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Multi-technique Quantitative Analysis and Socioeconomic Considerations of Lead, Cadmium, and Arsenic in Children's Toys and Toy Jewelry

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Abstract

A wide spectrum and large number of children's toys and toy jewelry items were purchased from both bargain and retail vendors and analyzed for arsenic, cadmium, and lead metal content using multiple analytical techniques, including flame and furnace atomic absorption spectroscopy as well as x-ray fluorescence spectroscopy. Particularly dangerous for young children, metal concentrations in toys/toy jewelry were assessed for compliance with current Consumer Safety Product Commission (CPSC) regulations (F963-11). A conservative metric involving multiple analytical techniques was used to categorize compliance: one technique confirmation of metal in excess of CPSC limits indicated a "suspect" item while confirmation on two different techniques warranted a non-compliant designation. Sample matrix-based standard addition provided additional confirmation of non-compliant and suspect products. Results suggest that origin of purchase, rather than cost, is a significant factor in the risk assessment of these materials with 57% of toys/toy jewelry items from bargain stores non-compliant or suspect compared to only 15% from retail outlets and 13% if only low cost items from the retail stores are compared. While jewelry was found to be the most problematic product (73% of non-compliant/suspect samples), lead (45%) and arsenic (76%) were the most dominant toxins found in non-compliant/suspect samples. Using the greater Richmond area as a model, the discrepancy between bargain and retail children's products, along with growing numbers of bargain stores in low-income and urban areas, exemplifies an emerging socioeconomic public health issue.

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1. Introduction:

Exposure to metals such as arsenic (As), cadmium (Cd), and lead (Pb) represents a significant threat to children's health and their behavioral/intellectual development.[1,2] High concentrations of these metals have been linked to hindered brain/sensory motor development (As, Cd, Pb), decreased kidney function (As, Cd), gastrointestinal complications (Cd), bone softening (Cd), and cancer.[3,4] At a critical developmental time , children under six are particularly vulnerable to the harsh effects of these toxins.[5] The risk of significant exposure from contaminated toys/toy jewelry is elevated because of mouthing and threat of ingestion common with children this age. The Intergovernmental Forum on Chemical Safety has identified a "risk triangle" with metal-tainted children's toys, accessibility of the toys to children, and their vulnerability to exposure.[6] Even with well-known dangers and increasing regulations, contamination of children's toys/toy jewelry continues to be a serious concern. In 2006, a four year old died after ingesting a metallic charm containing lead, prompting the Consumer Product Safety Commission (CPSC) to re-evaluate its lead regulations.[7]

Lead, cadmium, and arsenic may be present in products such as children's toys/toy jewelry for a variety of reasons. Lead is often used as a stabilizer in certain plastics, a paint color enhancer, or an anti-corrosion agent.[8] As restrictions on lead have increased, cadmium has been increasingly substituted.[9] Similar to lead, cadmium is used to brighten paint color and stabilize plastic, preventing hydrochloric acid formation that subsequently degrades the polymer.[9] In children's jewelry, cadmium can create a lustrous appearance and add mass to make the product more realistic.[10] The reason for the inclusion of arsenic in children's toys is unclear but may be related to certain color dyes.[11]

Government agencies have enacted restrictions on heavy metal concentration in food, paint, toys, and many other children's products. The CPSC has issued numerous toy/toy jewelry recalls including 79 product recalls in 2007 and 48 in 2008, which affected 14.5 million and 4 million toys, respectively.[12] Imported toys represent approximately 87% of the total toy market with 74% imported from China. Of the 127 aforementioned recalls, 113 were for Chinese imports.[13] Demand for low cost products presumably drives Chinese manufacturers toward cheap and often toxic materials, including inexpensive lead-based paints or metals leftover from China's depreciating lead/nickel-cadmium battery industry and prevalent metallic electronic waste.[14,15] With the CPSC's 2012 endorsement of the American Society for Testing and Materials newest regulation (F963-11), the United States has one of the most comprehensive standards for toys[16] -

in line with legislation from the European Union (EN 71-3) and International Standards Organization (ISO 8124).[16-19]

