose of 0.004 mg/day (lead), 0.02 mg/day (nickel) and 0.003 mg/day (Chromium) which would suggest low risk from exposure to these items.

The HQ values for lead, nickel and chromium in toys and baby items ranged between 0.007-0.115, 0.0015-0.0113 and 0.0036-0.0627 respectively (Table 3). The HQ values were below 1 indicating no non-carcinogenic adverse risk to children over the exposure period of 5 years. The HQ values for the other metals cadmium, copper and manganese were also low (Table 3). Additionally, the hazard index (HI) ranged between 0.0156-0.1447 therefore there was no non-carcinogenic

Table 3. Average Daily Dose of Ingestion (ADD) in mg/kg/day and Non-carcinogenic Risk (Hazard Quotient [HQ], Hazard Index [HI]) for heavy metals in toys and baby items.

Toys	ADD (mg/kg/day)						Non-carcinogenic [HQ]						Non-carcinogenic [HI]
	Pb	Ni	Cr	Cd	Cu	Mn	Pb	Ni	Cr	Cd	Cu	Mn	
Jewellery (Yellow)	9.0×10^{-5}	2.3×10^{-4}	2.0×10^{-4}	0	0	4.0×10^{-7}	0.022	0.011	0.062	0	0	2.9×10^{-5}	0.0956
Jewellery (Blue)	6.0×10^{-5}	6.5×10^{-5}	2.0×10^{-5}	0	1.9×10^{-5}	0	0.015	0.003	0.008	0	0.001	0	0.0266
Jewellery (Purple)	5.0×10^{-4}	7.7×10^{-5}	2.0×10^{-5}	0	6.7×10^{-6}	0	0.115	0.004	0.008	0	0.0002	0	0.1266
Jewellery (Pink)	6.0×10^{-5}	1.7×10^{-4}	2.0×10^{-5}	0	0	0	0.015	0.008	0.006	0	0	0	0.0295
Building Blocks (Pink)	5.0×10^{-5}	4.0×10^{-5}	1.0×10^{-5}	0	4.0×10^{-6}	0	0.113	0.002	0.004	0	0.0001	0	0.179
Building Blocks (Blue)	3.0×10^{-5}	3.3×10^{-5}	2.0×10^{-5}	1.3×10^{-6}	2.9×10^{-5}	0	0.008	0.002	0.008	0.001	0.0007	0	0.0201
Doctor Set	4.0×10^{-5}	4.5×10^{-5}	1.0×10^{-5}	6.7×10^{-7}	0	0	0.009	0.002	0.005	0.001	0	0	0.0168
Car (yellow)	5.0×10^{-5}	3.1×10^{-5}	1.0×10^{-5}	0	5.3×10^{-6}	1.7×10^{-6}	0.013	0.002	0.004	0	0.0001	1.2×10^{-2}	0.0191
Princess doll	7.0×10^{-5}	6.0×10^{-5}	3.0×10^{-5}	5.3×10^{-6}	1.6×10^{-5}	3.7×10^{-5}	0.018	0.003	0.011	0.005	0.0004	0.0027	0.0404
Pink bear	1.0×10^{-4}	6.7×10^{-5}	2.0×10^{-4}	4.0×10^{-6}	0	1.2×10^{-5}	0.029	0.003	0.063	0.004	0	0.0009	0.0999
Baby Items	**ADD (mg/kg/day)**						**Non-carcinogenic [HQ]**						**Non-carcinogenic [HI]**
	Pb	Ni	Cr	Cd	Cu	Mn	Pb	Ni	Cr	Cd	Cu	Mn	
Rubber duck	1.0×10^{-4}	7.9×10^{-5}	2.0×10^{-4}	5.5×10^{-5}	2.7×10^{-6}	1.3×10^{-5}	0.03	0.004	0.055	0.055	7.0×10^{-5}	0.901	0.1447
Sippy cup	6.0×10^{-5}	8.4×10^{-5}	1.0×10^{-5}	0	0	0	0.014	0.004	0.005	0	0	0	0.0234
Pacifier (brown)	6.0×10^{-5}	6.0×10^{-5}	2.0×10^{-5}	0	2.4×10^{-5}	0	0.016	0.003	0.007	0	0.0006	0	0.0263
Pacifier (bright star)	1.0×10^{-4}	1.1×10^{-5}	5.0×10^{-5}	4.0×10^{-6}	0	0	0.034	0.006	0.016	0.004	0	0	0.0599
Pacifier (silicone)	4.0×10^{-5}	3.5×10^{-5}	1.0×10^{-5}	0	0	0	0.01	0.002	0.004	0	0	0	0.0156
Rattle	3.0×10^{-5}	6.5×10^{-5}	1.0×10^{-5}	0	0	5.6×10^{-5}	0.007	0.003	0.004	0	0	0.004	0.0178
Bottle nipple	3.0×10^{-5}	5.6×10^{-5}	5.0×10^{-5}	0	0	2.7×10^{-6}	0.008	0.003	0.016	0	0	0.0002	0.0265
Teething ring	2.0×10^{-4}	1.9×10^{-4}	6.0×10^{-5}	8.0×10^{-7}	0	0	0.049	0.01	0.02	0.001	0	0	0.0793

health risk from the ingestion of heavy metals in the toy and baby items that were analysed. Toys and baby items are not regulated in Trinidad and Tobago or regionally, and it is not required by the law to present manufacture details on these products.

However, information on the risk from heavy metal contamination in these items is lacking, thus public awareness and monitoring should be done and regulatory guideline established for these items.

Conclusion

The toys and baby items in this study all contained Pb, Ni and Cr, while some also contained Mn, Cd, and Cu. However, the concentrations of these metals were relatively small and the use of these would pose relatively low risk to children.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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