Increasing regulation of these metals in consumer products has elicited an effort to evaluate screening effectiveness and assessment of regulatory limits. Several reviews are available, including Becker et al. (2010) and Zagury and coworkers (2012), that address heavy metal contamination of toys/toy jewelry as well as summarize the legislative/regulatory/business issues and challenges.[20-22] Studies by Weidenhamer and coworkers[14,23] represent important contributions here, including a 2006 report where atomic absorption spectroscopy (AAS) was used to determine lead in low-cost, purely metallic jewelry items (e.g., charms, bracelets) from retail stores in different geographic locations - a study finding nearly half of 139 jewelry items were over 80% lead by weight with an average lead content around 44% (wt.).[24] Their results reiterated findings of a larger, 2005 study by Maas et. al which used flame AAS to identify 285 jewelry items with lead greater than 30% (wt.).[25] Using flame AAS, Weidenhamer et. al also investigated lead contamination in the coating of inexpensive plastic jewelry, showing that many products exceeded the then current U.S. regulatory limit.[14] Using x-ray fluorescence spectroscopy (XFS) and AAS, Weidenhamer expanded to cadmium screening of inexpensive jewelry, finding non-compliant metal content (2011 CPSC standards; U.S. 2010e).[23] Overshadowed by lead, arsenic contamination was found using XFS in ~10% of jewelry items studied by Saunders et al.[26] In terms of the bioaccessibility of metal contaminants in children's products, Weidenhamer studied cadmium leached under simulated mouthing and digestion conditions,[23] reporting a linear trend of extractable metal over time, dangerous if swallowed. Zagury et al. reported the bioaccessibility of six metals under simulated gastrointestinal conditions, concluding that lead and cadmium were particularly prone to high leaching and exceeded EU regulation for items tested.[28]

In this paper, a variety of nearly 100 children's toys and toy jewelry items were purchased from either bargain or retail chain stores and were analyzed for arsenic, cadmium, and lead with multiple analytical techniques, including different types of AAS and XFS, to determine if the products violate current regulation and assess potential socioeconomic consequences related to the contaminated products. To our knowledge, a larger, more comprehensive multi-metal, multi-technique study of children's toys/toy jewelry items with different composition and from a range of store-types was lacking from the literature. During the course of our research, Zagury et al. published a seminal report examining metal content of ten metals, including those targeted here, in a large number of North American marketed children's toys/jewelry.[28] Our effort builds on these studies, adding multi-technique analysis and socioeconomic considerations by analyzing and comparing the metal content of children's toys/toy jewelry from bargain and retail stores.

2. Experimental:

2.1 Samples/Digestion. Children's toys/toy jewelry samples labeled "Made in China" were randomly selected/purchased from nationally recognized bargain and retail chain stores in the Richmond metropolitan area. Multiples of each toy or jewelry item were attained including low cost items (<$5.00) purchased from both store types and high cost items (>$5.00), not available at bargain stores, only purchased from retail stores. Separate analysis of individual samples representing multiples of the same toy were reported as an average (Supporting Information or SI). Toys/jewelry, as received or cut into smaller pieces, were digested with concentrated HNO_3 (Standard Method 3030). To aid removal of coatings, certain samples were stirred and/or heated during digestion. Acid digestions involving metallic products/components can be violent and were covered to protect against analyte loss. Sample digests were subsequently gravity-filtered (Whatman #43), diluted in volumetric glassware (18 MΩ water), and stored in plastic bottles until analysis. Post-digestion solids were oven dried 24-48 before massing.

2.2 Atomic Absorption Spectroscopy Analysis. Sample digests were screened for cadmium and lead on a Varian AA240FS flame atomic absorption spectrophotometer (FL-AAS) whereas samples were tested for arsenic, cadmium, and lead on a Varian GTA120AA240Z graphite furnace atomic absorption spectrophotometer (GF-AAS). A stabilizing matrix modifier, $NiNO_3 \bullet 6H_2O$, was added (50 ppm) to samples/standards tested for arsenic.[29] Standard calibration curve analysis (SI, Figs. SM-1 and SM-2) was performed on digested samples. As a secondary confirmation, standard addition (SA) analysis was run on specific samples, the range of SA increasing the sample signal 1.5-3.0 times the original value (SI, Fig. SM-3). Standardized aqueous metal solutions provided routine quality control of calibration curve effectiveness (GF-AAS; FL-AAS) with discrepancies quantifying the standard solution resulting in the generation of a new curve.

2.3 X-ray Fluorescence Spectroscopy Analysis. A Niton XL3t-700 X-Ray Fluorescence Analyzer (Thermo) was operated in multiple modes within the "Consumer Goods" function of the device as per manufacturer recommendation. The exact mode (e.g., painted product, metals/ceramics, plastics) used was matched with the assessed sample composition (60 second scans). Reference samples (Thermo) were routinely analyzed for quality control/instrument functionality checks.

2.4 Bioavailability Studies. Select non-compliant samples (BLCJP-01, BLCJP-02, BLCJP-06) were analyzed to determine bioavailability of metal contaminants via established protocol, relative bioavailability leaching procedure (RBALP), designed to simulate ingestion without certain digestion enzymes and other physiological conditions deemed negligible with regard to bioavailability.[30] Briefly, toys/toy jewelry were subjected to a 96 hour end-over-end (~ 10 rpm) wash in a dilute HCl (0.4 M) in glycine solution (pH 1.53; 37°C). Wash aliquots taken between 6 and 96 hours were analyzed using GF-AAS. A matrix matched standard (HCl-glycine) calibration curve was used with results additively compounded after certain intervals for total metal leaching over time.

3. Results and Discussion

Children's toys/toy jewelry items, selected at random and purchased from both bargain and retail stores in the greater Richmond metropolitan area, were analyzed for arsenic, lead, and cadmium content. Analysis for these metals was performed with multiple analytical techniques including flame (FL) and graphite furnace (GF) atomic absorption spectroscopy (AAS) and/or x-ray fluorescence spectroscopy (XFS). Metal concentrations determined from these techniques were compared to the United States Consumer Product Safety Commission (CPSC) regulation levels (CPSC, F963-11).

3.1 Analysis of Toys/Toy Jewelry From Bargain Stores

Table 1 summarizes, by analytical technique, the average and range of detected concentrations for arsenic, cadmium, and lead in jewelry/toys purchased from bargain stores-all considered "low cost" (<$5.00). A sample was labeled non-compliant if the metal concentration of arsenic, cadmium, or lead concentration exceeded the CPSC limit of 25, 75, and 90 ppm, respectively, with additional confirmation by a secondary technique. Non-compliant toys/toy jewelry measurements are shaded black. If only one technique showed metal concentrations exceeding CPSC limits, the sample was classified as "suspect" and shaded grey. A third classification, identified by bolded outline, signifies "borderline" products with metal concentrations below regulation but still high enough to elicit concern due to cumulative metal exposure over time.

Table 1 shows 16 of 46 (35%) bargain samples were found to be non-compliant for at least one of the metals as confirmed by two different analytical techniques. Of the remaining toys (30), an additional 10 toys/toy jewelry items were classified as suspect for one or more of the metals because they exceeded limits on one analytical technique. Thus, out of the 46 toys/toy jewelry tested from bargain stores, nearly 60% (26 of 46) were determined to be contaminated at some level by at least one metal. This result (i.e., 60%) is similar to previous reports employing only one analytical technique to investigate toxic metal content in low cost children's toys/jewelry.[24,28] The similarity of percent non-compliance from one technique studies suggests that a conservative, multi-technique approach, may more effectively indicate actual non-compliance. Single technique analysis have disadvantages that can affect results, including digestion ineffectiveness (AAS) and inherent XFS variability stemming from analyte depth, proper use, and the user's operational mode selection.

Of the 16 items identified as non-compliant, all but two (BLCTP-03, BLCTM-04) were classified as "jewelry" for children, with the bulk composition of these items split between plastic (6) and metal (8). More than half of the non-compliant products (56% or 9 of 16) were found to exceed CPSC regulations for lead with one also having excessive cadmium content (BLCJP-02). The other non-compliant metal items (7 of 16) were found to exceed the acceptable arsenic limit. While multiples of each item were tested and the results averaged, a significant level of variability, similar to other reports of this nature,[8,12,14,28] persisted in the measurements. As in those studies,[12,28] the variability is partly attributed to analyzing toys/toy jewelry from different production periods (i.e., the same toy purchased from different locations at different times). Prior reports suggest variability may stem from opportunistic use of contaminated raw materials at the manufacturing stage.[15]

The matrices of some of the digested toys/toy jewelry required for AAS analysis are likely complex, eliciting concern over matrix effects on analyte signal. To compensate, standard addition (SA) methodology, utilizing the sample's own matrix, was employed. Most of the sixteen non-compliant products (Table 1) identified in initial screening (i.e., two or more techniques (FL-AAS, GF-AAS, or XFS) measured concentrations over CPSC limits) were subsequently confirmed with SA (SI, Table SM-1). Some samples (BLCJM-03, BLCJM-07, BLCJM-11, BLCJP-04, BLCJP-005, BLCJP-09) initially measuring just below CPSC limits were eventually labeled non-compliant (Table 1) upon additional SA analysis (GF-AAS). Collectively, SA analysis with GF-AAS, confirmed the non-compliance claim of all 16 samples. SA analysis (GF-AAS) was also used to check the "suspect" status bargain toys that initially exceeded CPSC limits when tested with GF-AAS. In all cases with samples originally deemed "suspect," the classification was sustained by SA analysis (SI, Table SM-2).

3.2 Analysis of Toys/Toy Jewelry From Retail Chain Stores

A primary objective was comparing children's toys/toy jewelry purchased from bargain versus large retail stores to determine if place of purchase correlated impacted non-compliance. To facilitate this comparison another 46 children's toys/toy jewelry items were purchased from retail chain stores in the same Richmond (VA) area and surveyed for As, Cd, and Pb with XFS, a surface analysis technique. Retail toys/toy jewelry were further categorized into low cost (LC), <$5.00, (n=23) or high cost (HC), >$5.00, (n=23) items. Because many of the bargain toy/toy jewelry samples found to be non-compliant (9 of 16, 56%, Table 1) were acid-digested to remove only the outer coating (rather than the entire product), retail store samples were only surveyed with XFS to assess CPSC compliance. XFS, the industry standard for commercial testing, allows for non-destructive (i.e., no acid digestion) and high-throughput screening of products. Of the 46 products, only 7 (15%) were found to contain unsafe levels of one or more of the three analytes (**Table 2**) and were designated as "suspect" based on the use of a single technique (XFS). As in the case of bargain products, children's jewelry at retail stores was the product of greatest concern with 71% of the items deemed suspect. The overwhelming majority of retail store regulatory violations (86%) were from arsenic. While our study focused on arsenic, cadmium, and leadXFS detected non-compliant levels (>60 mg/kg, F963-11) of mercury in 19 of 92 items total (20%), including 12 bargain products and 7retail products.

In comparing collective product analysis of bargain stores versus retail stores, several key findings emerge. First, the rate of non-compliant/suspect toys/toy jewelry from bargain stores (57%) is nearly four times that of items purchased at large retail stores (15%). This finding indicates that the type of store from which these products are purchased may be a significant factor in public exposure. Secondly, both store types showed similar patterns in which of the three targeted metals products were found. Of the non-compliant/suspect bargain store samples, 54% (14 of 26) and 73% (19 of 26) were in violation of CPSC limitation for lead and arsenic, respectively, whereas only 14% and 86% of suspect retail items were high in lead and arsenic (SI, Fig. SM-4). The high arsenic levels in both types of samples may be a symptom of the attention lead contamination has received over the years compared to lesser known toxins as well as new policies of retail chains aimed at banning lead from children's toys.[31,32] Lastly, it is evident from the results that jewelry items, as opposed to toys, are much more likely to have metal concentrations that exceed CSPC limits, and therefore represent a greater threat to children who accidentally ingest them. Nearly 73% (24 of 33) of the total number of samples found to exceed limits with one or more techniques, regardless of purchase origin, were classified as children's jewelry (SI, Fig. SM-5). Metallic-based jewelry (16 of 24, 67%) was more problematic than plastic jewelry (8 of 24, 33%), a result consistent with the Zagury/Guney[28] report on low cost metallic jewelry versus Weidenhamer's examination[14] of low cost plastic jewelry (45% vs. ~10% high in lead, respectively).

In the current study, analysis of only low cost (LC) items, regardless of the place of purchase, resulted in a suspect/non-compliance rate of 42% (29 of 69 LC items), a rate similar to previous studies dedicated to LC items. If one examines only data for low cost items, the discrepancy between retail and bargain is slightly larger - a 57% non-compliant/suspect rate for bargain stores versus a 13% rate at retail stores. A 2005 report by Maas and coworkers studying lead content of inexpensive jewelry items, reported that nearly 60% of the 285 items tested had unacceptable levels of the metal.[25] Weidenhamer et al. focused on lead analysis in low cost, metallic jewelry,[15] and later in low-cost plastic jewelry,[14] reported non-compliance rates of 42% and 9%, respectively. A more recent study (2010) by Green, found only 4% of jewelry exceeded the lead limit allowable by California law.[33] Collective results of this and prior studies suggest a trend toward lower rates of lead non-compliance in low cost, children's items. However, results from the current study, suggest that price may not be as significant of a factor as the origin of purchase (i.e., type of store). Out of the 7 suspect items from the retail stores, there was a nearly even split between low cost (n=3) and high cost (n=4) products. If XFS determined "suspect" samples are assumed to actually be non-compliant, the difference between bargain vs. retail stores, while slightly less pronounced, remains significant (SI, Figs. SM-6 and SM-7).

The finding that low cost items from retail stores have a smaller likelihood of unsafe arsenic, cadmium or lead content suggests, as in other studies,[24,28] that the selection of supplier may be critical. One explanation postulated in the literature is that manufacturers are being opportunistic in the production of the toys/jewelry, using cheaper, contaminated raw materials to lower costs.[15] Alternatively, some national retail chains have, as of 2007, taken pre-emptive steps, self-imposed standards, testing, and enforcement, including requiring suppliers take back shipped merchandise failing to meet those standards.[31-32]

3.3 Bioavailability Studies

While total metal content of a completely digested sample or the outer coating of a toy/toy jewelry item is significant, an important aspect of overall toxicity is the bioaccessibility of the metals in contaminated children's products - that significant ingestion of toxins can occur either through ingestion or mouthing behaviors with the toys/jewelry. While ingestion may induce more acute illness or death, the latter mode is of particular concern with young children because of the frequency of the behavior (i.e., mouthing, licking, chewing, sucking), their critical developmental stage of life, and the cumulative health effects of continuous exposure.[21] Studies show a median of 39 and 9 contacts per hour for toy mouthing in children under two and over two years old, respectively.[21] Lead, for example, has a half-life of 35 days in erythrocytes, two years in the brain, and decades in the bone, with evidence of greater adsorption into the gastrointestinal tract and brain of children compared to adults.[27] With almost 90% of our non-complaint samples being small pieces of jewelry, bioavailability through mouthing and/or ingestion is of significant concern.

To assess bioavailability, a number of the 16 bargain store non-compliant items with a removable coating were selected. GF-AAS analysis of extracts from the bioavailability digests over time revealed a significant amount (e.g., ~0.04 μg Pb/hr) of lead leached from the items (SI, Fig. SM-9), albeit below the CPSC regulation for migratable metal (e.g., 6 μg Pb/6 hours). While our levels of migratable metal were lower than other reports,[23,28] those studies were often limited to bulk metallic items with much higher starting total metal concentrations (e.g., 10,0000-100,000 ppm Cd).[23,28] Extrapolation of our results, suggests the leachable lead content of items tested would exceed CPSC regulation after ~100 hours of exposure. Weidenhamer reports[23] similar findings to our study: leeching was linear with time and accelerated if the item was purposefully damaged prior to exposure to simulate wear-and-tear. Given the cumulative nature of these toxins in the body, extended exposure over time remains a significant concern even with items yielding migratable amounts well below government standards.

3.4 Socioeconomic Considerations

Our results suggest that for inexpensive toys/toy jewelry (<$5.00), manufactured in China, the origin of purchase (i.e., type of store) may be one of the most significant factors in assessing potential health risks to child consumers. Coupled with the increasing number and success of bargain stores in the current sluggish economy, our findings may serve as a harbinger of an important emerging socioeconomic public health issue.[34] Bargain stores have seen their net retail sales as well as the number of stores drastically increase between 2005 and 2011 while retail chain stores continue to recover from recession (2008).[34] A 2011 national review noted that the store count of the four major dollar store chains (21,500 locations) exceeded the number of three major national drugstore chains (19,700 locations).[34] If the increasing popularity, numbers, and profit margins of these bargain stores are considered in concert with our results, a greater number of children could be at risk for both acute (ingestion) and chronic (mouthing behaviors) exposure to contaminated toys/jewelry.

Bargain stores have achieved their recent success with a strategy built around offering the consumer convenience and low prices by stocking an inventory with larger percentages of inexpensive imports predominantly from China.[13,34] Studies suggest, however, that their success is partly a function of strategically locating their stores to target specific consumer demographics: low-income families (low prices), urban center populations (convenience), and rural populations with limited access to retail chains (convenience).[34] Dollar General, for example, is the dominant rural bargain store, with over 70% of its stores servicing communities of less than 20,000.[34] Family Dollar stores, on the other hand, tend to purposefully locate in less desirable urban markets. A 2012 study of bargain store locations in the country showed a disproportionate number in low income states such as West Virginia, Mississippi, Alabama, and Louisiana.[35] The study indicated high correlation of bargain store density with areas populated with mostly blue collar working families, lower levels of education, and low median income.[35]

In the context of this current report, consumer demographics in the aforementioned studies identify those most likely to purchase these items and have greater risk for acute or chronic metal exposure – a group also more likely to not have adequate health insurance coverage and suffer health issues. In 2009, The Urban Institute (TUI) showed low-income families (i.e., average incomes below twice the federal poverty level) had lower rates of health insurance coverage and were more likely to be uninsured, including an estimated 15% of children (2005).[36,37] The Institute for Research on Poverty, examining the Affordable Care Act's effect on low income families, reported that this demographic is particularly vulnerable, suffering from poorer health outcomes, lower life expectation, higher chronic illness rates, and more unaddressed health needs compared to middle or upper class families.[38] In short, those most vulnerable to exposure may also be the least likely to recognize and treat health consequences from toys/toy jewelry with unsafe metal levels, creating a socioeconomic driven public health hazard.

Using the greater Richmond, Virginia metropolitan area as a model, locations of bargain versus large retail chain stores reflect our investigations' suggested socioeconomic implications. Defined by the I-295/SR-288 barrier, **Figure 1** shows locations of Richmond's three major chains of bargain stores (60 locations) versus retail stores (19 locations). Interestingly, the bargain stores are more concentrated within the city limits (i.e., urban center) and to the east and south of the region. Retail stores, on the other hand are more prevalent in the north and west of the greater Richmond area. An overlay and examination of average income per region indicates a close correlation.[39] Bargain stores are more concentrated in low income and urban areas where large retail stores are much less plentiful. Store locations are likely the result of store assessment, with large retail stores selling children's products at a higher cost not wanting to directly compete with the convenience and low prices of the bargain stores in these areas.[40] We note that 12 of the 19 (>60%) retail stores are found in Richmond's affluent "West End" (i.e., highest median household income)[39] along with notably fewer bargain stores. This model system may be representative of similar metropolitan areas across the country, suggesting that this issue may be a developing national concern.

4. Conclusion

Multi-technique, multi-metal spectroscopic analysis of a number of randomly selected children's toys/toy jewelry items indicates a significant difference exists in the toxic metal content between products purchased at bargain versus retail stores, establishing origin of purchase as a major factor in assessing the safety of these particular products. The discrepancy between bargain and retail products is likely to be even more pronounced if sample selection were conducted with bias from these findings or prior studies.[9,10,12,14,23-25,28] With a nearly four-fold higher rate of violation for low cost children's toys/toy jewelry compared to retail stores, bargain stores that seem to also employ marketing strategies targeting low-income and urban areas, may be creating an socioeconomic public health concern. Healthcare-centered reports indicate consumers most likely to suffer even low levels of poisoning from these metals in these products are also more likely to suffer from poor health or not have health insurance. This study suggests that stores can make decisions to limit exposure risk to consumers by screening their own merchandise, more careful selection of import manufacturers, and/or decreasing their percentage of imported products. This particular issue will experience another variable with the advent CPSC certification tags (June 2013) for toys 3rd party independently tested for metal contaminants, though voluntary and cumbersome requirements for certification may dampen participation and effectiveness.[41]

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Supporting Information (SI)

Additional experimental details; Representative FL-AAS and GF-AAS calibration curves, SA analysis (GF-AAS); Data tables: SA analysis (GF-AAS) for non-compliant and "suspect" toys/jewelry; Analysis summary as a function of metal; bioavailability GF-AAS analysis of selected non-compliant bargain toys/jewelry.

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Figure 1. GoogleMaps© of greater Richmond, Virginia metropolitan area showing locations of (**A**) three national chain bargain and (**B**) three national retail stores. Regions reflecting highest median household income between 2005-2010[39] is shaded yellow (B).